Improving the Innovation Process at the Ideation Step Using Enterprise Content Management Systems and the Graph Theory

by

Houcine DAMMAK

MANUSCRIPT-BASED THESIS PRESENTED TO ÉCOLE DE TECHNOLOGIE SUPÉRIEURE IN PARTIAL FULFILLMENT FOR THE DEGREE OF DOCTOR OF PHILOSOPHY
Ph.D.

MONTREAL, JULY 11, 2023

ÉCOLE DE TECHNOLOGIE SUPÉRIEURE
UNIVERSITÉ DU QUÉBEC

BOARD OF EXAMINERS

THIS THESIS HAS BEEN EVALUATED

BY THE FOLLOWING BOARD OF EXAMINERS

Mr. Mickaël Gardoni, Thesis Supervisor
Department of Systems Engineering, École de Technologie Supérieure

Ms. Ma Lorena Escandon-Quintanilla, Thesis Co-supervisor
School of Creative Industries, Toronto Metropolitan University

Mr. Yvan Beauregard, President of the Board of Examiners
Department of Mechanical Engineering, École de Technologie Supérieure

Mr. Michel Rioux, Member of the Board of Examiners
Department of Systems Engineering, École de Technologie Supérieure

Mr. Vincent Sabourin, External Examiner
Department of Strategy, Social and Environmental Responsibility, UQAM

THIS THESIS WAS PRESENTED AND DEFENDED

IN THE PRESENCE OF A BOARD OF EXAMINERS AND THE PUBLIC

ON JULY 6, 2023

AT ÉCOLE DE TECHNOLOGIE SUPÉRIEURE

ACKNOWLEDGMENTS

The PhD journey has been one of the most challenging and exciting times of my career. For this, I owe credit to my advisors, Mickael Gardoni and Ma Lorena Escandon-Quintanilla. They taught me how to be a better researcher and they guided me through this journey in a professional way. Also, they offered me wonderful opportunities that made my work more thrilling, thank you!

I am also grateful to the board of examiners who took the time to review my thesis, and for their comments to improve the end result: Dr. Yvan Beauregard, Dr. Michel Rioux, and Dr. Vincent Sabourin.

I greatly appreciate our research group, Luz Maria J.N., Ahmed C., Abdellatif D., and Marouane M., for their continuous support throughout my studies.

A big thank you to all my family for supporting and encouraging me on this journey, especially to my parents Abdelaziz and Emna who were always present to encourage me despite the distance.

This work would never have been possible without my dear Malika, who encouraged me to continue this program. Thank you for your support and your incomparable patience. Finally, I thank my daughters Sarah and Julia, who were born and raised during this Ph.D. journey.

L'amélioration du processus d'innovation à l'étape de l'idéation à l'aide des systèmes de gestion de contenu d'entreprise et de la théorie des graphes

Houcine DAMMAK

RÉSUMÉ

L'étape de l'idéation dans la gestion de l'innovation est une étape importante qui nécessite un effort humain. Plusieurs chercheurs ont travaillé sur cette étape en proposant des outils de support (par exemple, des mots-clés, des post-its, des modèles physiques, du prototypage, etc.) Cependant, peu de chercheurs ont suggéré de se pencher sur les connaissances de l'organisation puisqu'elles sont plus proches de la réalité de l'organisation en termes de capacités et de savoir-faire. À cette fin, les solutions de gestion de contenu d'entreprise (ECM) dans le contexte de la gestion de l'innovation pourraient être une option intéressante à explorer en tant que source de connaissances internes pouvant être consultées au cours de la phase d'idéation.

Dans cette thèse, nous proposons d'utiliser les solutions ECM à l'étape de l'idéation pour améliorer le processus de gestion de l'innovation par la suite. En outre, pour minimiser le temps de lecture et d'interprétation, nous proposons d'utiliser des outils de visualisation avec l'ECM dans notre approche. La théorie des graphes a été utilisée dans l'analyse en raison de ses fortes propriétés d'analyse et de son utilité dans notre contexte pour mettre en évidence les relations entre les contenus stockés dans l'ECM.

Suite à la recherche théorique sur l'utilisation de l'ECM dans le processus de gestion de l'innovation et aux lacunes de la littérature, un énoncé de problème est formulé et une approche initiale est présentée :

Comment soutenir l'étape d'idéation dans le processus d'innovation en utilisant des systèmes de gestion de contenu d'entreprise couplés à des outils de visualisation ?

Ensuite, deux études de cas ont été réalisées dans lesquelles le chercheur a tenté de tester l'approche proposée en utilisant des brevets comme contenu pour soutenir l'étape d'idéation.

- Cas 1 : Lors de l'utilisation de l'ECM comme outil de support à l'étape d'idéation, le concept de " graphe de contenu " a été introduit pour éviter que les participants n'omettent des contenus précieux. Le "graphe de contenu" résulte de l'application des techniques de la théorie des graphes aux résultats de recherche de l'ECM. Cette approche a été expérimentée lors de l'événement "24 heures d'innovation" en fournissant aux participants les contenus extraits par le "graphe de contenu". Nous avons remarqué que l'équipe soutenue a non seulement gagné beaucoup de temps au cours du processus de génération d'idées, mais a également proposé des idées plus attrayantes et plus détaillées. Ils ont été mieux guidés vers une solution créative.

- Cas 2 : L'approche utilisée dans le cas 1 a révélé que le processus de génération d'idées utilisant uniquement des graphiques de contenu manquait de "bisociation" parce que les participants se limitaient uniquement à l'espace d'exploration des contenus proposés. Dans ce contexte, pour élargir les possibilités de bisociation et donc l'espace d'exploration, les résultats du "graphe de contenu" ont été convertis en cartes et combinés avec d'autres cartes d'incitation à la créativité (TRIZ, Industrie 4.0). Cette approche a été expérimentée lors d'un deuxième événement d'innovation, "59 minutes d'innovation". Les participants ont été guidés vers des solutions plus créatives en combinant plusieurs cartes des différents jeux de cartes, et ils ont proposé des idées plus attrayantes et plus détaillées.

Afin d'accroître la productivité et la qualité des idées, des contenus spécifiques ont été fournis aux participants lors des sessions d'idéation. En outre, le nombre de contenus a été réduit en les regroupant par classification des brevets afin de faciliter le processus d'idéation. En plus, des indices créatifs ont été ajoutés pour créer des bisociations et élargir l'espace de la solution.

Mots-clés: créativité, gestion de l'innovation, idéation, gestion de contenu d'entreprise (ECM), outils de visualisation, théorie des graphes

Improving the Innovation Process at the Ideation Step Using Enterprise Content Management Systems and the Graph Theory

Houcine DAMMAK

ABSTRACT

The ideation step in Innovation management is an important step that requires human effort. Several researchers worked on this step by proposing support tools (for example, keywords, post-its, physical models, prototyping, etc.). However, few researchers suggested looking into the organization's knowledge as it is closer to the organization's reality in terms of capabilities and know-how. To this aim, Enterprise Content Management (ECM) solutions in the innovation management context could be an interesting option to explore as a source of internal knowledge that can be consulted during the ideation stage.

In this thesis, we propose using ECM solutions at the ideation step to improve the innovation management process afterwards. Also, to minimize the reading and interpretation time, we propose using visualization tools with the ECM in our approach. Graph Theory was used in the analysis due to its strong analysis properties and its utility to our context to highlight the relationships between contents stored in the ECM.

Following theoretical research on the use of ECM in the innovation management process and the gaps in the literature, a problem statement is formulated, and an initial approach is presented:

How to support the ideation step in the innovation process by using Enterprise Content Management systems coupled with visualization tools?

Then, two case studies were performed where the researcher attempted to test the proposed approach by using patents as contents to support the ideation step.

- Case 1: While using the ECM as a support tool in the ideation step, the concept of "Content Graph" was introduced to avoid participants omitting valuable contents. The "Content Graph" results from applying the Graph Theory techniques on the ECM search result. This approach was experienced in the 24h innovation event by providing participants with the contents extracted by the "Content Graph". We noticed that the supported team not only gained much time during their idea-generation process and also proposed more appealing and detailed ideas. They were better guided to a creative solution.

- Case 2: The approach used in Case 1 revealed that the idea generation process using only content graphs lacked "bisociation" because the participants restricted themselves only to the exploration space of the proposed contents. In this context, to enlarge the bisociation possibilities and so the exploration space, the results from the "Content Graph" were then converted into cards and combined with other creative prompt cards (TRIZ, Industry 4.0). During a second innovation event, “59 Minutes of Innovation”, this approach was experimented. Participants were guided to more creative solutions by combining several cards from the different sets in the card deck, and they proposed more appealing and detailed ideas.

To increase productivity and quality of ideas, dedicated contents were provided to participants in ideation sessions. Besides, the number of contents were reduced by grouping them by Patent classification to ease the ideation process. Moreover, creative cues were added to create bisociations and enlarge the solution space.

Keywords: creativity, innovation management, ideation, enterprise content management (ECM), visualization tools, graph theory

TABLE OF CONTENTS

Page

INTRODUCTION 1

CHAPTER 1 CONCEPTUAL FRAMEWORK & METHODOLOGY 5
1.1 Context...5
1.2 Background...8
1.2.1 The ideation step as part of the innovation process 9
1.2.2 Definitions.. 10
1.2.3 Visualization tools 18
1.3 Methodology 19
1.4 Knowledge Creation Framework..21
1.5 Expected results 23

CHAPTER 2 ENHANCING CREATIVITY BY LEVERAGING EXISTING ORGANIZATION'S KNOWLEDGE THANKS TO AN IMPROVED APPROACH OF USING ECM 25
2.1 Introduction...26
2.2 State of the art: Taxonomy & Metadata..28
2.2.1 Taxonomy overview 28
2.2.2 Metadata overview... 29
2.2.3 Metadata and its Usage 30
2.3 Organization's Content and the importance of using ECM in an ideation session 33
2.3.1 ECM in the innovation process at the ideation stage.................................. 33
2.3.2 Discussion and limitations 36
2.4 Approach to improve the use of organization's content in an ideation session...........37
2.5 Conclusion 41

CHAPTER 3 GRAPH BASED TOOLS FOR ECM SEARCH RESULT ANALYSIS TO SUPPORT THE IDEATION STEP 43
3.1 Introduction...44
3.2 ECM contribution in an ideation session...46
3.2.1 Using ECM in an ideation session.. 46
3.2.2 Limitation of the actual method... 47
3.2.3 Proposed method to improve using ECM in an ideation session.............. 47
3.3 Graph representation of ECM search result analysis.......................................49
3.3.1 Input data 49
3.3.2 Introduction to graph theory: basic terminology and notations................ 51
3.3.3 Limit of the representation.. 51
3.4 Examples of Graph tools and utility for ECM result analysis 52
3.4.1 Biconnected Graphs: Connected components 52
3.4.2 Articulation Points (or cut vertices) and Cut edge (or bridge).................. 53

3.4.3 Clustering 54
3.4.4 Graph node groups (Collapse/ contraction) 55
3.4.5 The degree of a vertex and adjacency list 55
3.4.6 Singleton 56
3.5 Conclusion 57

CHAPTER 4 ENTERPRISE CONTENT MANAGEMENT SYSTEMS: A GRAPHICAL APPROACH TO IMPROVE THE CREATIVITY DURING IDEATION SESSIONS – CASE STUDY OF AN INNOVATION COMPETITION “24H OF INNOVATION” 59
4.1 Introduction 60
4.2 Background 62
4.2.1 Using ECM in an ideation session – Innovation context 62
4.2.2 Use of graphs in ECM search results relationship analysis 64
4.2.3 Graph representation of ECM Search result analysis 65
4.2.4 Patent classification 72
4.3 Steps of the proposed approach 73
4.4 Case Study 75
4.4.1 Innovation competition 75
4.4.2 Preparation and utilization of the proposed approach 76
4.4.3 Summary of applying the steps of the proposed approach 82
4.4.4 Results 87
4.5 Conclusion and discussion 87

CHAPTER 5 IMPROVING THE IDEATION PROCESS WITH CUSTOMIZED CREATIVE CUES: A CARD-DECK APPROACH 89
5.1 Introduction 90
5.2 Background 91
5.2.1 Bisociation & limiting the exploration space 91
5.2.2 Card-decks as a creativity tool 92
5.3 Proposed approach 93
5.3.1 Innovation principles - TRIZ 94
5.3.2 Industry 4.0 tools 95
5.3.3 Content Cards 96
5.3.4 Creation of a solution space with 10,626 possibilities of bisociations 98
5.3.5 Scenario of experimentation or use of cards 98
5.4 Evaluation of the Card-decks approach 104
5.4.1 Idea production 104
5.4.2 Quality of ideas 105
5.4.3 Contribution of each card type 106
5.5 Discussion 106
5.6 Conclusion 107

CONCLUSION 109

ANNEXE I APPROVAL OF THE ÉTS RESEARCH ETHICS COMMITTEE 1.... 111
ANNEXE II APPROVAL OF THE ÉTS RESEARCH ETHICS COMMITTEE 2.... 113
ANNEXE III OTHER PUBLISHED CONFERENCE AND JOURNAL ARTICLES 115

BIBLIOGRAPHICAL REFERENCES 117

LIST OF TABLES

Page

Table 1.1 KM tools supporting innovation processes Taken from Grimaldi & Rippa (2011, p. 48) 6

Table 1.2 Methodology landscape by chapter 21

Table 2.1 Content Classification Metadata Table Taken from Yim (2018, p. 33)....30

Table 2.2 Business Function Classification Metadata Mapping (User Identity) Taken from Yim (2018, p. 47)....31

Table 2.3 Business Function Classification Metadata Table Taken from Yim (2018, p. 34)....31

Table 2.4 Content Classification Metadata Mapping (Contracts) Taken from Yim (2018, p. 39)....32

Table 2.5 Auxiliary Classification Metadata Mapping - Manual Input (Contracts) Taken from Yim (2018, p. 43)....32

Table 2.6 Patent Metadata Classification using the IPC (International Patent Classification) Adapted from Dammak et al. (2020, p. 947)....39

Table 3.1 Example of a list of Structured Content....50

Table 4.1 The steps of applying the approach 74

Table 4.2 Patent Classification using the IPC (International Patent Classification) 77

Table 4.3 Extract of the search result performed on the ECM 78

Table 4.4 Application of the approach....85

Table 4.5 The representative patents identified using our proposed approach....86

Table 5.1 Experimentation Scenario — Step by step 103

Table 5.2 Number of ideas generated by Board....104

Table 5.3 Mapping the generated ideas with the used cards....105

LIST OF FIGURES

Page

Figure 1.1 A typical Stage-gate product innovation system Taken from Cooper & Edgett (2009, p. 189)....9

Figure 1.2 Modeling the ECM system 13

Figure 1.3 Mapping a company's content....17

Figure 1.4 DSRM Process Model Taken from Peffers *et al*. (2007, p. 54)....22

Figure 2.1 Business Function Classification Taxonomy....31

Figure 2.2 Sample Metadata Classification for Content Adapted from Yim (2018, p. 32)....33

Figure 2.3 Reference Model for Visualization Taken from Card (1999, p. 17)....38

Figure 2.4 Approach to apply the Card (1999) reference model on the organizations' content while looking for insights....38

Figure 3.1 Modeling the ECM system 47

Figure 3.2 Proposed Method 48

Figure 3.3 Example of aggregation 52

Figure 3.4 Example of cut edge and cut vertex 53

Figure 3.5 The degree of a vertex....56

Figure 4.1 Proposed approach 64

Figure 4.2 Different types of adjacency matrices (Graph Theory, 2016) 66

Figure 4.3 Example of aggregation 68

Figure 4.4 The degree of a Vertex....72

Figure 4.5 Our challenge featured in the official 24h competition deck - 2019 Edition (Video Challenges 2019 24h ENG 190516 - YouTube, n.d.)....76

Figure 4.6 An initial graph composed of 3 subgraphs is drawn from the list of patents 79

Figure 4.7 Results of applying Graph Analysis Tools Sub-Step 6.1 80

Figure 4.8 Results of applying Graph Analysis Tools Sub-Step 6.2 80

Figure 4.9 Light patent graph 81

Figure 4.10 Evolution of the brainstorming stage 83

Figure 4.11 The proposed solution for our challenge shared on YouTube as part of the Local Winning Videos 84

Figure 5.1 Different card types that will be used in the experimentation scenario 94

Figure 5.2 Example of Aggregation 98

Figure 5.3 Board 1 - Creativity Quadrant - Breakout room 1 100

Figure 5.4 Board 1 - Brainstorming Board section - Breakout room 1 101

Figure 5.5 Board 2 - Contents Cards - Breakout room 2 101

INTRODUCTION

0.1 Context

In today's fast-paced market, organizations need to innovate in their product and service offerings to stay competitive. In this context, several organizations have decided to put creative teams in place to face this challenge. The size and the engagement of these creative teams is different from one organization to another depending on different factors like the organization size and revenue, the budget allocated for innovation, the sector, the grants offered by local governments for innovation activities…

These creative teams are usually from different departments and have a specific number of hours per week/month allocated to this activity. Some members could be dedicated full-time to the innovation activity. The latter is very important to organizations since it may define and support strategic decisions.

Since the creative team is chosen from different departments, they probably may have different backgrounds, which may enrich the proposed ideas. Participants in these teams, when generating new ideas and solving challenges rely on the information they can process and retain, which is their own knowledge. However, new information is created every day within the organization by their peers or by external sources like the competition, researchers… and published on the internet. This new information should be easily accessible to creative teams.

Enterprise Content Management systems (ECM) appeared to store and control this information. They allow the organization to process a large amount of information and classify them by metadata (domain of expertise, researcher, technology, data…) which allow users of these systems to retrieve the information quicker.

Multiple organizations have taken this technological shift and implemented an ECM system. ECM systems are mainly used for daily and operational tasks. Usually, the main reasons to implement ECMs are: to reduce searching times, unify the presentation or adhere to reporting obligations. After organizing and structuring the content, ECM will deliver it to users in a list format. We believe that using ECM systems by creative teams in innovation activities will be beneficial. We also think that there are areas of improvement on the way how the ECM displays its search result. We will use visualization tools based mainly on the Graph theory to change this output to a graph format highlighting the relationships between contents stored in the ECM.

0.2 Research problem

As aforementioned, we are planning to explore the use of Enterprise Content Management systems to support creativity. As mentioned previously, ECM is the platform that stores content and makes it available to users when they need it. So, we will propose a framework that couples the ECM output and the innovation process at the ideation step. And this by proposing a relational analysis of the list of contents displayed by the ECM and representing them in a graph using visualization tools. The difficulty here is the important number of analysis properties to identify the proper graphs and all the combinations between these analysis properties. So, we propose a graphical representation with a relational analysis between these contents and thus by using the graph theory to visualize and analyze the result of the ECM system.

0.3 Objectives

This research aims to propose and observe the use of Enterprise Content Management systems coupled with visualization tools to support the ideation step in the innovation process. Here are the main objectives:

- Review the literature on the use of ECM systems in the innovation process,
- Propose an approach on how visualization tools based on the Graph theory will be coupled with the ECM,
- Experiment the proposed approach in an innovation competition,

- Document the results of the use of ECM coupled with visualization tools and its impact on the creative teams and the innovation process,

Research question

How to support the ideation step in the innovation process by using Enterprise Content Management systems coupled with visualization tools?

0.4 Structure of the thesis

This thesis is a thesis by articles; in the following, we will explain each chapter's content.

- Chapter 1 presents the conceptual framework and the methodology used in this work. It details the context, terms and definitions used in this thesis, our methodology and presents the expected results.

- Chapter 2 presents article 1, “Enhancing creativity by leveraging existing organization`s knowledge thanks to an improved approach of using ECM”, in which we are positioning our work and presenting the problem statement. This article has been submitted to the Technology Analysis & Strategic Management Journal in January 2023 and it is under review.

- Chapter 3 presents article 2, “Graph-based tools for ECM search result analysis to support the ideation step”, which documents the Graph tools and utility for ECM search result analysis. This article was presented in the PLM19 conference in Moscow, Russia in July, 2019, and later published as part of the proceedings of said conference “Product Lifecycle Management in the Digital Twin Era”.

- Chapter 4 presents article 3, “Enterprise Content Management Systems: A graphical approach to improve the creativity during ideation sessions – case study of an Innovation Competition “24h of innovation””, where we experiment our proposed approach in an innovation competition, and we present the results. This article has been published in the International Journal on Interactive Design and Manufacturing (IJIDeM) in August, 2020.

- Chapter 5 presents article 4, “Enhancing the ideation process with customized creative cues: A Card-decks approach”; it uses the “Content Graph” presented in Chapter 4 by converting it into cards with the combination of other cards. Using a Card-decks approach, we leveraged the bisociation to benefit the ideation session. During a second innovation event “59 Minutes of Innovation”, the approach was experimented and showed interesting results. This article has been submitted to the International Journal on Interactive Design and Manufacturing (IJIDeM) in May, 2023.

- Chapter 6 presents the discussion and conclusion. The chapter includes an overview of the presented articles, the limitations of the research, a discussion of the results, impact on the ECM world and future work.

CHAPTER 1

CONCEPTUAL FRAMEWORK & METHODOLOGY

This chapter presents the conceptual framework and methodology that supported the development of the thesis. First, we will start by describing the context. Second, a background containing definitions of the main terms and notions will be presented. Then, the chapter presents the framework and the methodology with the expected results.

1.1 Context

With all new technologies and the fast pace of creating new products, organizations are invited to innovate to stay competitive and continue their growth strategy. Any organization today can benefit from this rapidly developing technological environment. To be on edge, some big organizations decided to create a new role to manage innovation. This role may have different names from one organization to another, but the common one we found is 'CInO', which stands for 'Chief Innovation Officer' (Lourens, 2016). This role is not classic in the organization. It is part of the C-level, which means that the person having this role is part of the management committee that defines the strategic directions the organization is taking. The CInO has a team of employees some of them are dedicated 100% to innovation, and the rest are from different departments and are involved part-time. Meetings are scheduled on a regular basis to go over the challenges the organization is facing and to brainstorm innovative solutions. Topics today do not stop at creating new products, it includes big data management, social media, mobile technology, 3D scanners, the cloud and also the internet of services and things (Uhl & Gollenia, 2016).

In essence, the 'CInO' role is mainly associated with strategy development and product and process development as part of new business opportunities and growth initiatives. An Accenture survey published in 2012, it was mentioned that already 60% of respondents employ a Chief Innovation Officer (or similar position) (Koetzier & Alon, 2013). The growth in the numbers since 2009 indicates the growing realization of the key role the CInO can play in an organization.

The CInO is responsible for managing the innovation process. In early steps of this innovation process, participants are invited to use their creativity to come up with new ideas. Those ideas are usually inspired by the participants' background and their own knowledge. Some researchers proposed different tools to support this important step of the innovation process: the ideation step.

Based on the researcher's personal experience as a Consultant in digital transformation and by working with different management solutions, he noticed that organizations today hold valuable knowledge in their digital and paper content. This knowledge is supported by information systems designed specifically to facilitate its use.

(Grimaldi & Rippa, 2011) enumerated the KM (Knowledge Management) tools that are available to support the innovation process in the following table.

Table 1.1 KM tools supporting innovation processes
Taken from Grimaldi & Rippa (2011, p. 48)

KM Tool	Definitions
Business Intelligence	A set of methodologies and architectures that transform raw data into meaningful and useful information. It allows business users to make informed business decisions with real-time data that can put a company ahead of its competitors.
Content management tools	A set of technologies that support the evolutionary life cycle of digital information and higher-value documents. Those digital information and documents are often referred to as content or digital content in form of text, such as documents, multimedia files, such as audio or video files, or any other file type, which follows a content lifecycle which requires management. Construction dissemination It may support the import and creation of documents, the identification of all key users and their roles, the assignment of roles and

	responsibilities to different instances of content categories, the ability to track and manage multiple versions of a single instance of content, the ability to publish the content to a repository to support
KM Tool	Definitions
	access to the content. Archiving/e-discovery solutions are examples of Content management to store, search, and retrieve data or information about data, while document management supports the management and retention of higher-value intellectual property, such as contracts, deals, legal matters, standard operating procedures, regulatory submissions, engineering schematics, plant and facilities maintenance materials, and patent submissions.
Data management tools	A structured collection of records or data that is stored in a computer system. The structure is achieved by organizing the data according to a database model, or collection of databases, designed to help managers make strategic decisions about their business.
Collaborative tools	Collaborative software (also referred to as groupware or workgroup support systems) designed to help employees involved in a common task achieve their goals. Groupware is the basis for computer supported cooperative work. A single gateway through which employees, customers, or partners can retrieve and share knowledge. Portals can help reduce the inconvenience and inefficiency caused by using multiple applications by integrating a wide range of application programs, so that information can be exchanged and shared irrespective of a type of application.

To cope with this challenge of supporting the innovation process, we selected Content Management Tools for this research work. Content Management tools have different names but the most common is ECM (Enterprise Content Management). It is defined as the technologies, tools, and methods used to capture, manage, store, preserve, and deliver content across an enterprise (*AIIM: Association for Innovation and Image Management*, n.d.). It is also defined (Usman et al., 2009) as a collection of strategic resources and capabilities that provides an automated enabling framework for efficient lifecycle management of valuable organization assets, i.e. contents and processes, to carry out required business operations in a collaborative fashion, supports governance and compliance, provides integration within and outside the business boundaries to achieve business intelligence, knowledge management and decision support capabilities with a focus on the fulfillment of business goals and objectives for competitive advantage.

The extant literature found that mostly focused on the operational and tactical benefits of ECM and very few of them focused on the strategic benefits. From the operational benefits, using ECM will allow for saving costs and reducing workload by streamlining tasks, and improving search and retrieval (Alalwan et al., 2014). Regarding tactical benefits, ECM improves internal and external collaboration, enhances content quality, and maintains consistency and standardizes workflows. From a strategic level, it includes increasing decision-making capabilities and facilitating creativity (Alalwan et al., 2014).
So, ECM is beneficial for an organization's creativity. This benefit comes from the fact that ECM users will have access to valuable information that is in a useable format and easily accessible. This access to information will allow enhancing the creativity of users to create new knowledge. ECM are the tools that will facilitate the organization to be creative, innovate continuously and manage its knowledge.

1.2 Background

In this chapter, we present the background that helps frame the different subsequent chapters in this thesis. It presents where our work is positioned in the innovation process. Then, we are introducing some definitions of the main terms and notions that will be used and a deeper description of the importance of data, the different data sources, and visualization tools.

1.2.1 The ideation step as part of the innovation process

With new technologies and the ease of access to information, organizations today need to innovate continuously. Different approaches are used to manage the Innovation program and most existing methodologies encourage organizations to collect ideas from employees, suppliers, clients… Those insights have shown attractive added value in many organizations due to the proactive behaviour that is developed with stakeholders. In this section, we will present the Innovation system described by Robert George Cooper and Scott J. Edgett (Cooper & Edgett, 2009).

The authors state that many companies already have a solid innovation process, or a Stage-Gate system implemented. So, the process is in place to launch s new product or process. This Stage-Gate system starts from Stage 1: ideas to Stage 5: Launch. Senior executives consider that the process is not enough if we don't have the right input which is solid and high value ideas.

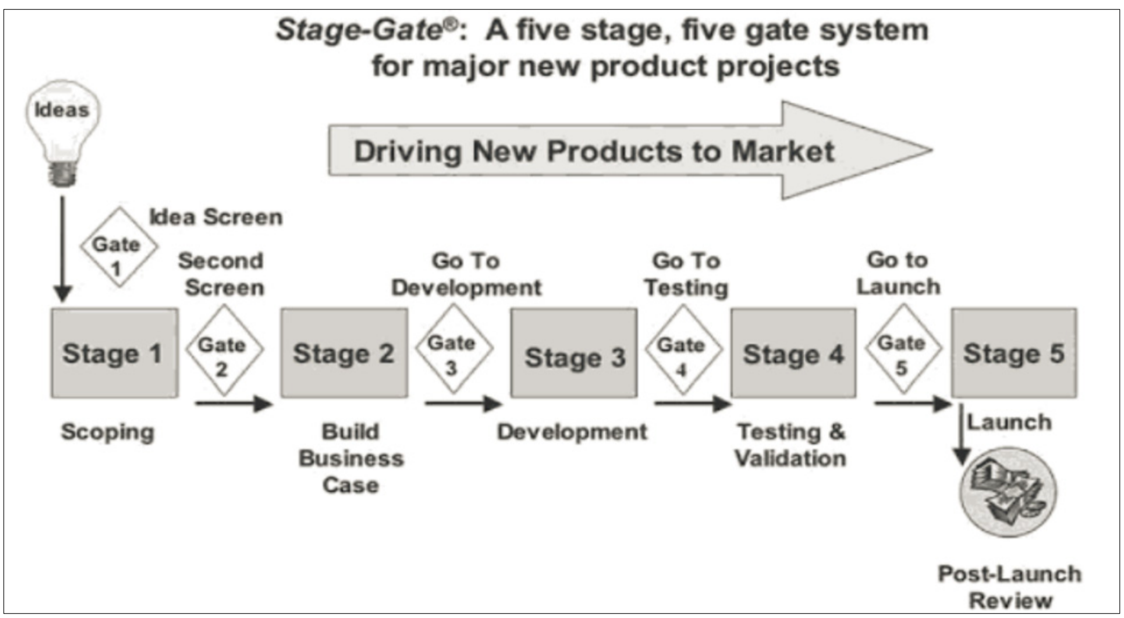


Figure 1.1 A typical Stage-gate product innovation system
Taken from Cooper & Edgett (2009, p. 189)

Different approaches appeared to solve this problem by organizing: Brainstorming sessions, Jam sessions, Innovation days, challenge-driven events, Shark Tank competitions… and these events proved their results by providing a considerable number of ideas and then following an evaluation process we could reach the expected strong and high-value ideas.

The ideation step which is the first step in the innovation process is the most critical step. We believe that companies can leverage their knowledge throughout the organization, expand their knowledge further based on existing expertise, appropriate knowledge from partners and other organizations, and develop entirely new expertise by probing new technologies or markets (Von Krogh et al., 2001).

Some authors propose that to generate radical innovations, it is necessary to combine already existing knowledge in an unexpected fashion (Fleming & Szigety, 2006).

The combination of teams existing technical knowledge and limited domain-specific knowledge provokes more original and diverse ideas, confirming creative value in the combination of KDD (knowledge discovery from databases) with teams' existing knowledge (Escandon-Quintanilla, 2017).

So, existing knowledge is very essential for the ideation step. This existing knowledge may come from internal or external data that an organization holds or has access to. In this thesis, we focus our research work on the ideation step of the innovation process, and we can help creative teams generate ideas.

1.2.2 Definitions

In this thesis, we will use multiple terms, and starting by defining those terms is very interesting to the reader. Here are the main terms that will be used:

All organizations, regardless their size, market, or market share, must deal with data in different forms. This data represents a valuable source of knowledge. We start here by defining some key terms used in this work.

- Data: These are symbols that represent the properties of objects and events (Ackoff, 1989).
- BIG Data: the volume of the data is too large. Secondly, it is impossible to analyze it using conventional technologies (Manyika, 2011).

- Knowledge: Can be defined as information that is validated, contextual, relevant and actionable (Soliman & Youssef, 2003). Jacobs (Jacobs, 2009) described it as a massive pool of data that allows creating insights and values that are not possible to generate from smaller scale of the same data.
- Tacit Knowledge: is subjective and informal (Polanyi, 1958) (Ikujirō Nonaka & Takeuchi, 2007). It is usually hard to express, transfer or share using common ways.

Any organization's data comes from different sources and in different forms. Kabir and Carayannis (Kabir & Carayannis, 2013) present knowledge in two forms: Explicit and Tacit. It is usually impossible to analyze it using conventional technologies especially if we add the information available on the internet to this data. That's why and as mentioned above, it is called Big Data.

Several researchers studied the importance of Big Data and the knowledge that it has for organizations.

Provost and Fawcett (Provost & Fawcett, 2013) mention that insights and knowledge from big data boost management's ability to make well-informed decisions.

According to Kabir and Carayannis (Kabir & Carayannis, 2013), knowledge has the potential to create economic value for an organization and bolster innovation, productivity, and growth. Thus, it is also a possible primary source of competitive advantage.

Knowledge and the capability to create and utilize knowledge are considered to be the most important source of a firm's sustainable competitive advantage (Ikujirō Nonaka & Takeuchi, 2007) (Ikujiro Nonaka, 1990) (Ikujiro Nonaka et al., 1994).

In a nutshell, Big data:

- It is a source of innovation that can enable the development of new products, processes, and services.
- Using various analytics data can generate knowledge and insights to support and improve organizational decision-making significantly (Provost & Fawcett, 2013).
- Offers the promise of unlocking novel insights and accelerating breakthroughs (Y. Chen et al., 2016).

Companies can leverage their knowledge throughout the organization, expand their knowledge further based on existing expertise, appropriate knowledge from partners and other organizations, and develop entirely new expertise by probing new technologies or markets (Von Krogh et al., 2001).

Some authors propose that to generate radical innovations, it is necessary to combine already existing knowledge in an unexpected fashion (Fleming & Szigety, 2006).

The combination of teams existing technical knowledge and limited domain-specific knowledge provokes more original and diverse ideas, confirming creative value in the combination of KDD (knowledge discovery from databases) with teams' existing knowledge (Escandon-Quintanilla, 2017).

As mentioned previously, access to digital data is becoming much easier and cheaper. That's why we believe that Big Data will make a massive difference in the organization's innovation quality. Some researchers have already worked on this and proved that Big Data might positively impact the generated ideas (Escandon-Quintanilla, 2017).

Today, organizations have a vast amount of data from different sources. These data are in different formats like documents, management platforms, and databases that are not easy to use and represent a huge amount of uncontrolled content that must be managed efficiently. Content management tools has appeared to cope with these challenges. Content Management tools could become the system of record of all these data and knowledge.

Enterprise Content Management (ECM) has been defined as "the strategies, tools, processes, and skills an organization needs to manage all its information assets (regardless of type) over their lifecycle"(H. A. Smith & McKeen, 2003).

ECM is different from DMS, Web Content Management… it manages the entirely of an organization's assets like: reports, spreadsheets, web pages, presentations, emails, office documents, images, audio or video files (Vom Brocke et al., 2010).

efficiency, availability, traceability, and consistency

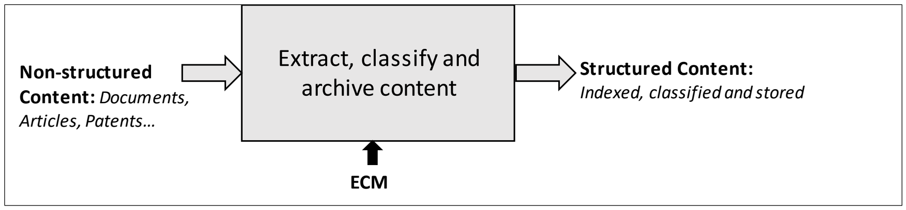


Figure 1.2 Modeling the ECM system

An ECM implementation should follow the following content stewardship activities (H. A. Smith & McKeen, 2003):

- Capture: It contains all the activities related to collecting content. It is usually about identifying the content it wants to capture and all its dimensions. This content could be captured from internal to external databases.
- Organize: It involves indexing, classifying, and linking databases together. This step utilizes techniques like: OCR (Optical Character Recognition) and smart templates for indexing, workflows for classification based on business rules and ODBC connections to link content with other databases.
- Process: Analyze the content already classified to inform decision-makers and other existing management systems.
- Maintain: It is mainly related to the maintenance of the content. How to keep it accessible? How to link it with new content? And for how much time should we keep it?

In the following section, we will describe in further detail the capture and the organize steps which are the main steps in an ECM implementation.

1.2.2.1 Capture

As aforementioned, Data within organizations comes from different sources. Those sources can be divided mainly into internal sources related to the internal documents, data, and information that any organization owns and controls and external sources that usually the organization does not own or control. Therefore, we start by mapping a company's content. Here is an overview of the primary sources.

1) Internal Sources

Employees and internal operations usually feed internal sources of data every day. This data contains information about human resources, operations, marketing, business development, vendors, partners, R&D, patents, and the list is much longer. It is usually spread into different departments. Internal data within an organization are mainly present in two forms: Digital and non-digital.

a. Digital

To control digital data, since the 70s, organizations started to use different tools/technologies to store it from old supercomputers, hard drives to the cloud nowadays. And to manage all this data and to make beneficial for organization's daily activities, different management solutions systems appeared and also communication and collaboration tools. Here is a short overview of the main solutions.

- **Management solutions**
  - ERP: Enterprise Resource Planning: is the solution that manages all the operations within an organization from Orders to production, if applicable, to delivery. ERP solutions represent an important data source for all organization's operations. The leading solutions in the market are SAP and Oracle.
  - CRM: Customer Relationship Management: is the solution to the sales activity within an organization from accounts, and contacts to sales opportunities. The most important output of this solution is the sales funnel that allows executives to see their forecast in terms of sales. The leader in the market is: Salesforce.
  - HR: Human Resources Management: As its name shows, it is meant to manage human resources. All the information related to employees, benefits, insurance… are focused on one platform.

- PM: Project Management: This solution contains essential and sensitive information related to projects that the organization worked or is working on from project plan and scheduling to allocated resources. Microsoft Project is considered one of the leaders in the PM market.
- PLM: Product Lifecycle Management: It is a solution to manage product's lifecycle from R&D, design to manufacturing and even service. Important information related to products resides in this solution and could be used as a source of inspiration to innovate in product offers.

- **Communication/Collaboration Tools**
  - Document sharing platforms: These platforms are meant to share documents between employees. Any types of document, they could be classified for example by department, customer, project. Employees can work on the same document and collaborate virtually. The main available tools are SharePoint, Box, Google Drive, and Dropbox.
  - Email: Since its apparition, organizations have switched from regular mail or fax to electronic mails. Those emails contain all information related to the operations of an organization from sales, and production to legal. Tons of essential data is exchanged every day using this tool. The main solutions are Outlook, and Gmail.
  - Instant messaging: it is a communication tool that replaces emails when employees want a quick chat between themselves. Skype for business is very knowledgeable in this area.

The list of solutions mentioned above is not exhaustive. Thousands of solutions exist in the market especially when we talk about niche markets. In a nutshell, those solutions, especially management solutions, are present to help and assist employees in their daily activities within the organization. They all require inputting data to give an output that makes operations and decision-making process easier. Each of those solutions contains vast amounts of unstructured data and information. These data may include valuable information that can be used elsewhere. The majority of those solutions has developed their own internal search engine to easily access the information that resides in it.

b. Non-Digital

Non-digital data is also present in the majority of organizations. And it is represented mainly by papers. Besides, in the recent decade, many organizations decided to go paperless. Nevertheless, we still see papers/documents moving from one office to another or department to another. Within these papers, important information resides. The amount of paper differs from one organization to another but in some of them an archive room exists in which thousands of papers occupy a space.

When the information is stored in papers, multiple challenges face the organization:

- Too much paper
- Losing documents
- Data security
- Different document versions
- Risk of a total loss of the documents by a fire or a
- Water damage

2) External Sources

External sources of data are also crucial for organizations. They are represented mainly by:

- Internet
- Magazines
- Forums
- Social Networks
- Trade shows
- Market trends

These external sources of data will allow organizations to be well-informed about what's going on outside the company. They will know what the competition is doing, and how the media is talking about them. We believe that having access to external sources of data is beneficial.

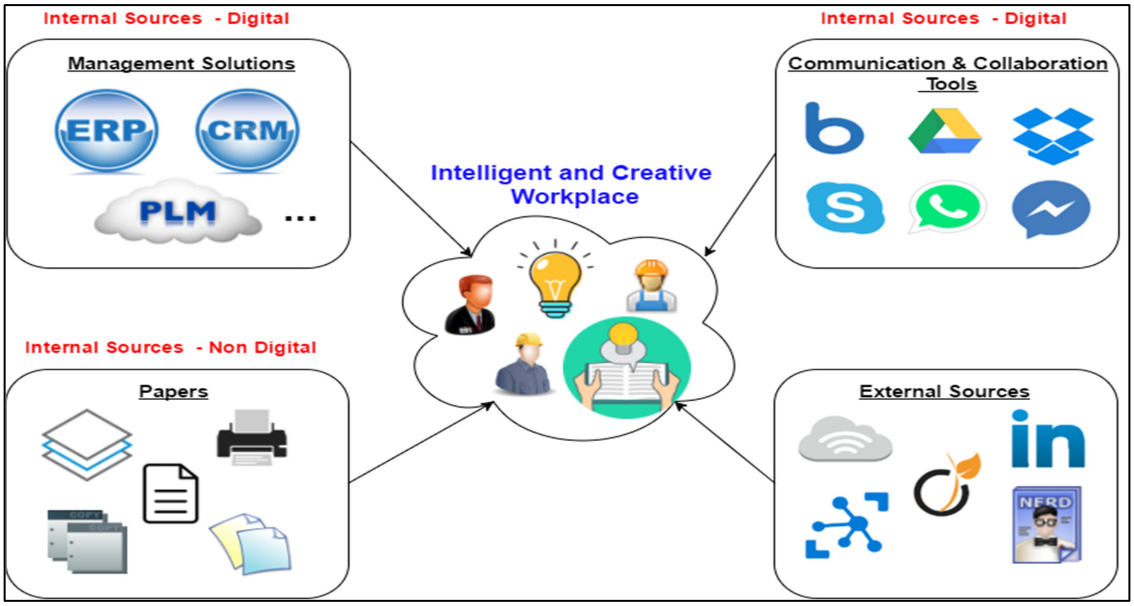


Figure 1.3 Mapping a company's content

1.2.2.2 Organize

Using the technologies mentioned above (OCR, workflows, business rules, smart templates…), this content will be organized.

So, we will start with unstructured and uncontrolled content everywhere in the workplace to end up with structured content. This content will be indexed and classified in the corresponding digital archives.

ECM solutions are mainly used for daily and operational tasks. Usually, the main reasons to implement ECMs are: to reduce searching times, unify the presentation or adhere to reporting obligations (Vom Brocke et al., 2010).

After organizing and structuring the content, ECM will deliver it to users in the format of a list. We will use visualization tools to change this output to a graph format highlighting the relationships between contents.

Enterprise Content Management System (ECMS) has become a mandatory solution for every organization. Their repositories are becoming crowded with huge volumes of structured and unstructured content. However, we noticed that only a few researchers worked on the ECM as a creative support tool. We are proposing to harness the use of ECM in the innovation process and to couple it with visualization tools. The coupling with visualization tools aims to present the search result in a graph format and study the links between the contents.

1.2.3 Visualization tools

The ECM tool permits to extracting, classifying, and archiving content from Non-structured Content (like documents, Articles, Patents) (see Figure 1.3). The output of this system is a list of Structured Content: Indexed, classified, and stored.

In this study, we propose using graphs to visualize and analyze the result of the ECM. We define a 'Content Graph' as a graph representing the relationship between contents. A content Graph is a network with nodes that are connected unidirectionally by links of various relations and are intended to organize the entire relation structure between contents. ECM result graph has several noticeable benefits compared to actual search results in a list format.

The main advantages of using a graph representation are:

- *A standard tool for data visualization*

Graphs have long provided visual languages and have been widely used in many different disciplines as formal representation systems. We propose to use graph representation to better understand the links between contents and to have additional analysis tools. Compared to an ECM search result in a list format, using a content graph presents several advantages and noticeable benefits.

- *Minimize the reading and interpretation time*

The content graph is a particularly good way of presenting the contents residing in the ECM especially when using the search function. Displaying a search result in a graph instead of a list will show the entire content of the search result. Content graph representation describes the diversity and the depth of the ECM as a whole search result without omitting any content residing at the bottom of a list and highlighting the relationship between them. It is essential to participants in an ideation session to understand the relationship between all their organization's content to clarify their thinking and to optimize their creativity exercise.

- *Power tool to analyze the ECM search result*

The other great advantage of this presentation way is the possibility to use many structural analysis tools proposed by the graph theory. These tools allow a quantitative analysis of connectivity and relationships between contents. For example, with the content graph, all contents are represented on a graph. Using analysis properties, the graph representation provides a power tool to analyze the ECM search result. This analysis will provide the user the easiest way to access to the right information and save time. Also, it will highlight relationships between contents that a user without applying analysis properties could not access to them. These relationships may present an exciting support tool for creativity.

In the following section, we will present some examples of analysis tools issued from the graph theory and their utility in the analysis of content graphs.

1.3 Methodology

In this section, we are detailing the methodology used to guide this work.

As mentioned previously, providing support tools to creative teams in innovation activities during the ideation step could be beneficial.

To implement our methodology, we had to follow these steps:

a. Need identification

In innovation activities, we always start from a defined need. This need could be:

- Developing a new product that has a better design,
- Improving the client call center satisfaction level,

- Reducing the cost of certain materials,
- Enhancing the quality of a product

The need identification step is present is all the subsequent chapters. This step is very important as it defines the goal for the next steps.

b. Collecting data

Based on the identified need, data should be collected from different sources to be used as a support tool during the ideation generation step.

To collect data, different support tools could be used like the ECM. This data will be a catalyst to enhance teams' creativity. However, a significant quantity of data may overwhelm creative teams and slow down their innovation exercise. To cope with this challenge, we will analyze the relationships between the data and display it to creative teams in a graph format. Analysis properties from the graph theory will be used. Chapter 3 describes the essential analysis properties and their utility in our use case.

c. Idea generation

Creative teams based on their background use their knowledge to generate ideas for the identified need. They also rely on the data collected from other sources to enrich their creativity exercise. By working as a team, multiple opportunities could be noticed like having participants that have a different background so this may enhance the diversity of ideas. Also, the possibility of combining ideas using bisociation could provide more innovative ideas.

The idea generation step is described and experimented with in the use case detailed in Chapter 4. In this step we are using the analysis properties described in Chapter 3.

This same use case is used to experiment with a novel approach of combining ideas to provide innovation windows. This approach is described in Chapter 5.

d. Evaluation:

Once ideas are generated and creative teams make decisions on which one will be submitted, a panel of evaluators will evaluate and rank the best ones based on predefined ideas. The evaluation is presented in Chapter 4 for the '24h innovation' competition use case and in Chapter 5.

Table 1.2 Methodology landscape by chapter

	Chapter 2	Chapter 3	Chapter 4	Chapter 5
Need identification	X	X	X	X
Collecting data		X		
Idea generation			X	X
Evaluation			X	X

By following the steps described above, we have decided to experience our methodology initially in the "24h Innovation" competition and then in a second event called: "59 Minutes of Innovation" organized by our research laboratory team.

Here is a brief overview of this competition: The 24 Hours of Innovation is an international creativity competition invented by "L'École supérieure des technologies industrielles avancées" (ESTIA) in France (*Les 24h de l'innovation / The 24h of Innovation*, n.d.). L'École de technologie supérieure (ÉTS) in Montreal, Quebec, Canada, was invited to participate in this event since 2010. In this competition, students are invited to work during 24 consecutive hours to solve a problem submitted by companies and researchers, creatively. A local committee chooses the best projects and sends the winning project to an international committee which will choose the three best international projects from all the local winning projects. Different prizes are given to the winners.

In the use case presented later in this work, we applied our methodology in the "24h Innovation" 2019 Edition. In that edition, it had different participants from all over the world. In total, the competition had 2000 participants from 14 countries to solve 18 challenges.

1.4 Knowledge Creation Framework

The researcher selected the Design Science Research Methodology (DSRM) for Information System (IS) Research proposed by Peffers *et al.* (2007) since it enables research based on the study of the current environment. It includes six steps: problem identification and motivation, definition of the objectives for a solution, design and development, demonstration,

evaluation, and communication. This methodology was based on Design Science research principles and focused on a consensus-building approach from existing researches to produce the design. This process model/ framework consists of six activities in a nominal sequence that we present in the subsequent chapters and each step of the process is well-detailed.
This process will be implemented and evaluated at each step of our work and will serve as a foundation to position our work as a reference.

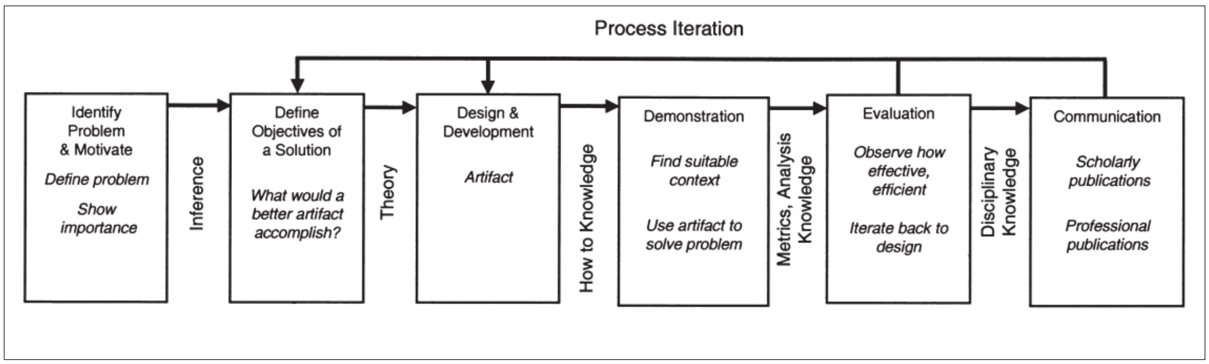


Figure 1.4 DSRM Process Model
Taken from Peffers *et al*. (2007, p. 54)

As aforementioned, this framework will be applied in this research work. Therefore, each chapter is represented by at least one of the activities mentioned in this model.
In this chapter 1, we are at the first step, “Problem identification and motivation” the identification of the opportunity to include ECM in the innovation exercise. Knowledge collaboration and by providing content to participants, this may improve the innovation process at the ideation step.
In chapter 2, we are presenting the second step of the framework which is “Define the objectives for a solution”. We are presenting and discussing the problem. Then, we go through a state of the art to position our work. Finally, we are designing a methodology presenting how we are willing to work to solve this problem.
In chapter 3, we present the third step of the framework which is “Design and development”. We are presenting and discussing the available tools from Graph Theory and their utility in our context.

In chapter 4, we present the fourth step of the framework, “Demonstration”. After talking about the problem and the available tools, we are applying our approach in a use case. This use case represents a demonstration for future research works. In the use case, we are working on a proof that Content management solutions may improve participants’ creativity at the early step of the innovation process. Then the fifth step “Evaluation” is applied to evaluate our approach and discuss the findings. At the end the Sixth step “Communication” was used to publish this chapter in the Academic Journal: International Journal on Interactive Design and Manufacturing (IJIDeM).

In chapter 5, since the selected framework is iterative, we have decided to repeat the following steps: 4, 5 and 6 with another use case. After having promising results in chapter 4, we thought about involving other aspects in our approach. In this chapter, we are discussing using our approach in a new method by combining it with creative cues in a card-decks scenario to benefit from this bisociation and create a solution space with thousands of possibilities. Also, we are preparing to include it as a software tool to make it more accessible to users.

1.5 Expected results

While participating in innovation activities, creative teams need support at the ideation step. The latter is the step used in the Stage-Gate process in many companies to launch new products or services.

We believe that providing creative teams with the right proper support, will enhance their creativity and generate better ideas. In order to evaluate and rank these ideas, we will rely on an independent jury provided by the “24h Innovation” competition organizing committee. Creative teams will be supported by multiple information loaded in an Enterprise Content Management Solution. This information will be analyzed using the graph theory to define the links between them.

We expect that creative teams having access to our proposed approach detailed in Chapter 4 will have more creative ideas related to the given challenge and thus by being better ranked in the competition compared to teams who do not have this support.
Also, by combining the latter approach with creative cues in a card-decks scenario creative teams will get a substantial support tool in the innovation exercise. This combination with creative cues uses bisociation.

CHAPTER 2

ENHANCING CREATIVITY BY LEVERAGING EXISTING ORGANIZATION'S KNOWLEDGE THANKS TO AN IMPROVED APPROACH OF USING ECM

Houcine Dammak[a], Mickaël Gardoni[a,b], Lorena Escandon[c]

[a] Département de génie des systèmes, École de technologie Supérieure,
1100 Notre-Dame Ouest, Montréal, Québec, Canada H3C 1K3
[b] Institut National des Sciences Appliquées, 24 Boulevard de la Victoire,
67000 Strasbourg, France
[c] Ryerson University, 350 Victoria St, Toronto, M5B 2K3, Ontario, Canada

Paper submitted for publication, January 2023

This article positioned our work by presenting a literature review and then the problem statement. It also presents the proposed approach.

Abstract.

Participants in ideation session should have insights to come up with new ideas. To this aim, the organizations' knowledge contains valuable content that could be leveraged to benefit ideation sessions. Enterprise Content Management systems (ECM), which store some of the organization's content, could be used as a support tool. This amount of information requires further processing to be used by participants in ideation session.

This paper proposes a reference model to convert organization's content as raw data into views that display contents to creative teams. Three activities were proposed: 1- Data classification using taxonomy & metadata, 2- Data analysis to find patterns and links between contents (Graph theory, AI, Data mining), and 3- Representation of the analysis result to participants to boost their creativity.

This paper proposes an approach to enhance creativity during ideation session by converting existing organization's knowledge into creativity insights and exploration areas.
Further research work and experimentation will be conducted to validate the proposed approach.
This paper fulfills the need to create insights in ideation session by leveraging existing organization's knowledge.

2.1 Introduction

With the rapid change in the world, many organizations are steering towards investing in an intelligent and creative workplace. This is primarily because of the new technologies and their advancement, which have increased the competition in the market and propelled many organizations to adopt this new wave of advancement, which is being threatened by the small players who are continuously changing the market by adopting this new change. Thus, raising the alarm for organizations, especially the large ones, that have yet to adopt these new technologies.
Even companies like HP, who are early adopters of new technologies to share information between the different business units and employees, still struggle with storing this mass amount of data. The HR executive at Hewlett-Packard Co said: "If only HP knew what HP knows" (Sieloff, 1999). Hence, proving that when it comes to storing and utilizing this enormous amount of data, all organizations, no matter how big or small, struggles and it is one of the significant challenges for them. Furthermore, this information provides an opportunity for many organizations to utilize them in their innovation processes for any products or services as it contains valuable knowledge in it.
Innovation and adaptation of the change in the market are crucial for every organization in order to stay in the game, or else if they fail, the same situation might arise with them as it happened with prior companies like Kodak, Nokia, Blockbusters and Blackberry, for example, disappeared or are stumbling because they did not innovate in their products and offerings. Innovation is a process that does not necessarily relate to a product, or just by

implementing an innovation program, they will become innovative, but the reality states otherwise.

One of the crucial steps for innovation is the ideation step which requires the generation of ideas (Escandón-Quintanilla, 2016). This step is usually handled by creative and knowledgeable teams that have access to valuable information. Therefore, much research has suggested the use of ideation support tools. For example, researchers like Escandon-Quintanilla, 2017 used keywords as a support tool at the ideation step, whereas others used data mining. These tools will further help ideators in their innovation exercise as they will provide them insights, solutions and ideas related to other challenges, hence promoting more creative ideas.

One of the objectives of ideation sessions is to set an environment and implement creativity methods or techniques to help participants generate, express, and combine ideas. Ideation support tools could be in these sessions to look for ideas and insights in the organization's existing knowledge. However, what is a more challenging task for the organization is collecting this enormous volume of data and then organizing them, which, if done manually, can consume not only a lot of time of its employee but also can put mental pressure on them. Therefore, to organize the data effectively and efficiently, the organization can do so by adopting a strategy/approach to classify its content. Taxonomy is one of these approaches that was adopted by corporate organizations to cope with this challenge. Taxonomy may help to classify the organization's content by capturing metadata. Enterprise Content Management tool, known as ECM, is used in classification organization's content by capturing its related metadata. It will allow the organization to save costs and reduce workload by streamlining tasks and improving search and retrieval of previous valuable content, that is to say knowledge or ideas, to help to generate ideas.

This paper will discuss how we can use organization's content in enhancing creativity in the workplace by providing it to innovation teams in a comprehensive and easy to use way. Corporate taxonomy and classification tools like ECM could be used as support tools and could play a vital role in the ideation process. However, these tools have some limitations to performing this task. In this paper, we will be focusing on enhancing creativity from a selected organization's content by taking advantage of ECM. The limitations of this approach will be discussed.

2.2 State of the art: Taxonomy & Metadata

2.2.1 Taxonomy overview

Taxonomy plays an essential role in categorizing and classifying information based on its purpose and use. Bridges (2007) discusses how a well-developed taxonomy can be derived from the organization's work usage and business culture and how it requires the use and adaptation of unique terms drawn from each industry associated with the organization's functions and specialized lines of business. In ECM, taxonomy can be beneficial in capturing contextual organizational metadata with the content produced or received. It also makes it easy and helps in the maximum production of content metadata (Munkvold *et al*., 2006).

Reamy (2007) further explains how taxonomy and ECM go hand in hand. He describes how taxonomy delivers great value, and by combining it with content management, organizations can get greater value from both, and the synergy among them creates even more value. Reamy (2007) also explains the primary way how taxonomy can be used within an ECM application is through tagging documents as they get published with subject matter keywords; it gives more power to the keyword by enabling the search engine to place the users' input in a well-ordered relationship with other terms (Alalwan, 2013).

Freund et al. (2005) discuss how metadata and taxonomies are essential to enterprise-wide information search and retrieval and how they have become one of the most popular research areas nowadays.

A case study by Munkvold *et al*., *(*2006) talks about how a company named Statoil utilizes corporate taxonomy within the ECM system in the entire organization. A corporate taxonomy is basically a way of representing the information available within an enterprise (Woods, 2004). At the same time, Statoil combined corporate taxonomy with the ECM software in order to support the maximum automated definition and maintenance of their taxonomy. Moreover, Munkvold *et al*., 2006 discuss the purpose of corporate taxonomy in Statoil as the basis for users to navigate through content collections and conduct searches. It was also used to provide a basis for defining and coordinating access rights to the content collection. Further, categorize user roles and their responsibilities and then serve as a basis for automatically creating organizational metadata on content pieces (Munkvold *et al*., 2006).

2.2.2 Metadata overview

One way we will look at the data is through Metadata which is defined as a description of stored data (Kim, 2005). As Kim (2005) further goes on and talks about it in one of his articles about the different phases of metadata management systems, where initially, it was file-based data dictionary systems which were changed to repositories based on relational database systems. Now finally being known as enterprise information integration systems by several vendors. He further explains how this metadata management system is integral, but in today's era, very few satisfactory universal metadata management systems are on the market.

Moreover, Day (2001) further discusses the seven distinct purposes of Metadata; where the first one is resource description, where we can identify and describe the entity, and the Metadata is all about it. Next, we will focus more on information retrieval or for a web, which is known as resource discovery. At the same time, the third and fourth purpose states how Metadata can be used to administer and manage resources, such as flagging items for an update after a set period has elapsed and then moving forward with intellectual property rights. The fifth purpose is providing contextual information about a resource, but this will not be used for every resource. Finally, the last two goals that Day (2001) discussed are the preservation management of digital resources and, ultimately, providing information on the context and providing information on context and authenticity.

Greenberg *et al*., 2005, talk about the importance of Metadata and how it can be beneficial in improving resource discovery by helping search engines and people discriminate relevant from nonrelevant documents during an information retrieval operation. Moreover, time is of the essence, and doing a manual creation of Metadata is not only costly but also time-consuming and prone to more errors (Thönssen, 2010). Hence, a survey conducted by Greenberg (2006) talks about "how the metadata experts' opinion on functionalities for automatic metadata generation applications strengthened the supposition that it is unrealistic to depend on traditional humanly generated metadata approaches, given the massive number of digital resources requiring metadata."

Even with this mass amount of data available nowadays, there is still an insufficient approach for automatic generation of Metadata as they are restricted to text documents or are limited to system properties provided by document creation tools (Thönssen, 2010). Therefore, we will be utilizing the ECM Metadata to improve the ECM search result by better classify contents and to use it in the ideation stage as a support tool to enhance creativity.

2.2.3 Metadata and its Usage

Metadata can be extracted from any organization using a different framework for each, depending on the size of the organization and the information lifecycle in a segment of the company (Yim, 2018). Moreover, Yim (2018) also discussed how a good metadata taxonomy design must be tailored specifically to the business itself. To reach that, companies must analyze the data they possess properly. For example, Yim (2018) talks about how metadata can be used for content type classification, where we can divide the content into four categories that are category function, category, type and finally subtype and then input relevant information according to each category they might fit in as seen in Table 1.

Table 2.1 Content Classification Metadata Table
Taken from Yim (2018, p. 33)

Content Function	Content Category	Content Type	Content Sub Type
Administrative	Publications	Press Release	
Administrative	Publications	Industry Newsletters	
Environmental	Permits	Water Permit	Water Acquisition Permit
Environmental	Permits	Water Permit	Water Well Permit
Legal	Contracts & Agreements	Commercial Contract	Purchase Agreement

Legal	Contracts & Agreements	Commercial Contract	Lease Agreement
Legal	Contracts & Agreements	IT Contract	Software Licensing Agreement

In another business scenario, Yim (2018) explains how an organization can classify contracts and agreements with auxiliary metadata fields by using manually input and auto-generated metadata fields where the metadata values are assigned systemically through a pre-defined metadata rule or logic. Tables 2 and 3 show how metadata attributes are used to define the roles of an individual or organization (Yim, 2018).

Table 2.2 Business Function Classification Metadata Mapping (User Identity) Taken from Yim (2018, p. 47)

Employee	Organizations	Business Unit
Alice	Commercial	Crude Management
Bob	Commercial	NGL Management
Charlie	Commercial	Natural Gas Management
David	Legal	
Eve	Legal	
Fred	Accounting	Volume Accounting
Gary	Information Technology	Enterprise Business Systems

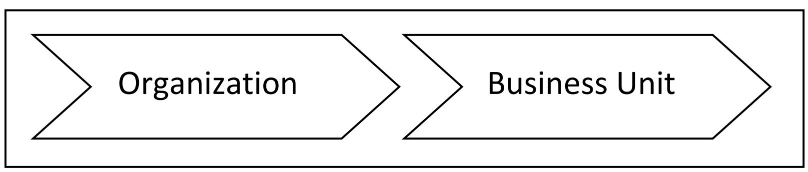


Figure 2.1 Business Function Classification Taxonomy

Table 2.3 Business Function Classification Metadata Table Taken from Yim (2018, p. 34)

Organization	Business Unit
Accounting	Payroll Accounting
Accounting	Volume Accounting
Commercial	NGL Management
Commercial	Crude Management
Information Technology	Network Infrastructure
Information Technology	Enterprise Business Systems
Legal	

On the other hand, Yim (2018) also illustrates in Tables 4 and 5 how metadata attributes for two separate and different contracts can be stored in an ECM system. To make it simpler to keep these contracts, he divided information into ten categories. Furthermore, he wrote relevant information in each class so that instead of going through an entire agreement, the user can use the help of the ECM and metadata table to extract all pertinent information they might need.

Table 2.4 Content Classification Metadata Mapping (Contracts)
Taken from Yim (2018, p. 39)

	Sample Contract 1	Sample Contract 2	Sample Contract 3
Content Function:	Legal	Legal	Legal
Content Category:	Contracts & Agreements	Contracts & Agreements	Contracts & Agreements
Content Type:	Commercial Contract	Commercial Contract	IT Contract
Content Sub-Type:	Purchase Agreement	Lease Agreement	Software Licensing Agreement

Table 2.5 Auxiliary Classification Metadata Mapping - Manual Input (Contracts)
Taken from Yim (2018, p. 43)

	Sample Contract 1	Sample Contract 2
Content Function:	Legal	Legal
Content Category:	Contracts & Agreements	Contracts & Agreements
Content Type:	Commercial Contract	Commercial Contract
Content Sub-Type:	Purchase Agreement	Lease Agreement
Internal Business Entities:	Company I-A	Company I-B
External Business Entities:	Company E-X	Company E-X
Commodities:	Natural Gas	NGL
Contract Number:	CCPC-NG-00165	CCLA-NGL-00335
Execution Date:	11/1/1999	5/15/2013
Termination Date:	7/31/2020	12/31/2035

Figure 2 shows a sample Metadata classification for a Contract (Content) as proposed by Yim (2018).

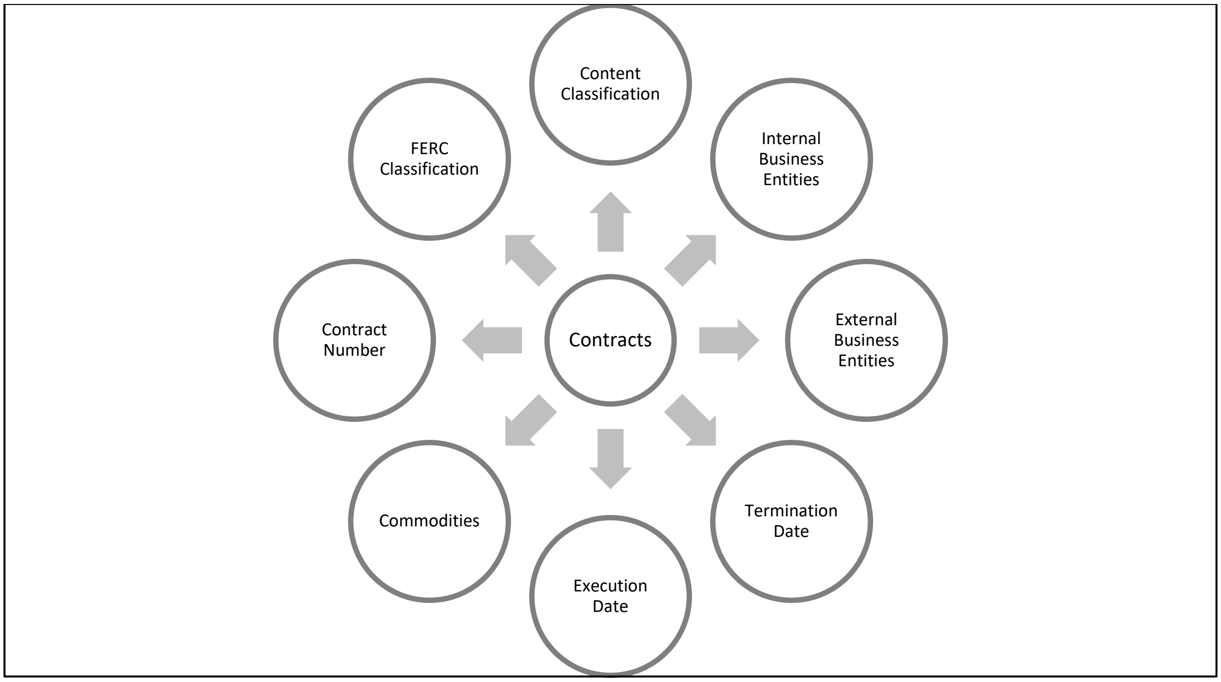


Figure 2.2 Sample Metadata Classification for Content
Adapted from Yim (2018, p. 32)

2.3 Organization's Content and the importance of using ECM in an ideation session

2.3.1 ECM in the innovation process at the ideation stage

With the everchanging dynamics of the markets, many organizations have been forced to adopt them in order to stay competitive. However, the most challenging part for an organization is ensuring they have the right software/tool or a system to control this vast amount of data.

Many organizations today have an enormous amount of information which is present everywhere and can be seen in different formats such as documents, communications, databases and many more, and they represent a great asset for any organization. Hence, reusing this content and data-driven management would be efficient and provide better productivity, profitability, and competitiveness for the organization (AIIM: Association for Innovation and Image Management, n.d.) and in our case, improve creativity by nourishing the brainstorming session by previous valuable knowledge and ideas. Nevertheless, the problem that arises in these kinds of situations is how to gather all these enormous volumes of different data and organize them to make it convenient to be interpreted for everyone. One-way organizations can achieve a more reliable and efficient way of storing data is by adopting ECM, also known as Enterprise Content Management, which converts non-structured content to structured content using its main functionalities (Alalwan et al., 2014). The goal of using ECM is to help to better exploit the organizations' content.

Enterprise Content Management, or ECM, is defined as the technologies, tools, and methods used to capture, manage, store, preserve, and deliver content across an enterprise (AIIM: Association for Innovation and Image Management, n.d.). Whereas Nonaka & Takeuchi, 1995 defined ECM as a collection of strategic resources and capabilities that provides an automated enabling framework for efficient lifecycle management of valuable organizational assets, that is, contents and processes, to carry out essential business operations in a collaborative fashion, supports governance and compliance, provides integration within and outside the business boundaries to achieve business intelligence, knowledge management and decision support capabilities with a focus on the fulfilment of business goals and objectives for competitive advantage (Usman *et al.*, 2009). This tool is usually used on the operational side of an organization but on the other hand; it can also be used in an ideation session, where participants can be given access to it, where they will be able to see its impact on the creativity of an organization as they have access to valuable information that is structured and easily accessible.

On the bright side, ECM has proven its efficiency not only in the industrial world but also in the research world. For example, in a survey conducted by a research team from the University of Economics in Prague, the results show that 92% of organizations expect benefits from innovations in ECM systems (Kunstová, 2010). Consequently, proving that the availability of information is one of the critical success factors for organizations to survive.

Much research that has been done on ECM has usually focused more on the operational and tactical benefits that it provides rather than looking at the strategic benefits that it can also offer. For example, from the operational benefits point of use, ECM can help save costs and reduce workload by streamlining tasks and improving data search and retrieval (Alalwan et al., 2014). On the other hand, ECM provides tactical benefits by improving internal and external collaboration and enhancing content quality while maintaining consistency and standardizing workflows. Using ECM for strategic benefits could also increase decision-making capabilities and facilitate creativity by proposing valuable content (Alalwan et al., 2014).

Vom Brocke et al., 2010 discussed ECM's four main steps: capture, organize, process, and maintain. The first step, which is capture, is all about identifying the content from internal to external databases. In the second step, the content is indexed, classified, and linked. In organizing, different techniques like Optical Character Recognition (OCR) and smart templates are used for indexing which can identify the metadata, workflows for classification based on business rules and ODBC connections to link content with other databases. In the process stage, the content is analyzed and classified in order to inform decision-makers and other existing management systems. The last step is mainly related to the maintenance of the content, such as how to keep it accessible? How to link it with new content? On top of that, for how much time should we keep it?

By implementing ECM solutions, not only the search period is reduced, but also it unifies the presentation or adherence to reporting obligations. In the early stages of the innovation process, participants are invited to use their creativity to develop ideas. Those ideas are usually inspired by the participants' background and own knowledge. The combination of teams existing technical expertise and limited content outside of the domain-specific knowledge provokes more original and diverse ideas, which confirms there is a creative value in combining KDD (knowledge discovery from databases) with teams' existing knowledge.

As part of facilitating creativity, ECM could contribute to the innovation management process. One of the crucial steps of this process is the ideation step. We believe that providing tools like ECM to the participants can help enhance this step. It is because they have access to all the content indexed, and the content is classified more easily. This access to information will allow them to enhance creativity, which will create new knowledge. Escandon-Quintanilla, (2017) further goes on and discusses how participants are invited to come up with ideas which are usually inspired by the participants' background and knowledge in the early steps of the innovation process.

2.3.2 Discussion and limitations

When it comes to using ECM in the ideation session, we have identified few limitations and one of the main purposes of this article is to present these limitations and to discuss approaches to solve them.

Today, ECM is mostly used for daily operational tasks as it helps reduce search times, unify the presentation, or adhere to reporting obligations (Vom Brocke et al., 2010). However, implementing ECM will give access to more information and faster, thus creating a crucial ground for an effective innovation process. That is why by using ECM in the ideation step, participants can more easily access all the content, thus giving them access to more information and allowing them to be more creative by feeding their reflexions with new knowledge.

Therefore, we believe that ECM is not yet used at its full potential and that it should play a more important role and contribute more to the organization's success by enhancing.

2.3.2.1 Lack of tools to analyse contents – Analysis of patterns and links

Some researchers proved that access to large databases of information could overwhelm users in their innovation process and tend them to return to known solutions, decreasing creativity (Escandon, 2017). Moreover, suppose we use ECM in its current format with a long list of contents in an ideation session. In that case, participants may lose time demystifying this list to understand the indexes and set a priority list which will lead us to conclude that we need to improve the output of the ECM. As part of this improvement process, tools to analyze the links between contents should be proposed in order to make it easier for participants to utilize the content. In addition, analyzing content may provide more insights about them and lead to interesting findings to enhance creativity.

2.3.2.2 Inefficient ways in presenting the outcome of the Analysis - Exploiting the analysis result

By analyzing content, links between them will be highlighted and patterns could be identified. However, some researchers have concluded that extensive data can overwhelm users. Today, ECM is presenting the search result in a table format displaying contents and its associated metadata. Even if the data was analysed, we don't believe that presenting the results in a table format is user friendly especially when the list becomes long. To avoid this situation, we should provide efficient ways to exploit/display the result of this analysis; this exploitation could be displayed in a graph or a view format. We believe that exploring a graph or a view format will be benefitting to participants.

2.4 Approach to improve the use of organization's content in an ideation session

As mentioned above, the ECM could be an interesting tool to use the organization's content. However, two main limitations were identified in the use of ECM in an ideation session. This section is discussing these limitations and proposing approaches to improve the use of ECM in an ideation session in order to look for insights within the organization's existing knowledge and better ways to exploit them. Both identified limitations are related to the processing of the actual search result from the ECM to support the existing organization's knowledge in enhancing the creativity in the workplace. Taxonomy will be used as it plays an essential role in categorizing information based on its purpose and use.

The ECM search result is a valuable information extracted from the company's existing data. However, this search result requires work to analyse it and present it in an understandable/comprehensive visual in order to enhance the creativity in an ideation session. The range of possible graphs or views is wide and depends on different parameters when it comes to analysing raw data (like a table with a list of contents). Some researchers already did the exercise of analyzing the different software tools (Dkhil, 2011) and found their number is important and in general, the overall architecture of these software tools is structured according to a reference model provided by (Card, 1999). This reference model will be used as a guideline to our approach.

Card, 1999 presents visualization (views) as a mapping from data to views format that the human perceives. The following figure presents this reference model that shows how the flow of data goes through a series of transformations. The human may interfere at different steps to adjust these transformations.

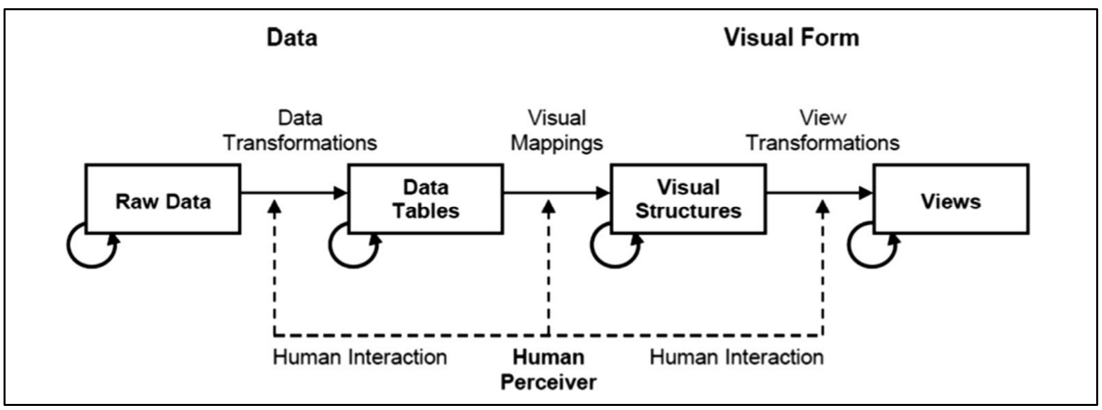


Figure 2.3 Reference Model for Visualization
Taken from Card (1999, p. 17)

Using an analogy to this reference model to apply it in our context, the following figure presents the modelling of our approach that will be explained later step by step:

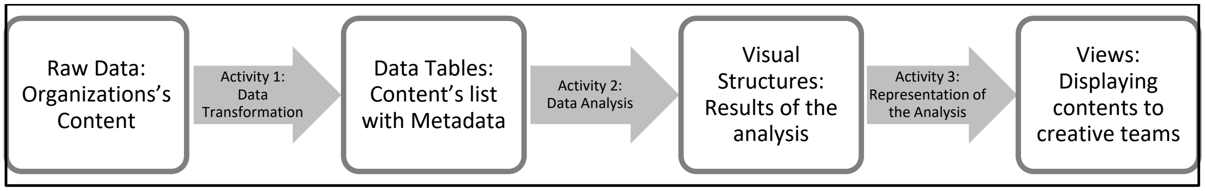


Figure 2.4 Approach to apply the Card (1999) reference model on the organizations' content while looking for insights

From this analogy, three main activities were identified to transform raw data to views. This transformation will study the links between the organizations' content stored in the ECM, analyze patterns and finally display them in a comprehensive view to creative teams in ideation sessions.

The main goal is to find better ways to use the organizations' content to find insights in an ideation session.

- Activity 1:

As mentioned above, the output of the ECM is considered our input in the innovation process. The ECM started with organization's data as a Raw Data then it converted it into an adapted data by adding metadata (Classification, taxonomy to it). Activity 1, in our approach, is considered as raw data. Activity 1 which is data transformation converts raw data into more usable data tables. In our context, the raw data is the entire organization's content that is available and is difficult to use/exploit by participants in ideation sessions since it could overwhelm them and have negative impact on their creativity. This activity will transform the list of contents to an adapted state of data which is easier to analyze. The adapted data is usually presented in a table format and shows the relationship between data. Using taxonomy, a classification system could be developed to convert this raw data into an adapted data that is easier to understand. Dammak *et al.*, (2020) used Patents as raw data and used the IPC system (Internal Patent Classification) to identify the related metadata. Table 6 presents one of the examples used by Dammak *et al.*, (2020) on patents.

Table 2.6 Patent Metadata Classification using the IPC (International Patent Classification)
Adapted from Dammak et al. (2020, p. 947)

	Sample Patent 1
Section & Section Description:	A: HUMAN NECESSITIES
Class & Class Description:	A45: HAND OR TRAVELLING ARTICLES
Sub Class & Sub Class Description:	A45B: WALKING STICKS; UMBRELLAS

- Activity 2:

This activity will analyze the adapted data and present its result in different format. This activity is dedicated to find solutions to the first limitation that was identified while using Organization's content in an ideation session. The core of the reference model is the mapping of adapted data to results of the analysis. Data tables are based on mathematical relationships whereas the results of the analysis are based on graphical properties processed by human vision. In the reference model, this is the most difficult activity.
From this activity, we are able to analyze all the relationship between contents and identifying the most important analysis properties.
Dammak *et al.*, (2020) used Graph theory analysis tools to analyse the relationship between contents (Biconnected Graphs, Articulation Points, Clustering, Graph node groups…). Other researchers like (Escandon-Quintanilla and Gutierrez-Lopez, 2019) proposed to use Data mining tools and Artificial intelligence for the analysis. The main goal here is to find patterns and reduce the list of contents to make it easier for participants to use them in ideation sessions.

- Activity 3:

The aim of this activity is to transform the result of the analysis to views. It is about representing it in a comprehensive way to users. This activity is mainly dedicated to face the second limitation that was identified in using the Organization's content in an ideation session. Based on the reference model (Card, 1999), displaying information to users will be in the form of visualization. From the analysis tools that were used in Activity 2, patterns were identified between contents and the information could be shared with participants in a format of a view. We believe that a visualization is much easier to participants to understand so it will minimize the reading and interpretation time. Dammak *et al.*, 2020 worked on the displaying the Organization's content in a view format, by analyzing the data using the Graph theory they introduced the notion of "Content Graph" which is weighted graph presenting the contents as nodes and the weighted edges between graphs represent the links between them. They tested their approach in an innovation event and proved that teams using the “Content Graph” gained a lot of time during their idea generation step and proposed more appealing and detailed idea. Other researchers proposed to display contents in the form of card decks, as a way to combine gaming and ideation session (Escandon-Quintanilla and Gutierrez-Lopez, 2019).

We believe that representing the result of the analysis in a views format could minimize the reading and interpretation time by participants in an ideation session.

2.5 Conclusion

Our proposed approach presents a way for participants in ideation session to use their valuable organization’s content. This approach presents to organizations how to look at these contents and exploit them. Organization’s content contains valuable insights that are underutilised. This approach should be valid for organizations from different industries and different sizes.

The focus was limited on the organization’s content which contains existing internal knowledge. We believe that another activity is worth mentioning which is combining these views with external data in order to improve the enhancement of the creativity.

CHAPTER 3

GRAPH BASED TOOLS FOR ECM SEARCH RESULT ANALYSIS TO SUPPORT THE IDEATION STEP

Houcine Dammak[a], Abdellatif Dkhil[a], Mickaël Gardoni[a,b]

[a] Département de génie des systèmes, École de technologie Supérieure,
1100 Notre-Dame Ouest, Montréal, Québec, Canada H3C 1K3
[b] Institut National des Sciences Appliquées, 24 Boulevard de la Victoire,
67000 Strasbourg, France

Paper published in: PLM2019, IFIP Advances in Information and Communication Technology, vol 565. Springer, Cham.
Doi: https://doi.org/10.1007/978-3-030-42250-9_16

This article documents the Graph theory tools and their potential of utility for ECM search result analysis.

Abstract.

ECM is defined as the technologies, tools, and methods used to capture, manage, store, preserve, and deliver content. Using ECM in the ideation step of the innovation process may enhance the creativity of users to create new knowledge. ECM users will have access to valuable information that is structured and easily accessible. Some researchers proved that access to large databases of information can overwhelm users, in their innovation process, and tend them to return to known solutions which will decrease the creativity (Hicks et al., 2002).To avoid this situation, instead of presenting the results of the research to the participants as a content list with related metadata, we will propose a graphical representation

with a relational analysis between these contents. In this paper, we propose to use the graph theory to visualize and analyze the result of the ECM application.

3.1 Introduction

Organizations today have access to an enormous amount of information. This information is present everywhere in the workplace in different formats: documents, communications, databases… and it represents a great asset for any organization. The reuse of information and data-driven management is considered a route to greater efficiency and decision making resulting in improved productivity, profitability, and competitiveness (*AIIM: Association for Innovation and Image Management*, n.d.).

Availability of information is one of the critical success factors for organizations to survive. While trying to overcome this critical success factor, organizations are facing different challenges like the huge volume of data and information that exist in different formats and that is not easy to use.

Since this amount of information is usually non-structured and is present in different locations in the workplace, some information management tools have appeared. From these information management tools, we consider content management tools (ECM: Enterprise Content Management) which have the main goal to manage all the organizations' content.

ECM is defined as the technologies, tools, and methods used to capture, manage, store, preserve, and deliver content across an enterprise (*AIIM: Association for Innovation and Image Management*, n.d.). It is also defined as a collection of strategic resources and capabilities that provides an automated enabling framework for efficient lifecycle management of valuable organization asset, i.e. con-tents and processes, to carry out required business operations in a collaborative fashion, supports governance and compliance, provides integration within and outside the business boundaries to achieve business intelligence, knowledge management and decision support capabilities with focus on fulfilment of business goals and objectives for competitive advantage (Ikujirō Nonaka & Takeuchi, 2007).

The main ECM steps are (Vom Brocke et al., 2010):

- Capture: It contains all the activities related to collecting content. It is usually about identifying the content that it wants to capture and all its dimensions. This content could be captured from internal to external databases.
- Organize: It involves indexing, classifying, and linking databases together. This step utilizes different techniques like OCR (Optical Character Recognition) and smart templates for indexing (to identify the metadata), workflows for classification based on business rules and ODBC connections to link content with other databases.
- Process: Analyze the content already classified in order to inform decision makers and other existing management systems.
- Maintain: It is mainly related to the maintenance of the content. How to keep it accessible? How to link it with new content? And for how much time we should keep it?

ECM is used mainly for daily and operational tasks. Usually, the main reasons to implement ECM solutions are: reducing searching times, unifying the presentation or adhering to reporting obligations (Vom Brocke et al., 2010). ECM has proven its efficiency not only in the industrial world but also in the research world.

In early steps of the innovation process, participants are invited to use their creativity to come up with ideas. Those ideas are usually inspired by the participants' background and own knowledge. Some researchers proposed different tools to support this important step in the innovation process which is the ideation step. The combination of teams existing technical knowledge and limited domain-specific knowledge provokes more original and diverse ideas, which confirms there is creative value in the combination of KDD (knowledge discovery from databases) with teams' existing knowledge (Escandon-Quintanilla, 2017).

The ideation step in an innovation process is a critical step. Providing tools to participants in ideation sessions may enhance creativity. As mentioned above, ECM is a tool that will be provided to participants of ideation sessions to see its impact on the creativity of an organization. ECM users will have access to valuable information that is structured and easily accessible. This access to information will allow enhancing the creativity of users to create new knowledge. The gap is present, and the benefits expected are really promising but unfortunately until today, in the ECM research, Creativity, Innovation and Knowledge Management have played a minor role.

With the Content Management tool, we are planning to use indexes (Metadata) related to each content to do searches. By using this metadata layer, the participant will receive a list of contents as a search result. Most commercial ECM tools present the search results as a list of contents (documents) grouped by the category of the content (Example: Thesis, Article, Product catalog, Invoices…) and details with all the metadata related (Date, field, author, location, university…). The metadata depends on the category of documents, and it is configured at the implementation stage of an ECM solution. So, the participants of an ideation session, depending on the criteria that they will select, will receive a list of content as a search result. This list of content may inspire them in their ideation session to come up with innovative ideas.

3.2 ECM contribution in an ideation session

3.2.1 Using ECM in an ideation session

As mentioned above, ECM will convert non-structured content to structured content using its main functionalities. Then, by providing the ECM as a support tool to participants in an ideation session they will have access to all the content indexed and classified. While doing a search in the ECM, participants will have the search result in a list format (see figure 3.1). This method offers structured search results for contents to access to the most relevant ones that will support their creativity.

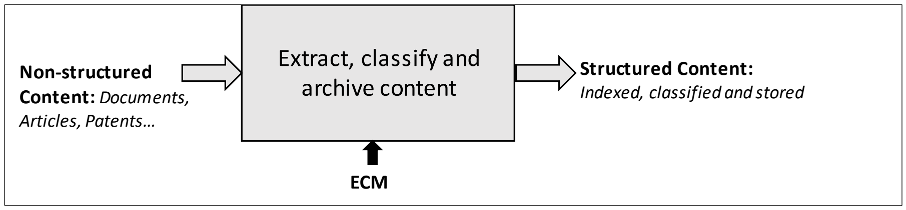


Figure 3.1 Modeling the ECM system

3.2.2 Limitation of the actual method

The actual representation of search result in the ECM allows users to have access to a list of indexed contents. Usually, organizations have thousands of contents stored in an ECM which may result in a communicative limitation. By having a long list of contents, participants may lose time to demystify this list to understand the indexes and set a priority list. So, the actual method has a limitation in describing the entire structure of contents with multiple relationships. To cope with this challenge, what information should we analyze? and how to display it?

3.2.3 Proposed method to improve using ECM in an ideation session

Some researchers proved that access to large databases of information can overwhelm users, in their innovation process, and tend them to return to known solutions which decrease the creativity (Escandon-Quintanilla, 2017). To avoid this situation, instead of presenting the search results to participants as a list of contents with the metadata related, we are proposing a relational analysis between these contents to display them in a graph which may help them.
As mentioned previously, ECM is the platform that stores content and makes it available to users when they need it. So, we are proposing a framework that couples the ECM output and the innovation process at the ideation step. And this by proposing a relational analysis of the list of contents displayed by the ECM and representing them in a graph (see Figure 3.2). The difficulty here is about the important number of analysis properties to identify the right graphs and all the combinations between these analysis properties.

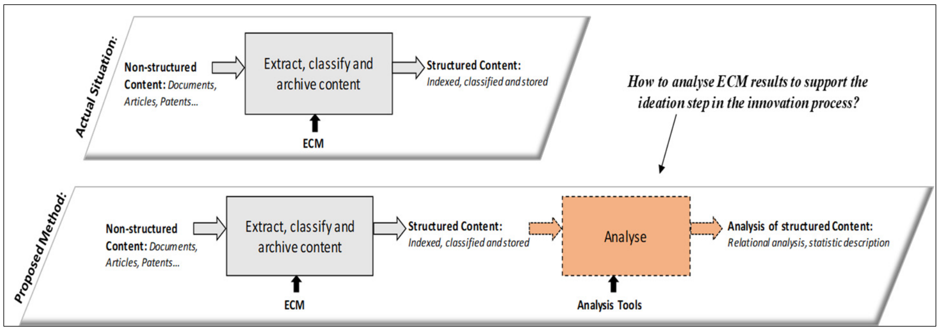


Figure 3.2 Proposed Method

3.2.3.1 Use of graph tools to analyze ECM search results

In this study, we propose to use graphs for visualizing and analyzing the result of the ECM application. We define a content graph as a graph in with the nodes represent contents (or indexes), the lines represent the relations, and the labels on the lines represent the nature of the relations. Content Graph is a network with nodes that are connected unidirectionally by links of various relations and are intended to organize the entire relation structure between contents (or indexes). ECM result graph has several noticeable benefits compared to actual search result which is in a list format. The advantages of using graphs will be discussed in the following section.

3.2.3.2 Advantages of using graph representation.

Our methodology consists of using graph theory tools to analyze the ECM results. Using a graph representation have many different advantages. A graph is a standard tool for data visualization. This representation tool permits to minimize the reading and interpretation time. In fact, we propose to use graph representation to better understand the links between contents and to have additional analysis tools. Using a content graph presents several advantages. The content graph simplifies the representation and the relation between contents (or indexes) by using standard representation allowing a comprehensive structure of the organization’s content. Graphs have long provided visual languages and have been widely used in many different disciplines as formal representation system (Bang-Jensen & Gutin, 2008) (Herman et al., 2000).

The content graph is a particularly good way of organizing the organization's content residing in the ECM especially when using the search function. Displaying a search result in a graph instead of a list brings a view of the entire content of the search result. Content graph display describes the diversity and the depth of the entire ECM search result without omitting any content residing in the bottom of a list and highlighting the relationship between them. It is essential to participants in an ideation session to understand the relationship between all their organization's content to clarify their thinking and to optimize their creativity exercise.

The other great advantage of this presentation way is the possibility to use many structural analysis tools proposed by the theory of graphs. These tools allow a quantitative analysis of connectivity and relationships between contents (Herman et al., 2000).

In the following section, we will present some example of analysis tools issued from the graph theory and their utility in the analysis of content graphs.

3.3 Graph representation of ECM search result analysis

3.3.1 Input data

The ECM tool permits to extract, classify, and archive content from Non-structured Content (documents, Articles, Patents…) (see Figure 3.1). The output of this system is a list of Structured Content: Indexed, classified, and stored. An example of a list of Structured Content is given in the following table.

Table 3.1 Example of a list of Structured Content

Category				Category 1			Category 2		
				Index	Index	Index	Index	Index	Index
				University (a)	Field (b)	Year (c)	d	e	f
1	Content	c1	Thesis 1	ETS (x)	Innovation (s)	2012 (u)			
1	Content	c2	Thesis 2	McGill (y)	Innovation (s)	2012 (u)			
1	Content	c3	Thesis 3	Concordia (z)	Innovation (s)	2012 (u)			
1	Content	c4	Thesis 4	ETS (x)	Innovation (s)	2012 (u)			
1	Content	c5	Thesis 5	ETS (x)	Innovation (s)	2015 (j)			
1	Content	c6	Thesis 6	ETS (x)	Electrical (r)	2015 (j)			
1	Content	c7	Thesis 7	McGill (y)	Electrical (r)	2012 (u)			
1	Content	c8	Thesis 8	Concordia (z)	Electrical (r)	2012 (u)			
2	Content	c9					q	t	p
2	Content	c10					q	t	p
2	Content	c11					q	t	P
2	Content	c12					q	t	p
2	Content	c13					w	i	l
2	Content	c14					w	o	l
2	Content	c15					w	o	l
2	Content	c16					q	o	k

This example considers that we have two categories of contents (the first one is Thesis) and the first category has three indexes (University, Field and Year) (Table 3.1). After organizing and structuring the content, ECM delivers it to users in the format of a list. We are using graph tools to change this output to a graph format that highlights the relationships between contents. The goal here is to study the links between all the contents presented in the search result and to present them in a graph format. A common way to represent a graph is the adjacency matrix which is a matrix A(n, n) where n is the order of the graph. An entry (u, v) of the matrix is either 0 if there is no edge between u and v or the weight of the edge (u, v) if it exists (this representation implies that no edge has a weight equal to 0). From the list of Structured Content, it is simple to extract two adjacency matrices which can be transformed into a graph. The first is the content/content matrix A(n, n): n corresponds to the number of contents. An entry (i, j) of this matrix A(n, n) indicates the value of the link between content i and content j. The second matrix is index/index matrix. An entry (i, j) of this matrix indicates the value of the link between index i and index j.

Her, and to simplify we use only the adjacency matrix corresponding to content - content link matrix (An entry (i, j) of this matrix indicates the link between content i and content j). From this matrix, a graph called content - graph can be presented.

3.3.2 Introduction to graph theory: basic terminology and notations

A graph G = (V, E) is a mathematical structure often used to define relationships between objects. It consists of a set of vertices V and pairs of vertices connecting them (edges, E). A graph can be directed or undirected. In a directed graph, given the edge e = (u, v), we say that u is the origin of e and v is the destination of e. In undirected graphs, u and v are the endpoints of the edge. An undirected graph (or graph) G = (V, E) consists of a finite set V of vertices, and a set E of unordered pairs of distinct vertices called the edges. We say that vertex v is adjacent to vertex u if there is an edge (u, v). In this paper, the used graph is an undirected graph: this graph corresponds to the content/content matrix A(n, n) (Eades & Tamassia, 1989) (Harel & Koren, 2006).

The order of graph corresponds to the number of nodes and a path in a graph is a sequence of vertices (v0, v1; …, vk) such that (vi−1, vi) is an edge for i = 1, 2, …, k. The length of the path is the number of edges, k. A path is simple if all vertices and all the edges are distinct. A path in a graph G is a sequence of vertices such that from each of the vertices there is an edge to the successor vertex. A path is called simple if none of the vertices in the path are repeated. A cycle is a path starting and ending at the same node. A cycle is a path containing at least one edge and for which v0 = vk. A cycle is simple if its vertices (except v0 and vk) are distinct, and all its edges are distinct.

3.3.3 Limit of the representation

The graph-based representation permits us to use classical graph theory tools and concepts, but some drawbacks exist. The essential limit is that lost the detailed of the link. An edge represents an aggregate index between two contents. Figure 3.3 shows an example of the aggregation of the link between tow content i and j: only one link is established. The weight of this link corresponds to the number of aggregated links.

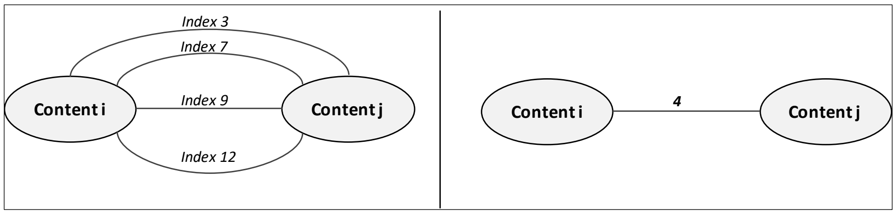


Figure 3.3 Example of aggregation

3.4 Examples of Graph tools and utility for ECM result analysis

This section aimed to show how classical concepts of graph theory can be applied to analyze ECM search result or to give quantitative information about these results. In our specific context, we present the utility in term of analysis between contents for each concept.

3.4.1 Biconnected Graphs: Connected components

Let G = (V, E) be a connected undirected graph, a graph G is connected if, for every pair of nodes v1 and v2, there is a path between nodes v1 and v2. A graph is said to be connected if it can be traveled from any one node to any others by moving along paths of edges. The graph is 2- connected if deletion of any node still keeps it connected; it is 3-connected if it still remains connected with the removal of any two nodes, and so on. It is required that a k-connected have at least k+1 nodes (Eades & Tamassia, 1989; Harel & Koren, 2006; Hossain & Rahman, 2015).

Notice that unlike strongly connected components of an oriented graph (which form a partition of the vertex set) the biconnected components of a graph form a partition of the edge set.

A graph G = (V, E) is k- connected (k-edge-connected) if at least k vertices (edges) must be deleted to disconnect G. A graph that is 2-connected (3-connected) is also called biconnected (tri-connected).

- Utility: The identification of connected component gives an indication about the clustered nature of ECM search result: each connected component represents an independent cluster. If a graph contains only one connected component, the graph is said to be connected and corresponds to a "one block" draw while a non-connected graph can be drawn in several blocks.

3.4.2 Articulation Points (or cut vertices) and Cut edge (or bridge)

Let G = (V, E) be a connected undirected graph. A node in the graph G is called cut point (or articulation point) if its removal disconnects a graph, i.e. increases the number of components. Also, it makes some points unreachable from some other (Eades & Tamassia, 1989). Articulation Point (or Cut Vertex) correspond to any vertex whose removal (together with the removal of any incident edges) results in a disconnected graph.

In graph G, a Bridge or cut edge is an edge whose removal results in a disconnected graph. An edge is a bridge if its removal results in disconnected sub-graph. A bridge is an edge such that the graph containing the edge has fewer components than the sub-graph that is obtained after the edge is removed.

Figure 3.4 shows an example of cut vertex and cut edge. cut the bridge disconnects the graph and forms disconnect subgraph (cluster).

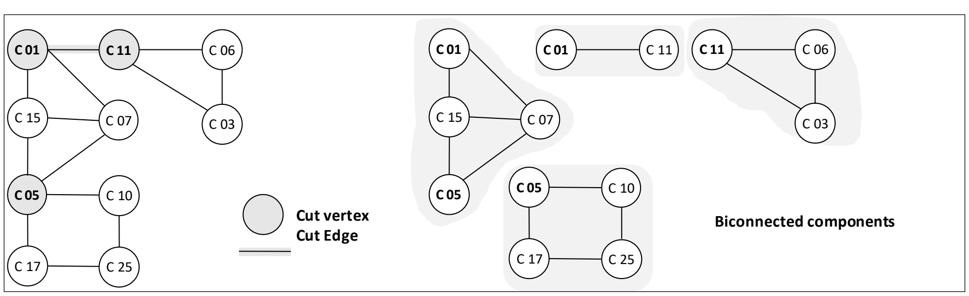


Figure 3.4 Example of cut edge and cut vertex

A graph is biconnected if it contains no articulation points. (In general, a graph is k-connected, if k vertices must be removed to disconnect the graph). The concept of a cut point can be extended from a single node to a set of nodes necessary to keep graph connected. Those nodes are referred to as a cut-set. A node cut-set is a subset of the nodes of a graph, whose removal (simultaneously removing all edges adjacent to those nodes) makes the graph no longer connected. If the set is of size k, then it is called a k-node cut, denoted by k (G). That is, the K(G) of a graph is the minimum number of the nodes that must be removed to make the graph G disconnected.

- Utility: Biconnected graphs, articulation points, bridge are of great interest in the analysis of d content graph because these are the “critical” points, whose failure will result in the network becoming disconnected. Also, the biconnected components of a graph are the equivalence classes. (see section 3.4.1)

3.4.3 Clustering

Clustering is a process of finding such groups based on chosen semantics. According to this semantics, the current clustering approaches can be roughly classified into two categories: content-based clustering and structured based clustering. Content-based uses semantic aspects of data such a category labels, while structure-based clustering takes advantage of structural information about data. Moreover, structured-based clustering is domain-independent so that it is suitable for graph visualization.

In order to cluster a graph, a metric of a node in the graph is required to quantify its features. Based in this metric, existing approaches of partitioning graphs (Everitt et al., 2011; Harel & Koren, 2006) can be loosely divided into the following groups: connectivity based partitions, which use standard concepts from graph theory, distance partitions from selected subsets, Neighbourhood based partitions, and other approaches.

There are several ways how to rearrange a given matrix (correspond to the graph) determine an ordering or permutation of its rows and columns. to get some insight into its structure:

- Utility: The goal of clustering is to reduce a large, potentially incoherent network to a smaller comprehensible structure that can be interpreted more readily. A clustered graph can greatly reduce visual complexity by replacing a set of nodes in a cluster with an abstract node. Clustering, as an empirical procedure, is based on the idea that units in a network can be grouped according to the extent to which they are equivalent, according to some meaningful definition of equivalence.

3.4.4 Graph node groups (Collapse/ contraction)

Collapsing graph is an alternative way to reduce visual complexity. Collapsing means removing from the visualization the nodes that are connected to one node or to a group of nodes. Any number of nodes can be collapsed into a single synthetic node: collapse set of nodes and expand it when needed.

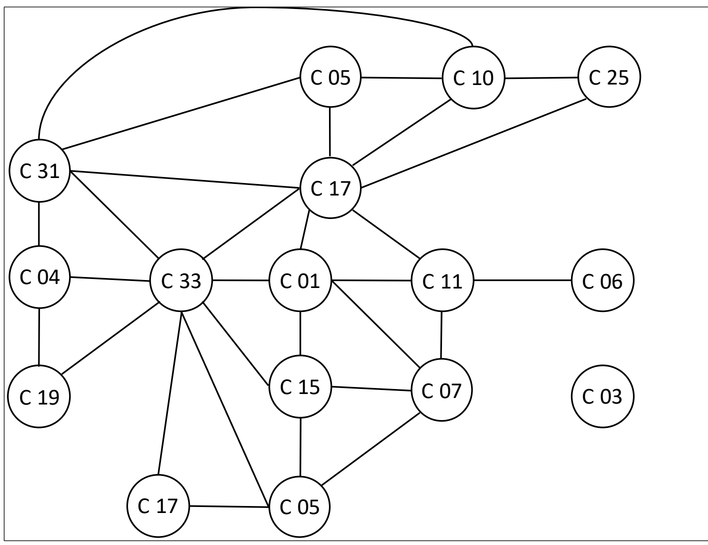
Such a synthetic node contains a user-provided text instead of normal disassembly listing.

- Utility: If a graph is too large to fit on the screen, groups of related nodes are (clustered) collapsed into super-nodes. The users see a "summary" of the graph, namely the super-nodes and super-edges between the super-nodes. Some clusters may be shown in more detail than others. The process collapsing involves discovering groups in the data. In the case of graph visualizing collapsing nodes Groups can be un-collapsed to display the original node content.

3.4.5 The degree of a vertex and adjacency list

A graph consists of vertices and edges connecting these vertices. The degree of a vertex i is the number of edges incident with it, except that a loop at a vertex contributes twice to the degree of that vertex. The degree of the vertex v is denoted by deg(v) and calculate from the adjacency or the neighborhood of vertex. Two vertices u and v are called adjacent or neighbors if u and v are endpoints of an edge e of G = (V, E). The degree of a vertex represents the number of edges incident to that vertex. Figure 3.5 shows an example of a graph and the degree of each vertex.

- Utility: To analyze a graph it is important to look at the degree of a vertex. The degree of vertex informs the Criticality of contents. Critical contents are those that have a significant number of links to other contents. In this example, content C33 correspond to 14 % of the total number of links.



V	deg(v)
C 31	5
C 05	3
C 10	3
C 25	2
C 17	7
C 04	3
C 33	8
C 01	5
C 11	4
C 06	1
C 03	0
C 07	4
C 15	4
C 19	2
C 05	4
C 17	2

Figure 3.5 The degree of a vertex

3.4.6 Singleton

The singleton graph is the graph consisting of a single isolated node with no edges. It is, therefore, the empty graph on one node. In Figure 3.5, the vertex C03 is a singleton.

- Utility: As known, there are two types of innovation: Incremental and Disruptive (or radical). Incremental innovation is a series of small improvements or upgrades made to a company's existing products, services, processes, or methods. In the other hand, disruptive innovation is an invention that changes radically an existing product, services, process, or method. We believe that a singleton in our content graph may bring a disruptive idea to participants in the ideation session.

3.5 Conclusion

This document intersects with the improvement of the use of the ECM result in the ideation phase. We propose to use the graph theory to facilitate access to the analysis results. The advantage of using the visualization of the results in the form of a graph was presented. The tools presented in this paper permit to analyze ECM result and to give indications about the relation between the used contents.

These tools aimed to highlight some particularities which are useful in the ideation session. Future research should consider some of these suggestions to further extend this line of research. Also, it would be interesting to explore other analysis properties.

CHAPTER 4

ENTERPRISE CONTENT MANAGEMENT SYSTEMS: A GRAPHICAL APPROACH TO IMPROVE THE CREATIVITY DURING IDEATION SESSIONS – CASE STUDY OF AN INNOVATION COMPETITION “24H OF INNOVATION”

Houcine Dammak[a], Abdellatif Dkhil[a,b], Ahmed Chrifi[a], Mickaël Gardoni[a]

[a] Département de génie des systèmes, École de technologie Supérieure,
1100 Notre-Dame Ouest, Montréal, Québec, Canada H3C 1K3
[b] Institut Supérieur des Sciences Appliquées et de Technologie de Gafsa. Gafsa, Tunisie

Paper published in: International Journal on Interactive Design and Manufacturing (IJIDeM) volume 14, pages 939–953(2020).
Doi: https://doi.org/10.1007/s12008-020-00691-8

Based on the previous chapters, in this chapter we are detailing more our proposed approach. Then, we are experimenting it in an innovation competition and discussing the results.

Abstract.

Big data could be a “gold mine” for creativity if it is used in the proper way, to this aim, we propose to use content management solutions to improve innovation process. Using ECM (Enterprise Content Management) in the ideation step of the innovation process may enhance the creativity of users to create new knowledge. Organizations have access to multiple information from internal and external sources. This information is present everywhere in the workplace and represent an interesting source of creativity. The access to large databases of information can overwhelm users, in their innovation process, and tend them to return to known solutions which will decrease the creativity. To avoid this situation, we will be coupling the ECM with graphical tools. In this paper, we propose a detailed approach on how

to use graphical tools with the ECM by applying the analysis properties from the graph theory in order to be more creative. Then, we present a case study where a team participating in an innovation competition uses our proposed approach at the ideation step to enhance their creativity. Indeed, we will test this approach to evaluate its effectiveness in the in the 24H innovation competition context.

4.1 Introduction

Nowadays, with all new technologies and the fast pace of creating new products, organizations are invited to innovate to stay competitive and to continue their growth strategy. Any organization today can benefit from this rapidly developing technology environment. To be on the edge on this, big organizations decided to create a new role to manage the innovation. This role may have different names from one organization to another but the common one that we found is 'CInO' which stands for 'Chief Innovation Officer' (Lourens, 2016). This role is not a classic role in the organization. It is part of the C-level which means that the person having this role is part of the management committee that defines the strategic directions the organization is taking. The CInO has a team of employees that some of them are dedicated 100% for innovation and the rest are from different departments and are involved part-time. Meetings are scheduled on a regular basis to go over the challenges the organization is facing and to brainstorm on innovative solutions. Topics today do not stop at creating new products, it includes big data management, social media, mobile technology, 3D scanners, the cloud and also internet of services and things (Uhl & Gollenia, 2016).

In essence, the 'CInO' role is mainly associated with strategy development and product and process development as part of new business opportunities and growth initiatives. In an Accenture survey published in 2012, it was mentioned that already 60% of respondents employ a Chief Innovation Officer (or similar position) (Koetzier & Alon, 2013). The growth in the numbers since 2009 indicates the growing realization of the key role the CInO can play in an organization.

The CInO is responsible of managing the innovation process. In early steps of this innovation process, participants are invited to use their creativity to come up with new ideas. Those ideas are usually inspired by the participants' background and their own knowledge. Some researchers proposed different tools to support this important step of the innovation process which is the ideation step. The combination of teams existing technical knowledge and limited domain-specific knowledge provokes more original and diverse ideas, which confirms there is creative value in the combination of KDD (knowledge discovery from databases) with teams' existing knowledge (Escandon-Quintanilla, 2017).

Since the amount of information in databases is very important, usually non-structured and present in different locations in the workplace, some information management tools have appeared. From these information management tools, we consider content management tools (ECM: Enterprise Content Management) which have the main goal to manage all the organizations' content.

ECM is defined as the technologies, tools, and methods used to capture, manage, store, preserve, and deliver content (*AIIM: Association for Innovation and Image Management*, n.d.). ECM is used mainly for daily and operational tasks. Usually, the main reasons to implement ECM solutions are: reducing searching times, unifying the presentation or adhering to reporting obligations (Vom Brocke et al., 2010). ECM has proven its efficiency not only in the industrial world but also in the research world. The ECM output will be provided to participants of ideation sessions to see its impact on the creativity of an organization. ECM users will have access to valuable information that is structured and easily accessible. This access to information may allow enhancing the creativity of users to create new knowledge.

The benefits expected are really promising but unfortunately until today, in the ECM research works, Creativity, Innovation and Knowledge Management have played a minor role.

So, the participants of an ideation session, depending on the criteria that they will select, will receive a list of content as a search result. This list of content may inspire them in their ideation session to come up with innovative ideas. Since organizations today have access to an enormous amount of information, even with the ECM search result, participants may be overwhelmed. So, we propose an original approach based on graph theory coupled with a relational analysis between these contents to visualize and analyze the result of the ECM application. This use will be experimented in an innovation competition.

In this paper, we propose a detailed approach for participants in ideation sessions to enhance their creativity then we present a case study where a team participating in an innovation competition uses our proposed approach.

4.2 Background

4.2.1 Using ECM in an ideation session – Innovation context

ECM is also defined as a collection of strategic resources and capabilities that provides an automated enabling framework for efficient lifecycle management of valuable organization asset, i.e. contents and processes, to carry out required business operations in a collaborative fashion, supports governance and compliance, provides integration within and outside the business boundaries to achieve business intelligence, knowledge management and decision support capabilities with focus on fulfilment of business goals and objectives for competitive advantage (Usman et al., 2009).

ECM is used mainly for daily and operational tasks. Usually, the main reasons to implement ECM solutions are: reducing searching times, unifying the presentation or adhering to reporting obligations (Vom Brocke et al., 2010). ECM has proven its efficiency not only in the industrial world but also in the research world. In a survey conducted by a research team from the University of Economics in Prague, the results show that 92% of organizations expect benefits from innovations in ECM systems (Kunstová, 2010). ECM provides faster information access and effective information sharing and searching. Thus, ECM creates crucial ground for effective innovation process.

The information is present everywhere in the workplace in different formats: documents, communications, databases, and it represents a great asset for any organization. The reuse of information and data-driven management is considered a route to greater efficiency and decision making resulting in improved productivity, profitability and competitiveness (Hicks et al., 2002).

Availability of information is one of the critical success factors for organizations to survive. While trying to overcome this critical success factor, organizations are facing different challenges like the huge volume of data and information that exist in different formats and that is not easy to use.

In early steps of the innovation process, participants are invited to use their creativity to come up with ideas. Those ideas are usually inspired by the participants' background and own knowledge. Some researchers proposed different tools to support this important step in the innovation process which is the ideation step.

With the ECM tool, we are planning to use indexes (Metadata) related to each content to do searches. By using this metadata layer, the participant will receive a list of contents as a search result. Most commercial ECM tools present the search results as a list of contents (documents) grouped by the category of the content (Example: Thesis, Article, Product catalog, Invoices. . .) and details with all the metadata related (Date, field, author, location, university. . .). The metadata depends on the category of documents and it is configured at the implementation stage of an ECM solution.

As mentioned previously, ECM is the platform that stores content and makes it available to users when they need it. The proposed approach couples the ECM output and the innovation process at the ideation step. This by proposing a relational analysis of the list of contents displayed by the ECM and representing them in a graph (see figure 4.1). The difficulty here is about the important number of analysis properties to identify the right graphs and all the combinations between these analysis properties (Dammak et al., 2019).

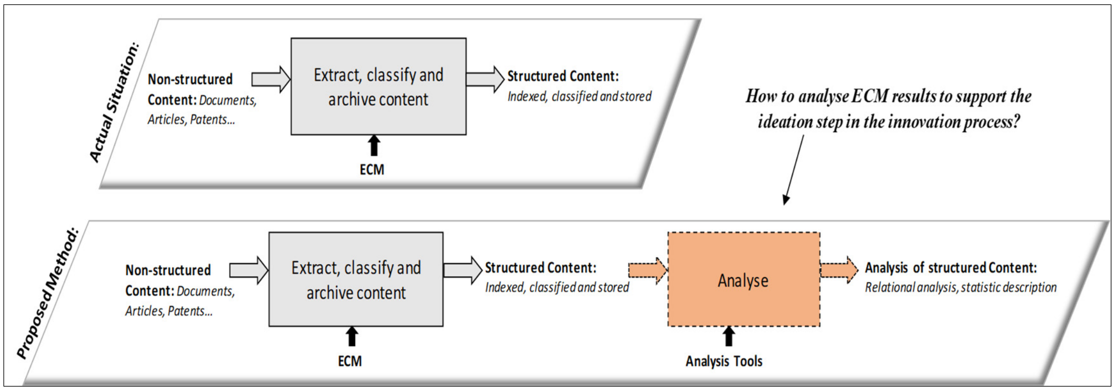


Figure 4.1 Proposed approach

4.2.2 Use of graphs in ECM search results relationship analysis

In this study, we propose to use graphs for visualizing and analyzing the result of the ECM. We define a 'Content Graph' as a graph representing the relationship between contents. Content Graph is a network with nodes that are connected unidirectionally by links of various relations and are intended to organize the entire relation structure between contents. ECM result graph has several noticeable benefits compared to actual search result which is in a list format.

The main advantages of using a graph representation are:

- *A standard tool for data visualization*

Graphs have long provided visual languages and have been widely used in many different disciplines as formal representation system. We propose to use graph representation to better understand the links between contents and to have additional analysis tools. Compared to actual ECM search result which is in a list format, using a content graph presents several advantages and noticeable benefits.

- *Minimize the reading and interpretation time*

The content graph is a particularly good way of presenting the contents residing in the ECM especially when using the search function. Displaying a search result in a graph instead of a list will bring a view of the entire content of the search result. Content graph representation describes the diversity and the depth of the entire ECM search result without omitting any content residing in the bottom of a list and highlighting the relationship between them. It is essential to participants in an ideation session to understand the relationship between all their organization's content to clarify their thinking and to optimize their creativity exercise.

- *Power tool to analyze the ECM search result*

The other great advantage of this presentation way is the possibility to use many structural analysis tools proposed by the graph theory. These tools allow a quantitative analysis of connectivity and relationships between contents. With the content graph, all contents are represented on a graph. By using analysis properties, the graph representation provides a power tool to analyze the ECM search result. This analysis will provide the user an easiest way to access to the right information and will save the time. Also, it will highlight relationships between contents that a user without applying analysis properties could not access to them. These relationships may present an interesting support tool for creativity.
In the following section, we will present some example of analysis tools issued from the graph theory and their utility in the analysis of content graphs.

4.2.3 Graph representation of ECM Search result analysis

4.2.3.1 Introduction to graph theory: basic terminology and notations

A graph G = (V, E) is a mathematical structure often used to define relationships between objects. It consists of a set of vertices V and pairs of edges E connecting them. A graph can be directed or undirected. In a directed graph, given the edge e = (u, v), we say that u is the origin of e and v is the destination of e. In undirected graphs, u and v are the endpoints of the edge. We say that vertex v is adjacent to vertex u if there is an edge (u, v). The order of graph corresponds to the number of nodes. The path in a graph is a sequence of vertices (v0, v1; …, vk) such that (vi−1, vi) is an edge for i = 1, 2, …, k. The length of the path is the number of edges, k.

A common way to represent a graph is the adjacency matrix. The adjacency matrix of a graph is a matrix A(n, n) where n is the order of the graph. An entry (u, v) of the matrix is either 0 if there is no edge between u and v or the weight of the edge (u, v) if it exists (this representation implies that no edge has a weight equal to 0).

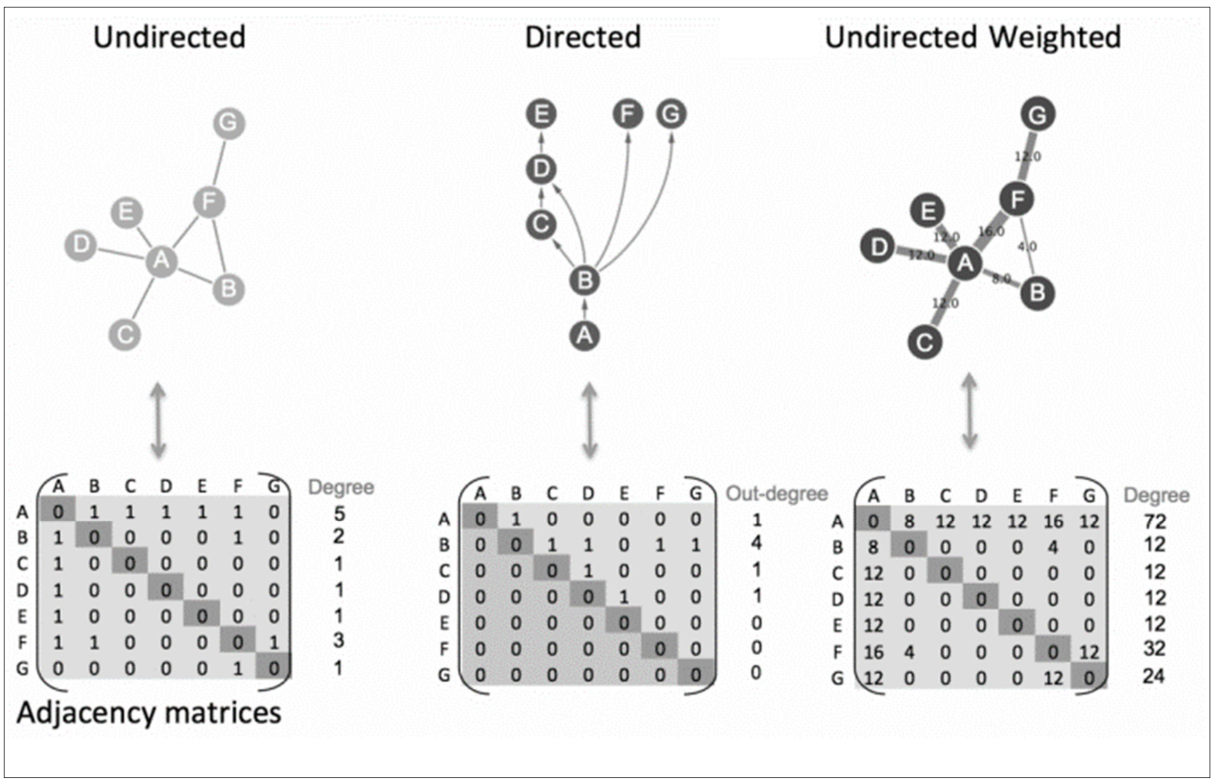


Figure 4.2 Different types of adjacency matrices

Taken from https://www.ebi.ac.uk/training/online/courses/network-analysis-of-protein-interaction-data-an-introduction/introduction-to-graph-theory/graph-theory-adjacency-matrices/

4.2.3.2 Content Graph representation

The ECM tool permits to extract, classify, and archive content from Non-structured Content (documents, Articles, Patents…). The output of this system is a list of Structured Content: Indexed, classified, and stored in the format of metadata.

Traditionally, after organizing and structuring the content, ECM will deliver it to users in the format of a list. We propose to use visualization tools to change this output to a graph format that highlights the relationships between contents. The goal here is to study the links between all the contents presented in the search result and to present them in a graph.

In order to draw the content graph, an adjacency matrix must be extracted from the list of Structured Content. From this list is possible to extract two adjacency matrices which can be transformed into a graph:

- The first is the content/content matrix A(n, n): n corresponds to the number of contents. An entry (i, j) of this matrix A(n, n) indicates the value of the link between content i and content j.
- The second matrix is index/index matrix. An entry (i, j) of this matrix indicates the value of the link between index i and index j.

Her, and to simplify we use only the adjacency matrix corresponding to content - content link matrix (An entry (i, j) of this matrix indicates the link between content i and content j). From this matrix, a graph called content graph can be presented.

In this paper, the used graph is an undirected weighted graph: this graph corresponds to the content/content matrix A(n, n).

4.2.3.3 Weight of the graph edge

The graph-based representation permits us to use classical graph theory tools and concepts, but some drawbacks exist. The essential limit is that lost the detailed of the link. An edge represents an aggregate index between two contents. The following figure shows an example of the aggregation of the links between two contents i and j: only one link is established. The weight of this link corresponds to the number of aggregated links.

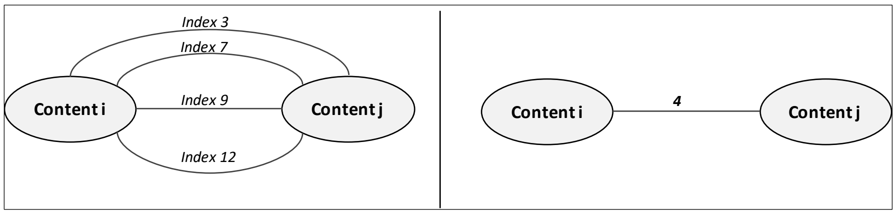


Figure 4.3 Example of aggregation

4.2.3.4 Examples of graph analysis tools and utility for ECM result analysis

This section aimed to show how classical concepts of graph theory can be applied to analyze ECM search result or to give quantitative information about these results. Also, simplify the access to the information. So, we will be presenting some graph analysis tools and their utilities in our context. The presented tools are used for undirected weighted graphs. This list is not exhaustive, we have selected only the tools we will be using later in the case study.

1) Biconnected Graphs: Connected components

Let G = (V, E) be a connected undirected graph, a graph G is connected if, for every pair of nodes v1 and v2, there is a path between nodes v1 and v2. A graph is said to be connected if it can be traveled from any one node to any others by moving along paths of edges. The graph is 2- connected if deletion of any node still keeps it connected; it is 3-connected if it still remains connected with the removal of any two nodes, and so on. It is required that a k-connected have at least k+1 nodes (Hossain & Rahman, 2015).

Notice that unlike strongly connected components of an oriented graph (which form a partition of the vertex set) the biconnected components of a graph form a partition of the edge set.

A graph G = (V, E) is k- connected (k-edge-connected) if at least k vertices (edges) must be deleted to disconnect G. A graph that is 2-connected (3-connected) is also called biconnected (triconnected).

- Utility: The identification of connected component gives an indication about the cluster nature of ECM search result: each connected component represents an independent cluster. If a graph contains only one connected component, the graph is said to be connected and corresponds to a “one block” draw while a non-connected graph can be drawn in several blocks. So, in this case, contents will be strongly connected in the content graph.

2) Articulation Points (or cut vertices) and Cut edge (or bridge)

Let G = (V, E) be a connected undirected graph. A node in the graph G is called cut point (or articulation point) if its removal disconnects a graph, i.e. increases the number of components. Also, it makes some points unreachable from some other (Kunstová, 2010). Articulation Point (or Cut Vertex) correspond to any vertex whose removal (together with the removal of any incident edges) results in a disconnected graph.

In graph G, a Bridge or cut edge is an edge whose removal results in a disconnected graph. An edge is a bridge if its removal results in disconnected sub-graph. A bridge is an edge such that the graph containing the edge has fewer components than the sub-graph that is obtained after the edge is removed.

A graph is biconnected if it contains no articulation points. (In general, a graph is k-connected, if k vertices must be removed to disconnect the graph). The concept of a cut point can be extended from a single node to a set of nodes necessary to keep graph connected. Those nodes are referred to as a cut-set. A node cut-set is a subset of the nodes of a graph, whose removal (simultaneously removing all edges adjacent to those nodes) makes the graph no longer connected. If the set is of size k, then it is called a k-node cut, denoted by k (G). That is, the K(G) of a graph is the minimum number of the nodes that must be removed to make the graph G disconnected.

- Utility: Biconnected graphs, articulation points, bridge are of great interest in the analysis of d content graph because these are the “critical” points, whose failure will result in the network becoming disconnected. Also, the biconnected components of a graph are the equivalence classes.

3) Clustering

Clustering is a process of finding such groups based on chosen semantics. According to this semantics, the current clustering approaches can be roughly classified into two categories: content-based clustering and structured based clustering. Content-based uses semantic aspects of data such a category labels, while structure-based clustering takes advantage of structural information about data. Moreover, structured-based clustering is domain-independent so that it is suitable for graph visualization.

In order to cluster a graph, a metric of a node in the graph is required to quantify its features. Based in this metric, existing approaches of partitioning graphs (Everitt et al., 2011; Harel & Koren, 2006) can be loosely divided into the following groups: connectivity-based partitions, which use standard concepts from graph theory, distance partitions from selected subsets, Neighborhood based partitions, and other approaches.

There are several ways how to rearrange a given matrix (correspond to the graph) determine an ordering or permutation of its rows and columns to get some insight into its structure:

- Utility: The goal of clustering is to reduce a large, potentially incoherent network to a smaller comprehensible structure that can be interpreted more readily. A clustered graph can greatly reduce visual complexity by replacing a set of nodes in a cluster with an abstract node. Clustering, as an empirical procedure, is based on the idea that units in a network can be grouped according to the extent to which they are equivalent, according to some meaningful definition of equivalence.

4) Graph node groups (Collapse/ contraction)

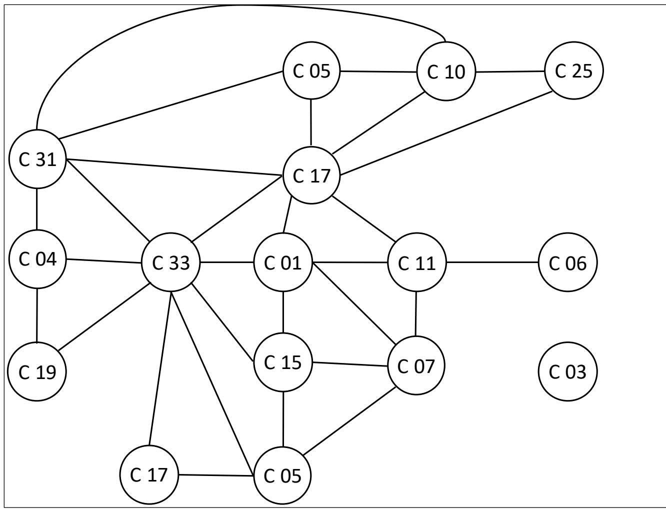
Collapsing graph is an alternative way to reduce visual complexity. Collapsing means removing from the visualization the nodes that are connected to one node or to a group of nodes. Any number of nodes can be collapsed into a single synthetic node: collapse set of nodes and expand it when needed.
Such a synthetic node contains a user-provided text instead of normal disassembly listing.

- Utility: If a graph is too large to share with users, groups of related nodes are (clustered) collapsed into super-nodes. The users see a "summary" of the graph, namely the super-nodes and super-edges between the super-nodes. Some clusters may be shown in more detail than others. The process collapsing involves discovering groups in the data. In the case of graph visualizing collapsing nodes Groups can be un-collapsed to display the original node content.

5) The degree of a vertex and adjacency list

A graph G(V, E) consists of vertices V and edges E connecting these vertices. The degree of a vertex v is the number of edges incident with it, except that a loop at a vertex contributes twice to the degree of that vertex. The degree of the vertex v is denoted by deg(v) and calculate from the adjacency or the neighborhood of vertex. Two vertices u and v are called adjacent or neighbors if u and v are endpoints of an edge e of G = (V, E). The degree of a vertex represents the number of edges incident to that vertex. Figure 4.4 shows an example of a graph and the degree of each vertex.

- Utility: To analyze a graph it is important to look at the degree of a vertex. The degree of vertex informs the Criticality of contents. Critical contents are those that have a significant number of links to other contents. In this example, content C33 correspond to 14 % of the total number of links.



V	deg(v)
C 31	5
C 05	3
C 10	3
C 25	2
C 17	7
C 04	3
C 33	8
C 01	5
C 11	4
C 06	1
C 03	0
C 07	4
C 15	4
C 19	2
C 05	4
C 17	2

Figure 4.4 The degree of a Vertex

6) Singleton

The singleton graph is the graph consisting of a single isolated node with no edges. It is, therefore, the empty graph on one node. In figure 4.4, the vertex D03 is a singleton.

- Utility: As known, there are two types of innovation: Incremental and Disruptive (or radical). Incremental innovation is a series of small improvements or upgrades made to a company's existing products, services, processes, or methods. In the other hand, disruptive innovation is an invention that changes radically an existing product, services, process, or method. We believe that a singleton in our content graph may bring a disruptive idea to participants in the ideation session.

4.2.4 Patent classification

Patents contains valuable information about new inventions. Big companies are usually in a race to patent their research since it protects their invention for a certain number of years. Different researchers in R&D departments start by analyzing existing and new patents to stay competitive and watch how the market and the competition is progressing. The use of patents can help analyzing a knowledge domain faster (Escandón-Quintanilla et al., 2018).

A classification system is an arrangement of hierarchical categories used to organize things by their characteristics or relationships. A patent classification system has as its primary purpose the establishment of an effective search tool for patent document retrieval by intellectual property offices and other users, in order to establish the novelty and evaluate the inventive step of technical disclosures in patent applications.

In a patent classification system, patents are classified according to the different areas of technology to which they pertain. Patent classes are deconstructed into detailed “sub” levels. The layout of the classification symbols may include Section, Class, Subclass, Group, and/or Subgroup (*International Patent Classification (IPC)*, n.d.).

Typical example of IPC or CPC classification symbol: A45B 19/08

A *section*
A45 *class*
A45B *sub class*
A45B *19/00 main group*
A45B *19/08 sub-group*

4.3 Steps of the proposed approach

The main goal is to explore the impact of the use of our approach within an innovation team. The approach is an enhanced ECM system that couples the standard ECM with graph theory analysis tools to provide participants with an output composed of a light search results representation.

As mentioned previously, we have decided to use patents as the contents that will be fed in the ECM system.

So, at the beginning of the innovation exercise, participants will be introduced to our approach to explain them how they will be supported in their idea generation process.

By providing the participants the list of contents, we expect the team using content data during their idea generation process to be inspired by the topics detailed in the contents. So, we are expecting to complement their thinking process to generate not only more ideas but also to increase the sophistication level of their final solution.

As a result, we are expecting that the contents shared with the team based on our approach presents a competitive advantage that may help the participants to be better ranked in the innovation exercise comparing to other teams who did not have access to the same information and have chosen the same challenge.

Table 4.1 The steps of applying the approach

	N	Step name	Step description
Before the competition	1	Submit the challenge	Submitting a challenge to the innovation competition
	2	Uploading contents in the ECM	Uploading hundreds of contents to the challenge in the ECM
During the Competition	3	Involvement of the teams	Involvement of the teams who picked the challenge once the competition started and talking to one of them about our approach
	4	Use of the ECM	With the team, we perform a search on the ECM to identify the list of contents in relationship with the challenge
	5	Draw the content Graph	An initial graph is drawn from the ECM search result and based on the corresponding metadata using an adjacency matrix
	6	Analyze of content graph	Application of some dedicated graph analysis tools to extract the most important information's. A light graph containing the representative contents is drawn.
	7	Use of the result by the team to support the creativity process	The team uses these representative contents (identified in the light graph) as a support to their thinking process.

Used content in this research work:

For this research work, we have decided to use patents as the contents that will be used and shared with participants. Patents were chosen due to their proven scientific value and since they have an international classification.

Hypothesis:

Teams using the results of our enhanced ECM approach during their idea generation process will have more appealing ideas and will be better ranked by the panel of experts.

4.4 Case Study

To perform this study, we have decided to follow the steps mentioned above to test our approach with teams in an innovation competition. This use will help us evaluate the impact of using our enhanced ECM approach and the advantages of using it.

4.4.1 Innovation competition

The “24h Innovation” competition had this year different participants from all over the world. In total, the competition had 2000 participants from 14 countries to solve 18 challenges.

The 24 Hours of Innovation is an international creativity competition invented by “L’École supérieure des technologies industrielles avancées” (ESTIA) in France (*Les 24h de l’innovation / The 24h of Innovation*, n.d.). L’École de technologie supérieure (ÉTS) in Montreal, Quebec, Canada, was invited to participate to this event since 2010. In this competition, students are invited to work during 24 consecutive hours to solve a problem submitted by companies and researchers, creatively. A local committee chooses the best projects and sends the winner project to an international committee who will choose the three best international projects from all the local winning projects. Different prizes are given to the winners.

4.4.2 Preparation and utilization of the proposed approach

4.4.2.1 Before the innovation competition

- *Step 1: Submit the challenge*

To participate in the event, we were invited by the organizing committee to submit a challenge that people are facing in their daily life and no real solution is known for it. In that context, we decided to work on the icy Montreal winters that citizens of Montrealer (and other cold cities in the world) are experiencing. The challenge that we have submitted to the organizing committee was: “How not to slide on icy sidewalks?”. And the description was: “Montreal and many other cities around the world face difficult winter conditions due to ice storms. Would you be able to help pedestrians avoid slipping on icy sidewalks? We need your creativity to find a solution to this problem that, despite the technological evolution and sophisticated devices, we still have not found a way to help the pedestrian arrive safe and sound at its destination.”

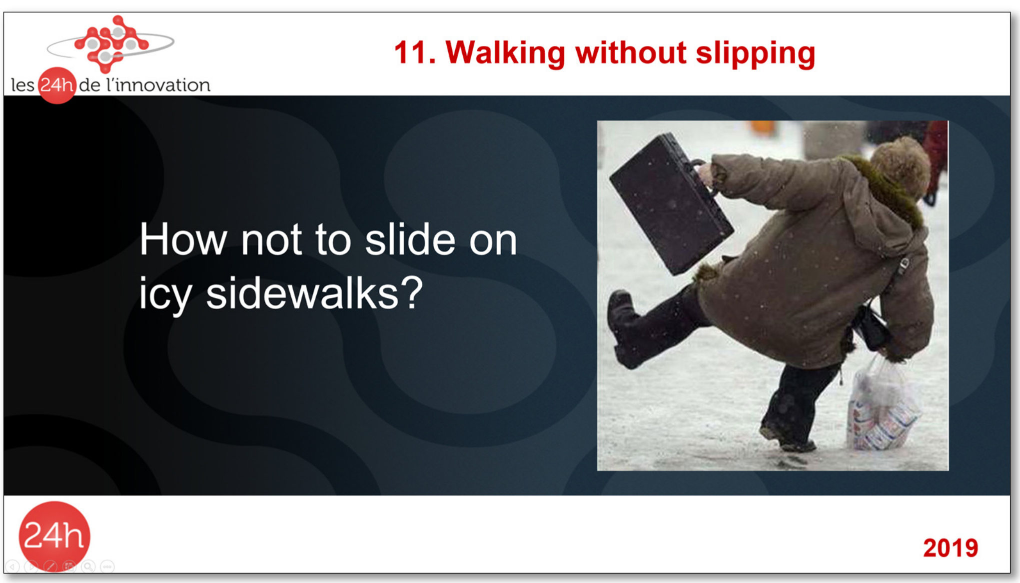


Figure 4.5 Our challenge featured in the official 24h competition deck - 2019 Edition (Video Challenges 2019 24h ENG 190516 - YouTube, n.d.)

- *Step 2: Uploading contents in the ECM*

The work has begun several weeks before the competition. Our mission was to upload hundreds of contents related and not related to the submitted challenge. These contents were downloaded from the web.

As mentioned previously, in our context the contents are patents. The choice of working on patents was made since patents has an international classification. So, for the input data we will be based our research on a common model that is approved widely.

As a first step we have identified the international classification for each patent using the International Patent Classification (IPC). In the table below you find an example. Then, we have uploaded them in the ECM.

Table 4.2 Patent Classification using the IPC (International Patent Classification)

Patent ID	Classification	Section	Section Description	Class	Class Description	Sub class	Sub Class Description
US5301704	A45B9/04	A	HUMAN NECESSITIES	A45	HAND OR TRAVELLING ARTICLES	A45B	WALKING STICKS; UMBRELLAS;

By using patent classifications up to the third level (Section, Class, Sub-class), we used them as metadata in the ECM system. So, we were able to store the patent in the ECM with rows representing the patents and columns representing the name of the patent and the corresponding metadata (Table 4.2). Then, as any Enterprise Content Management solution, we can filter/sort at the metadata level to facilitate the document retrieval.

4.4.2.2 During the innovation competition

- *Step 3: Involvement of the teams*

Once the competition started, all the challenges were shared with the teams. The countdown of the 24h has already began. We noticed that two teams have chosen our challenge. The organizing committee introduced us to one team and then we have shared our approach with them by explaining all the steps. All the team members had to sign a consent form to participate in our case study.

- *Step 4: Use of the ECM*

We have performed a search in the ECM with the selected team in order to come up with a list of patents related to the proposed challenge. This list of patents presented in table 4.3 are an extract from the search result that we have performed on the ECM with the team. set of patents that we have analyzed.

Table 4.3 Extract of the search result performed on the ECM

#	Patent Classification	Patent ID	Section	Section Description	Class	Class Description	Sub class	Sub Class Description
Content/ Patent 1	A45B9/04	US5301704	A	HUMAN NECESSITIES	A45	HAND OR TRAVELLING ARTICLES	A45B	WALKING STICKS; UMBRELLAS;
Content/ Patent 2	E01H5/04	EP1464759A2	E	FIXED CONSTRUCTIONS	E01	CONSTRUCTION OF ROADS, RAILWAYS, OR	E01H	STREET CLEANING; CLEANING OF
Content/ Patent 3	H05B3/34	US6943320	H	ELECTRICITY	H05	ELECTRIC TECHNIQUES	H05B	ELECTRIC HEATING; ELECTRIC
Content/ Patent 4	A63C19/08	US164562	A	HUMAN NECESSITIES	A63	SPORTS; GAMES; AMUSEMENTS	A63C	SKATES; SKIS; ROLLER SKATES;
Content/ Patent 5	A43C15/12	US20130042503A1	A	HUMAN NECESSITIES	A43	FOOTWEAR	A43C	FASTENINGS OR ATTACHMENTS
Content/ Patent 6	A43C15/14	US20060021254A1	A	HUMAN NECESSITIES	A43	FOOTWEAR	A43C	FASTENINGS OR ATTACHMENTS
Content/ Patent 7	E01H5/02	US5951078	E	FIXED CONSTRUCTIONS	E01	CONSTRUCTION OF ROADS, RAILWAYS, OR	E01H	STREET CLEANING; CLEANING OF
Content/ Patent 8	E01H5/04	EP2639355A1	E	FIXED CONSTRUCTIONS	E01	CONSTRUCTION OF ROADS, RAILWAYS, OR	E01H	STREET CLEANING; CLEANING OF

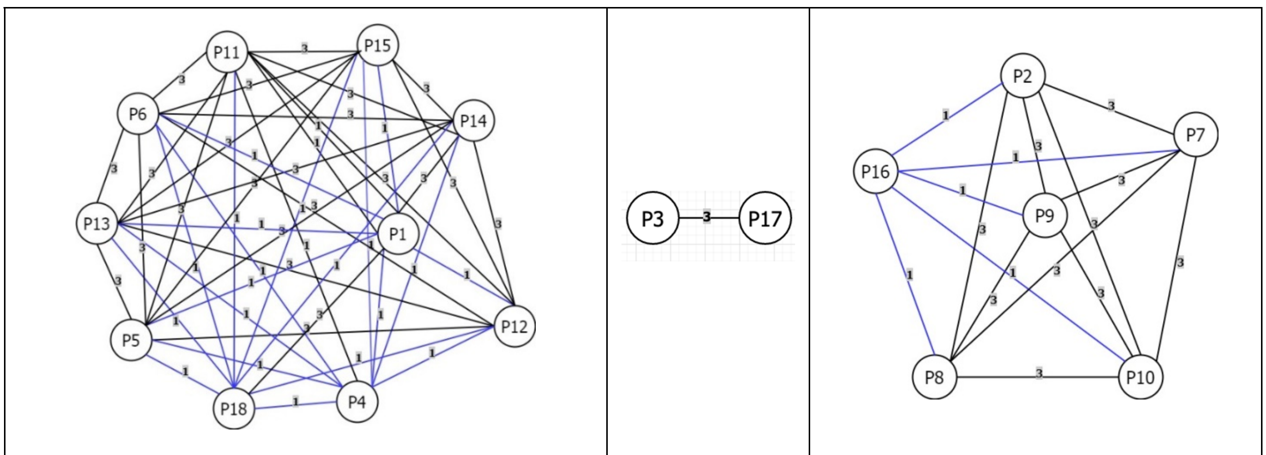
So, from this large list of search list, we will apply graphical tools to draw an initial graph then we will study and analyze the links between them using analysis properties from the graph theory in order to have a light graph. So, instead participants will consult this large list of documents, they will consult a shortened list from the light graph.

- *<u>Step 5: Draw the content Graph</u>*

By using an Adjacency Matrix, we were able to draw an initial graph representing patents. The graph shows the relationships between all the patents and highlighting the weights between them.

- The nodes represent patents
- The edges represent the relationship between patents with the weight.

The result of the adjacency matrix gave us a graph as showed in figure 4.6. This graph is composed of three sub-graphs: the node Pi corresponds to Patent i and the weight of the edge corresponds to the number of aggregated edges (see figure 4.3).



Subgraph 1 | Subgraph 2 | Subgraph 3

Figure 4.6 An initial graph composed of 3 subgraphs is drawn from the list of patents

- *<u>Step 6:</u>*

In order to lighten the information contained in the initial graph, we will be using some of the graph analysis tools mentioned above (Section 4.2.3.4). The different steps will be detailed below:

- **<u>Sub-Step 6.1:</u>** Application of the first clustering tool by grouping together all the patents that has the highest edge weight (equal 3 in this case)

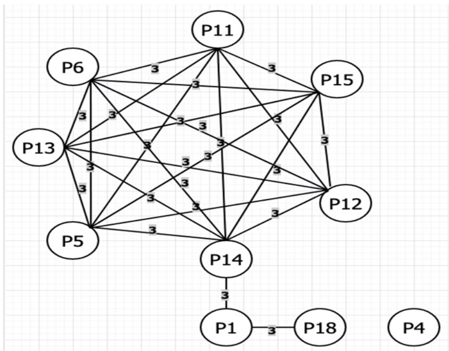
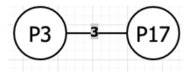
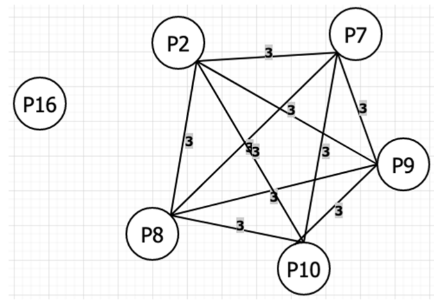
 Result: a singleton (P4) and a Strongly Connected Component 'SCC' (P11, P15, P12, P14, P5, P13, P6). If we disconnect the SCC, we obtain another disconnected graph (P1 et P18)		 Result: singleton (P16) and a SCC (P2, P7, P8, P9, P10)

Figure 4.7 Results of applying Graph Analysis Tools Sub-Step 6.1

- **Sub-Step 6.2:** Application of second clustering tool (SCC). To extract more clusters from the graph, we use the SCC to make another clustering

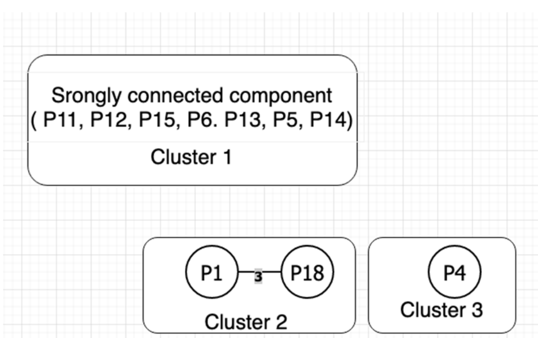
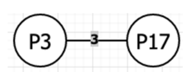
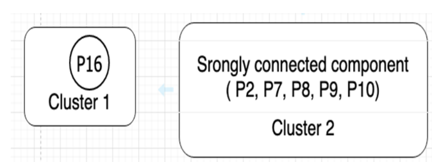
 Result: 3 clusters from the subgraph 1	 Result: 1 cluster from the subgraph 2	 Result: 2 clusters from the subgraph 3

Figure 4.8 Results of applying Graph Analysis Tools Sub-Step 6.2

- **<u>Sub-Step 6.3</u>**: Application of collapsing tool. In order to lighten the graph, we decided to use the collapsing tool. The goal of using the graph analysis tool collapse is to provide a representative patent for each cluster. The representative patent is the patent that has the highest degree of a vertex (the most connected) compared to the same patents within a cluster (see Property e). The nodes (patents) that has the same degree of a vertex have the same importance. In this case, we found several nodes that have the same degree of a vertex. So, we have decided that the representative patent will be selected randomly from the nodes that has the highest degree of a vertex.

Following the steps mentioned above and applying them to the initial graph, we were able to have a light graph composed of 3 subgraphs:

- Sub-graph 1: The representative patent of Cluster 1 is P15; The representative patent of Cluster 2 is P18;
- Sub-graph 2: The representative patent is P17
- Sub-graph 3: The representative patent of Cluster 2 is P10

This light graph presents a short list of patents from the initial set.

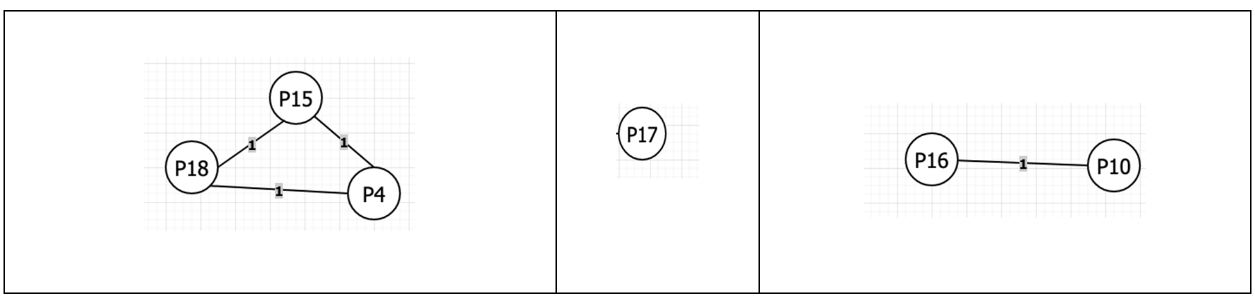


Figure 4.9 Light patent graph

- *<u>Step 7: Use of the result by the team to support the creativity process</u>*

The selected team uses these representative contents (identified in the light graph) as a support to their thinking process.

4.4.3 Summary of applying the steps of the proposed approach

As mentioned above, two teams have chosen our challenge. Following the steps of our proposed approach, we have worked with only one team. The proposed approach was used with the team as a source of inspiration in their innovation exercise. Instead of consulting the list of all the patents that was generated from the ECM as a search result, they used only the patents that were identified by the light patent graph. Analyzing the links between the patents using the graph theory allowed the team to consult a shortened list of patents. We have noticed that they were using these patents as a reference when they were sharing their ideas at the brainstorming stage. And we have also observed that they were trying to merge different patents together in order to have innovative ideas. They were focusing not only on proposing a solution that did not exist but also that responds to different important criteria. These criteria are:

- Economic: The solution must be affordable to implement.
- Social: The solution must respect the society especially in big cities like Montreal
- Environmental: The solution must be eco-friendly.

The team members were focused on providing a realistic solution that is not only easy to implement but also could help the maximum number of citizens and make their life easier. They considered seriously all the representative patents we have shared with them from the light patent graph by talking about each one separately and then they started to merge patents together. Different keywords come up from their discussions: Anti-slip overshoe; ice melting mat, icy sidewalk, surface, recyclable material, environmental impact, cost…

Then, they started to detail all the possible scenarios and propose solutions.

As we notice here, the majority of keywords they used and noted on the whiteboard are from the patents we have shared with them. So, we think that our approach is helping them to increase the sophistication level of their ideas by guiding their thinking.

The following images presents how their brainstorming stage evolved.

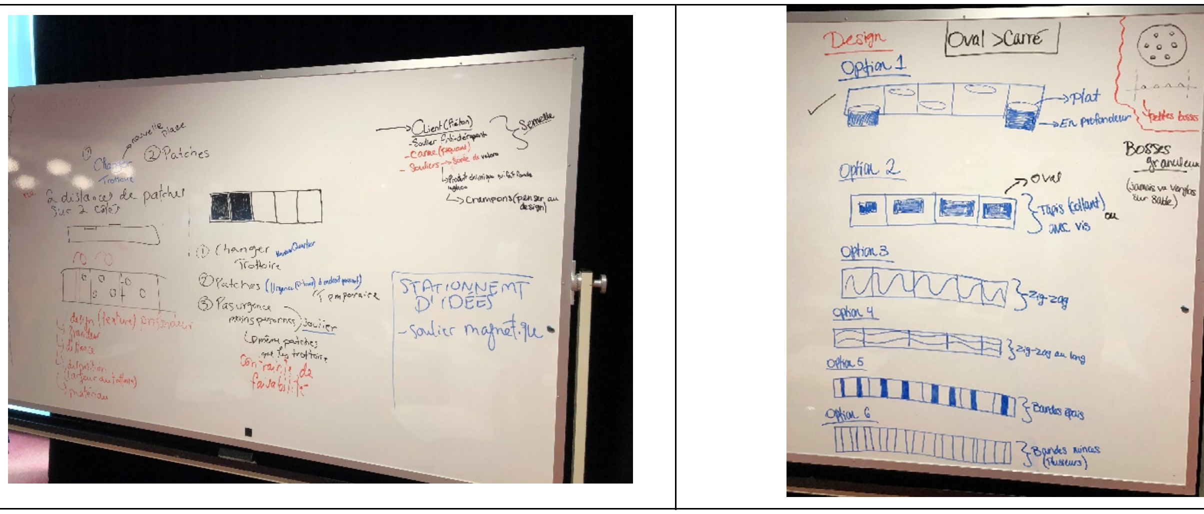


Figure 4.10 Evolution of the brainstorming stage

By the end of the 24h, each team submitted their solution through a 2-minute video on YouTube. Then the jury started evaluating the solutions. There are two rounds, one is local winning round then an international round that considers the local winners only.

The team that used our approach proposed an anti-slip overshoe for pedestrians in low density areas and, they proposed to install rubber patches on sidewalks in high density areas. Both solutions use recycle materials which use car tires. They also detailed their solution by providing further information about the shape, the height, the painting that will be used, the studs…

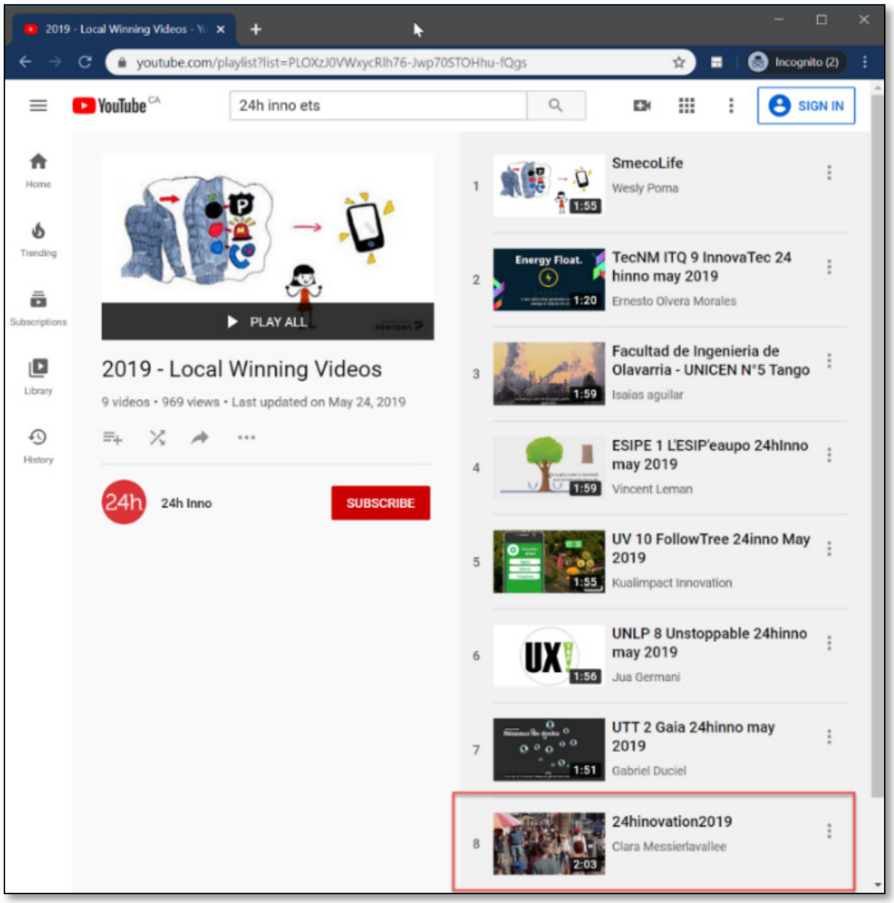


Figure 4.11 The proposed solution for our challenge shared on YouTube as part of the Local Winning Videos

The following table details the application of our proposed approach step by step.

Table 4.4 Application of the approach

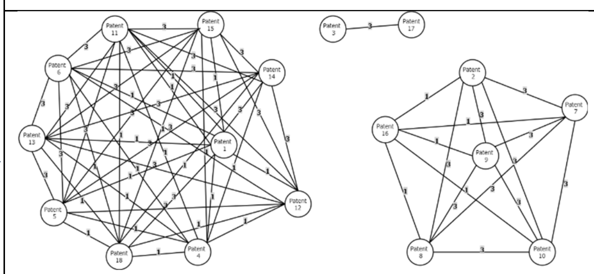
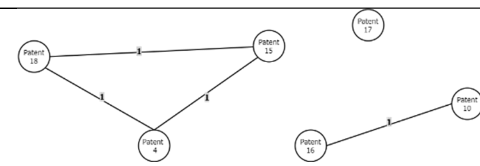
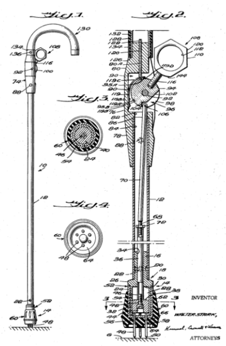
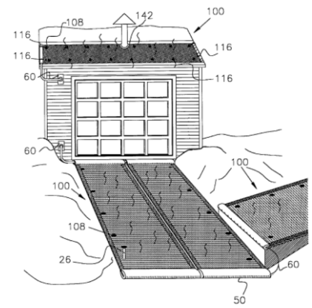
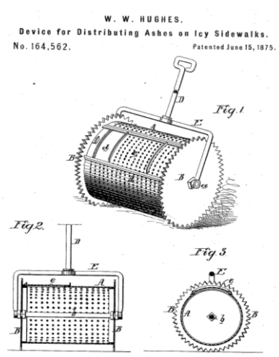
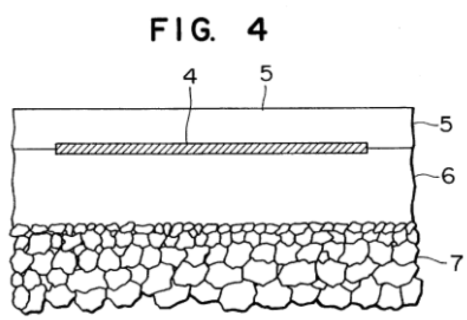
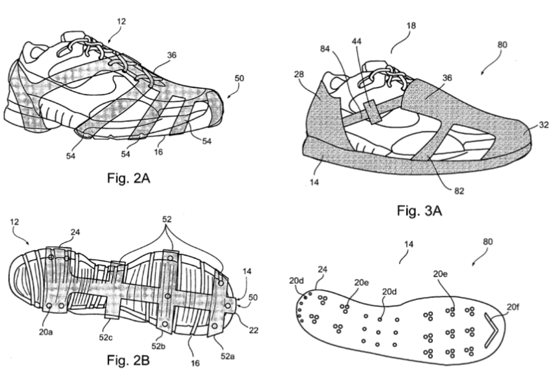
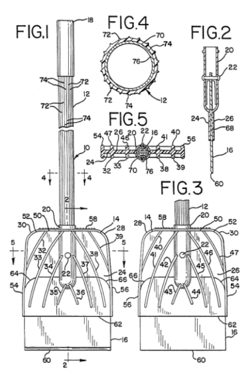
	N	Step name		Application of the approach
Before the competition	1	Submit the challenge		"How not to slide on icy sidewalks?"
	2	Uploading contents in the ECM		Hundreds of contents related and not related to the challenge were uploaded in the ECM
During the Competition	3	Involvement of the teams		The teams that chose out challenge were identified then the organizing committee introduced us to one of them
	4	Use of the ECM		A content search is performed on the ECM to display the list of patents related to the submitted challenge with their corresponding metadata– An extract of the search result is resented in Table 4.3
	5	Draw the content Graph		
	6	Analyze of content graph		 By applying the graph analysis tools on the initial graph, a light graph is drawn. The representative Patents are: 4; 10; 15; 16; 17; 18 (Table 4.5).
	7	Use of the result by the team to support the creativity process		Team members considered seriously all the representative patents shared with them and then they started to merge patents together. Different kind of solutions come up from their discussions: Anti-slip overshoe; ice melting mat, icy sidewalk, surface, recyclable material, environmental impact, cost…

Table 4.5 The representative patents identified using our proposed approach

Patent 18: Non-skid attachment for the ground-engaging end of canes, crutches, and the like (Stark, 1969) 	**Patent 17: Driveway, walkway and roof snow and ice melting mat** (Pearce, 2001) 
Patent 4: Device for distribution ashes on icy sidewalks (*Improvement in Devices for Distributing Ashes on Icy Sidewalks*, 1875)  	**Patent 16: Road snow melting system using a surface heating element** (Watanabe & Nagai, 1997) 
Patent 15: Anti-Slip Overshoe (Mor & Mor, 2008)  	**Patent 10: Ice Scraper** (Tisbo & Whitehead, 1999) 

4.4.4 Results

The supported team with whom we applied our approach has submitted an interesting solution. The supported team won the local competition which is not the case for the not supported team that did not use our proposed approach. The result may show that our proposed approach works in this case. The team proposed more appealing and detailing ideas and also was better ranked in the competition.

4.5 Conclusion and discussion

Our proposed approach presents an interesting way for Innovation teams to be more creative. We noticed that the supported team not only gained a lot of time during their idea generation process but also, they proposed more appealing and detailed ideas. They were guided to a creative solution. The proposed approach could be reutilized in other innovation competitions or even in brainstorming sessions within organizations and we will assess this approach in these different contexts. Indeed, it can be argued that the volume of data (documents and teams) was not enough to conclude that the use of our approach may enhance the creativity of teams at the ideation step. Our main goal was to provide an approach that analyze the relationships between contents listed by the ECM as a search result without the need to consult them all and also provide representative contents. All of this using the graph analysis properties from the Graph theory. As with the enormous amount of data present within organization, the necessity of having approaches that helps using them is important and especially benefit from its content to enhance the creativity.

CHAPTER 5

IMPROVING THE IDEATION PROCESS WITH CUSTOMIZED CREATIVE CUES: A CARD-DECK APPROACH

Houcine Dammak[a], Lorena Escandon[b], Mickaël Gardoni[a,c]

[a] Systems Engineering Department, École de technologie Supérieure,
1100 Notre-Dame Ouest, Montréal, Québec, Canada H3C 1K3
[b] School of Creative Industries, Toronto Metropolitan University,
350 Victoria Street, Toronto, Ontario, Canada M5B 2K3
[c] Institut National des Sciences Appliquées, 24 Boulevard de la Victoire,
67000 Strasbourg, France

Paper submitted for publication, May 2023

In this chapter, we described a novel approach using bisociation in which our approach was improved by adding creative cues and it was tested in a second innovation event.

Abstract.

Organizations looking to innovate in their product and service offerings rely on different tools and techniques to support the creative process. Previous studies show that card-decks help participants come up with more solutions by encouraging combinations of ideas, also called bisociation. For instance, "Oblique Strategies" which is a famous card-decks technique designed to help artists overcome creative blocks through lateral thinking proposes creative clues such as "reverse… cascades… only a part, not the whole, assemble some of the elements in a group and treat the group… emphasize the flaws…". However, these kinds of techniques and decks have limitations:

1) There are as many exploration spaces as there are different cards without links between the exploration spaces,

2) There are no cards dedicated to finding solutions using new information technologies,

3) The cards are generic and do not use the organization's existing knowledge.

This study is focusing on overcoming these limitations by proposing the following approach:

1) To enable the combination of exploration spaces, the TRIZ innovation principles are transformed into cards,

2) As TRIZ innovation principals don't cover information technologies possibilities, we have created new cards focused on Industry 4.0 tools (Connected devices, open data…),

3) To propose customized cards, we extracted content cards from company's existing knowledge residing in available documents thanks to data-mining tools and graph theory techniques. With these content cards, we should be guided towards more feasible solutions based on the company's existing knowledge.

These cards were tested by a team during an innovation competition, and they produced more ideas and were more feasible.

Keywords: Card-decks; Idea generation; Creativity; Knowledge management; TRIZ

5.1 Introduction

Teams in charge of designing new products, services, or processes within their organization have a clear mission to innovate in their offerings to stay competitive. So, they have to find new ways to innovate systematically. Especially that new domains of expertise are constantly being added to design processes, Audoux et al. (2019) proposes a methodology based on a multidisciplinary evaluation tool to help designers in the design of a sustainable and innovative product. Moreover, organizations are adopting innovation management techniques to establish better processes for idea generation and the channeling of those ideas through the innovation funnel all the way to the market. One of the most important steps of the innovation process is the beginning of the process, that is to say the ideation phase that could be supported by creativity tools such as card-decks (Escandón-Quintanilla et al., 2018; Escandón-Quintanilla, 2017; Dammak et al., 2020).

Park & Nam (2015) presented an innovative method using Product-Personification for generating ideas. In their method, they experimented with instruments such as Product-Personality Cards, Product's Talk Board, and Tool Cards during a generative design workshop. Escandón-Quintanilla and Gutierrez-Lopez (2019) suggested the use of different types of cards as creative cues to elicit creative solutions.
The question at the heart of this study is:

How to integrate customized card-decks to facilitate the idea generation process in an ideation session?

To improve creativity, it might be useful to extract a few ideas from the huge amount of data present within an organization. Indeed, with all the new contents that is being created every day, there is potential for new combinations of ideas.
In this work, the focus will be on techniques and processes that utilize information from patents and internal documents to provide hints of solutions or partial solutions to participants in idea generation sessions based on new cards-decks.

5.2 Background

Some research works proved the efficiency of these support tools, such as Escandón-Quintanilla et al. (2018), who presented an approach using keywords. Also, Dammak et al. (2020) introduced the notion of Content Graph by using the Enterprise Content Management (ECM) as a support tool and coupling it with graph theory.

5.2.1 Bisociation & limiting the exploration space

In 1964, Koestler (2020) wrote a theory on the act of creation, he posited that new ideas are the result of confronting two previously unrelated domains, and that the spark of that confrontation would result in a novel idea. This idea is further supported by de Brabandere in the book "Thinking in new boxes" Brabandere and Iny (2013), where it is also claimed that to create new ideas, it is necessary to change the frame of thinking.

In practice, this means that a group of people working on the creation of new ideas need to find new frames of thinking. Escandón-Quintanilla et al. (2018) propose providing information abstracted from patent mining, which is meant to provide a limited exploration space. They found that an unlimited exploration space can lead participants in an idea generation session to go back to dominant design ideas, and thus a better practice is for a moderator to provide a limited exploration space, with relevant information to the domain.

By using card deck, we believe that this may inspire participants in the ideation session especially by using contents from their own organizations which in turn increases domain knowledge, another vital component of creative production. We think that by combining cards with different idea elements, this may support divergent thinking and encourage participants with new ideas. The objective is to have a wide diversity of potential ideas, in order to identify original or novel ones to solve a problem. By making unexpected combinations, this will support participants in their creativity exercise (Dove and Jones, 2014). So, the application of the bisociation principles with the Cards decks approach can improved/guided brainstorming/ideation process.

5.2.2 Card-decks as a creativity tool

Creativity tools, like card-decks and canvases, have proven to be an effective aid for idea generation tasks, helping overcome fixation issues, and serving as cues for new solutions and combinations (Roy and Warren, 2019).

5.2.2.1 A brief history of card-based design tools Roy and Warren (2019)

One of the best-known decks is Oblique Strategies, produced in 1975 by Brian Eno and Peter Schmidt, now in a fifth edition and available as an iPhone app. The cards, each of which is a suggested course of action or thinking to assist in creative situations, were aimed at helping artists, especially musicians, to overcome creative blocks, but have been used in other fields, such as graphic design (Nassisi, 2020).

However, these kinds of techniques and decks have limitations:

1) There are as many exploration spaces as there are different cards, without links between the exploration spaces,

2) There are no cards dedicated to finding solutions using new information technologies,

3) The cards are generic and do not use the company's existing knowledge.

This study is focusing on overcoming these limitations by proposing a new approach to the use of card-decks in the ideation process.

5.3 Proposed approach

The challenge of coming up with new ideas in the current accelerated rate of innovation is exacerbated by the rapid change in new information technologies, and the lack of familiarity of most employees in an organization with the capabilities of those new technologies.

We propose a new set of cards to support idea generation for the application of new technologies in innovative solutions. To that end, we are building on the work by Escandon-Quintanilla and Gutierrez-Lopez (2019), who proposed a set of cards that include: TRIZ Cards, Data types Cards, Digital transformation Cards and Emotion Cards.

To address the limitations mentioned above, our approach is based on:

1) Enabling the combination of exploration spaces, the TRIZ innovation principles are transformed into cards,

2) As TRIZ innovation principals don't cover information technologies possibilities, we have created new cards focused on Industry 4.0 tools (Connected devices, open data…),

3) Proposing customized cards, we extracted content cards from company's existing knowledge residing in available documents thanks to data-mining tools and graph theory techniques.

In the next section, we explain the motivations behind the chosen cards in our experimentation scenario. See figure 1 for reference.

Figure 5.1 Different card types that will be used in the experimentation scenario

5.3.1 Innovation principles - TRIZ

TRIZ innovation principles will be used in this paper in a card format. These cards provide abstract concepts that can be applied in the solution (Mouatassim et al., 2020).

TRIZ, invented by russian scientist Genrich Altshuller (1926-1998) and also known as Teorija ReshenijaIzobretateliskih Zadatch, was developed on the basis of analysis of several hundred thousand of patents Petrov (2019). According to Terninko et al. (1998), any technology (product, service, or process) evolves along an evolutionary curve adopted by technical systems (sometimes called technological systems) (Fey et al., 2005). In order to solve an inventive problem, from the technical problem to the technical solution, TRIZ focuses mainly on three fundamental principles: ideality which use the Ideal Final Result (IFR) to increase the ratio between useful and harmful functions, patterns of evolution of technical systems and contradiction, negative interaction of pair tool/object, that is defined as a main axis.

As part of this paper, we will focus on the following concepts:

- Opening = Data types cards - these cards can provide ideas for data that might be untapped or not yet collected but can be useful

- Digital solutions = Digital transformation cards - these cards prompt participants to think of potential transformations to analog processes.
- Dedicated content = Content cards - these cards present content from the organization's ECM, highlighting content nodes that were identified as relevant for the problem.

Unlike previous card decks, the TRIZ-based innovation card decks can be linked to one-another. They are also based on existing technical knowledge, which makes it easier to understand the principles by providing examples applied in other industries. The TRIZ cards can be combined with the other cards in the deck, thereby promoting bisociation.

5.3.2 Industry 4.0 tools

This section presents in detail the origin of the cards, and their purpose in the proposed idea generation process. As TRIZ innovation principals don't cover information technologies possibilities, we have created new cards focused on Industry 4.0 tools (Connected devices, open data…), These cards are Data types and Data transformation.

5.3.2.1 Data types Cards

The data cards aim to solve the issue of lack of awareness of data that is/can be collected by an organization, be it internal or external. This is a comprehensive but non-exhaustive sample of data that can be collected (i.e. through sensors, or using automated processes) or captured (e.g. by users or employees).

These cards can likely spark ideas that might not have been explored before, by showing participants in the idea generation session an array of possibilities in the kinds of information that can be gathered for their purposes.

5.3.2.2 Digital transformation Cards

The digital transformation cards are based on Escandon- Quintanilla and Gutierrez-Lopez (2019). As with the TRIZ cards, the purpose of the digital transformation cards is to prompt participants with concepts for the solutions; the main difference is that the TRIZ cards are based on the TRIZ inventive principles, which are abstracted from patents (usually for physical devices), while the digital transformation cards are concepts meant for digital solutions (software solutions and applications).

5.3.3 Content Cards

As mentioned above, a content graph is a graph representing the relationship between the contents that an organization owns or has access to, as explained in the next section. With the large number of contents that resides within an organization, Dammak et al. (2020) proposed an approach to apply the analysis properties from the graph theory to lighten the content graph and make it easier to understand/read by its user.

These contents represent the great asset for any organization and using it as an existing knowledge to innovate is promising. In our approach, we see a big potential to combine the content cards with the other cards to foster the creativity of the participants.

Today, organizations have a huge amount of data from different sources. These data are in different formats like documents, management platforms, databases that are not easy to use and that represent a huge amount of uncontrolled content that needs to be managed efficiently. Content management tools were designed to support these challenges; they could become the system of record of data and knowledge within organizations.

Enterprise Content Management (ECM) has been defined as “the strategies, tools, processes, and skills an organization needs to manage all its information assets (regardless of type) over their lifecycle” Smith and McKeen (2003). ECM is different from DMS (Document Management Systems), Web Content Management, and other tools and processes in that it manages the entirety of an organization’s assets like: reports, spreadsheets, web pages, presentations, emails, office documents, images, audio or video files Brocke et al. (2010).

Dammak et al. (2019) proposed to analyze the output of an organization’s ECM to generate usable information for the end users, by identifying the most relevant relationships in the data through a content graph.

Proposing customized cards, we extracted content cards from company's existing knowledge residing in available documents thanks to data-mining tools and graph theory techniques.
As mentioned above, the graphical approach using the graph theory is based on the metadata extracted from the contents. Dammak et al. (2020) used the International Patent Classification system to generate the metadata for the used content in their use case. However, when contents do not have an International Classification System that we can rely on, ECM will prompt the user to type the metadata manually or capture it from the content using OCR (Optical Character Recognition).

5.3.3.1 What is a Content Graph?

We define a 'Content Graph' as a graph representing the relationship between contents. Content Graph is a network with nodes that are connected unidirectionally by links of various relations and are intended to organize the entire relation structure between contents. ECM result graph has several noticeable benefits compared to actual search result which is in a list format. The main advantages of using a graph representation are:

- Identify previously undetected links
- Quickly identify relevant relationships
- Transforms suspicions into knowledge (the information user can support arguments that were unfounded before)

The graph-based representation permits us to use classical graph theory tools and concepts, but some drawbacks exist. The essential limit is that lost the detailed of the link. An edge represents an aggregate index between two contents. The following figure shows an example of the aggregation of the links between two contents i and j: only one link is established. The weight of this link corresponds to the number of aggregated links.

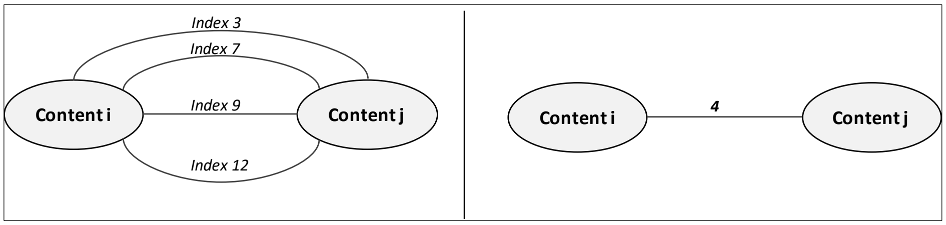


Figure 5.2 Example of Aggregation

5.3.4 Creation of a solution space with 10,626 possibilities of bisociations

Possible combination space between cards created. However, the number of possible combinations is very important. If we consider that we have only 6 cards in each quadrant with a total of 24 cards. Every time participants combine 4 cards together, one from each quadrant, they are looking at one of the 10,626 possible combinations. To determine the number of possible combinations, we used the following formula provided by Szyk and Czernia (2021):

$$C(n,r) = n!/(r!(n-r)!),$$

where:

- C(n,r) is the number of combinations;.
- n is the total number of elements in the set; and
- r is the number of elements you choose from this set.

Considering that TRIZ has 40 cards and the importance of valuable content that we could get from the organization's ECM, we believe that the possible combinations could be in the order of thousands or even millions.

5.3.5 Scenario of experimentation or use of cards

To perform this study, we organized an innovation event that we called "59 Minutes of Innovation". A step-by-step approach was implemented to make this event a success. These steps will be described in this section. This use case, "59 Minutes of Innovation", will help evaluate the impact of using the proposed approach and provide conclusions and discussions.

5.3.5.1 Ethics and recruitment

A formal request was sent for approval to the University Ethics Committee to organize an Innovation event with students. This request was approved, and standards are set to respect the University Ethics rules. Due to COVID-19, it was decided that the event will take place online using ZOOM and at lunchtime to have maximum exposure. A public event was created in the "Eventbrite" platform and was shared with students through different social media channels.

The "59 Minutes of Innovation" event had different participants from different cities and provinces in Canada gathered in different teams to solve one challenge.

5.3.5.2 Preparation and utilization of the proposed approach

Before the innovation challenge

Step 1: Submit the challenge

As part of the organizing committee of the "59 Minutes of Innovation" event, challenges were submitted by each member then discussed. At the end, one challenge was chosen. The challenge is: "How not to slide on icy sidewalks". Here is the description that was shared with the participants: "Montreal and many other cities around the world face difficult winter conditions due to ice storms. Would you be able to help pedestrians avoid slipping on icy sidewalks? We need your creativity to find a solution to this problem that, despite the technological evolution and sophisticated devices, we still have not found an effective way to help the pedestrian arrive safe and sound at its destination."

Step 2: Generate the content Cards

Generate Content Cards based on the challenge and the available organization's content by applying the Graph theory techniques (refer to 5.3.3). The approach detailing the choice of the content cards was experimented by Dammak et al. (2020).

Step 3: Prepare cards & collaboration tool (Innovation Whiteboard)

Since the vent is online, it was decided to use virtual whiteboards to enhance the collaboration between the participants. We used a tool called "Klaxoon" for this matter. Two boards were created. One has the content cards only. The second board has Content Cards, Triz Cards, Data Cards and Digital Transformation Cards.

Here are some images from the innovation whiteboards used:

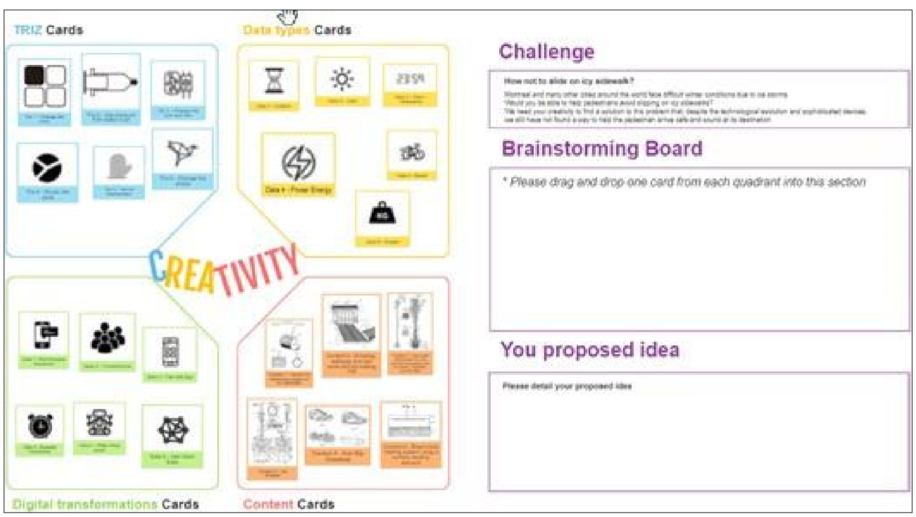


Figure 5.3 Board 1 - Creativity Quadrant - Breakout room 1

Figure 5.4 Board 1 - Brainstorming Board section - Breakout room 1

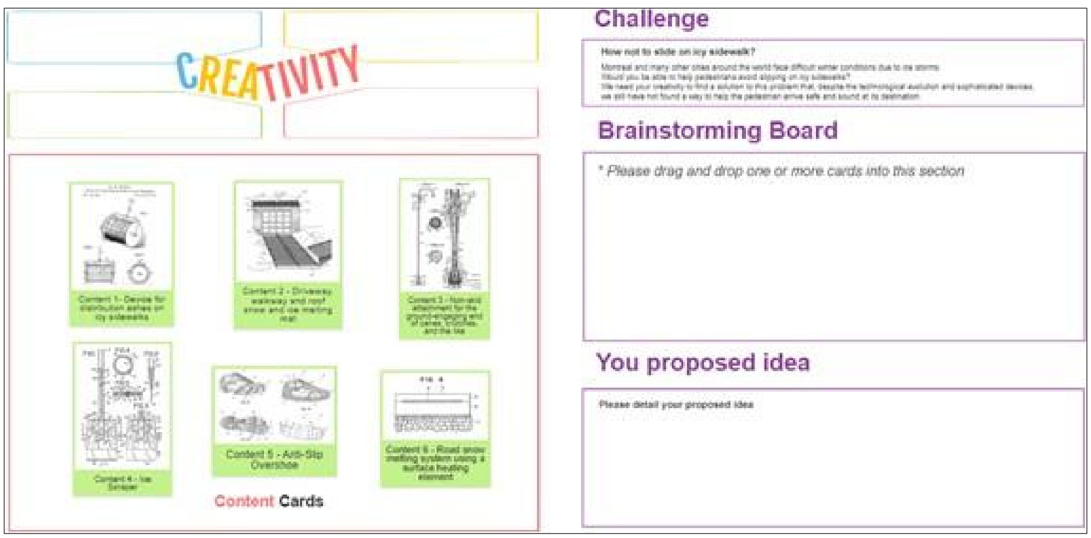


Figure 5.5 Board 2 - Contents Cards - Breakout room 2

Step 4: Call for participants

Promote the event to recruit participants for the innovation challenge

During the innovation challenge

Step 5: Onboarding the teams

The first period of the event was dedicated to explaining to the participants our approach and their involvement in the challenge. After collecting all consent forms from participants, they are divided into 2 different teams in a random fashion. To create teams, we used the out-of-box functionality from ZOOM called “Breakout rooms” which allowed us to form teams using a random selection.

Step 6: Generate ideas (using the Innovation Whiteboard)

Each team has a facilitator that will explain to them the use of the virtual board. Each participant is invited to get inspired from the cards in front of him/her and post an idea individually without collaborating with the team.

Step 7: Idea evolution & selection

Once all participants complete submitting their ideas, they are invited to vote and collaborate on these ideas in order to come up with one single idea that will be presented to the evaluation team. The use of the Cards is considered as a support tool in their thinking process.

So, the Brainstorming process that will be used is as follows: individual idea generation (inspired from cards), team discussion, voting, then combination of ideas

Step 8: Idea presentation

Each team presents his proposed idea to the evaluation team. A couple of minutes is allocated to each team for this presentation step.

Step 9 Idea evaluation

An independent jury composed of professors and teaching assistants was invited to evaluate the proposed ideas. Here are some criteria that were considered during the evaluation process:

- Applicable and relevant concept,
- The concept is technically feasible,
- The concept is innovative and stands out from existing products,
- The team used cutting-edge technologies...

Table 5.1 Experimentation Scenario — Step by step

	#	Step name	Step description
Before the innovation challenge	1	Submit the challenge to committee	Submitting a challenge to the organization committee
	2	Generate the content Cards	Generate Content Cards based on the challenge and the available organization's content by applying the Graph theory techniques.
	3	Prepare cards & collaboration tool (Innovation Whiteboard)	Two boards will be created. One will have only the content cards. The second board will have Con- tent Cards, TRIZ Cards, Data Cards and Digital Transformation Cards.
	4	Call for participants	Promote the event to recruit participants for the challenge
During the innovation challenge	5	Onboarding the teams	Explaining to the participants our approach and their involvement in the competition. After collecting all consent forms from participants, they are divided into 2 different teams in a random fashion.
	6	Generate ideas (using the Innovation White-board)	Each team has a facilitator that will explain to them the use of the board. Each participant is invited to get inspired from the cards in front of them and post an idea individually without collaborating with the team. The use of the Cards is considered as a support tool in their thinking process.
	7	Idea evolution & selection	Once all participants complete sub- mitting their ideas, they are invited to vote and collaborate on these ideas in order to come up with one single idea that will be presented to the evaluation team.
	8	Idea presentation	Each team presents their proposed idea to the evaluation team.
	9	Idea evaluation	An independent jury composed of professors and teaching assistants were invited to evaluate the proposed ideas.

5.4 Evaluation of the Card-decks approach

By the end of the innovation challenge, each team presented their proposed idea to the evaluation team. This idea generation process using the creative cards was very interesting. In this section, we will be highlighting the main findings. In order to analyze the results of our proposed approach, we have captured data during the course of the competition like: the quantity of ideas produced, the quality of ideas, the use of cards, and the combination of ideas. To perform this analysis, we have created an idea matrix for the results. This idea matrix matches the different ideas that were discussed during the event with the corresponding creative cards used for brainstorming. Also, in this matrix, we have highlighted the ideas that were used as part of the proposed solution based on the voting process that was performed in step 7. These ideas are called finalists.

5.4.1 Idea production

Team 1 had access to Board 1 Figures 3 and 4 with the Creativity Quadrant (24 Cards). This team was able to generate 14 ideas. Team 2 had access to Board 2 Figure 5 with only Content Cards (6 Cards). This team was able to generate only 9 ideas. So, we notice that the team that has access to more cards was able to propose more ideas. So, the more cards the participants have access to the more chance to generate more ideas.

Table 5.2 Number of ideas generated by Board

	Breakout Room #1 - Board 1 (24 cards)	Breakout Room #2 - Board 2 (6 cards)
Number of total ideas	14	9

5.4.2 Quality of ideas

Teams had access to different cards. Based on the idea matrix we generated after the challenge, we noticed that ideas that used more cards were selected to be finalists. Also, the more Card type used, the more the idea had a chance to be selected as finalists.

In conclusion, this suggests that cards are useful and that the more cards an idea uses, the better the results. Which tends to show that the approach proposed on the cards improves the ideation process.

Table 5.3 Mapping the generated ideas with the used cards

Idea #	Idea Description	Number of used Cards per type				
		Content Cards	Data Type Cards	Digital transformation Cards	TRIZ	Total
1	Melting ice with power from lights	1	1	1		3
2	Using mirrors to concentrate light (to melt ice)	1	1	1	1	4
3	Heating shoes (produce electricity when walking to heat/melt the snow)	1	1	1	1	4
4	Add chemical colour to salt that changes when it reaches certain temperatures (to warn walkers)	1			1	2
5	Use data to identify new materials (like salt) to avoid freezing			1		1
6	Can we make ice non-slippery by chemically changing the shape?			1	1	2
7	Use turbines to create the energy to melt the ice on sidewalks		2		1	3
8	Add ridges to sidewalks to help drain water when it melts (avoid re-icing)	1			2	3
9	Shoes with scratchers that "stop" on the ice	1				1
10	App-connected shoes that generate heat while you walk (temperature helps decide how "warm")	2	1	3	2	8
11	Use slip overshoe and change the sidewalk to an ice melting mat. for a heating mat, we can use sunlight and save the energy	2	1	1	2	6
12	Make the surface of sidewalks like a colander (avoids icy sidewalks when snow melts)				3	3
13	Heated water pipes under the sidewalks	1			1	2
14	Change the shape of the ice with the shoe soles	1			2	3
	Total per Card type	12	7	9	17	45

5.4.3 Contribution of each card type

Each card type was used with an average of 45/4= 11.25 and a standard deviation of 3.766. TRIZ cards were used 17 times, which shows that these cards are used a lot and that they are very important. Also, all TRIZ cards were used at least once.

Content cards were used 12 times with team 1 and 15 times with team 2. We consider this a big number, and this shows the importance of this type of cards. Also, all content cards were used at least once.

Data type cards were used 7 times. This is not a big number compared to the number of content cards or TRIZ cards used but there is 1 data type card that contributed to the presented idea. Data type cards were used as a secondary source of inspiration.

Digital transformation cards were used 9 times. This is not a big number compared to the number of content cards or TRIZ cards used but there are at least 3 Digital trans- formation cards that contributed to the presented idea. Digital transformation cards were used as a secondary source of inspiration as well.

To sum up, TRIZ card and content cards are the most efficient in terms of idea creation, however other types of cards have also contributed to the overall performance of the proposed approach.

5.5 Discussion

The purpose of the proposed approach based on cards is to improve the ideation process. Because of the time constraint, it was decided to keep the number of cards low (6 Cards for each quadrant). Limiting the exploration phase is consistent with previous work, it helps avoid overwhelming participants with a large amount of information.

Bisociation has shown its usefulness in the innovation challenge. The proposed cards seemed to enhance the performance of the ideation session by providing participants with an exploration space that is pertinent to the challenge and that is building on the knowledge of the organization.

The use of TRIZ cards provided participants with several partial solutions and by combining these cards with other card types, participants were able to combine them with their own knowledge, so it created an interesting innovation environment.

The fact that participants had access to content cards allowed them to generate more ideas related to these contents. So, in an organization context, this may help employees broaden their innovation space based on the company knowledge.

We believe that the key in this exercise is the bisociation. Allowing participants to combine cards with different aspects helped them to find new creative cues and having a successful brainstorming session.

We can argue that different parameters could be different in this exercise and could change the final result like: The number of chosen cards, the type of cards, the duration of the event, the participants background. However, we believe that this is an interesting approach that could be enhanced and reutilized in different fields.

5.6 Conclusion

This study suggests that cards are useful and that the more cards within a curated set a team employs to generate an idea, the better the results. Which suggests that the proposed approach on the use of cards does improve the idea generation process, by 1) Enabling the combination of exploration spaces with guides such as the TRIZ innovation principles, 2) Providing participants hints of solutions that suggest new technologies available, 3) Using content cards from the company's existing by extracting the knowledge with graph theory techniques.

We noticed that the supported team not only gained a lot of time during their idea generation process by being prompted with different exploration spaces sooner, but also they were guided to a more creative solution by combining several cards from the different sets in the card deck. In the end, they proposed more appealing and detailed ideas. The approach proposed in this article could be utilized in other innovation challenges or in brainstorming sessions within organizations, and we will assess this approach in these different contexts in the future. It can be argued that more research must be done to conclude that the use of our approach may enhance the creativity of teams at the ideation stage on all cases.

In future work, we can use Artificial Intelligence to help us choosing the cards to explore the solutions space systematically and comprehensively.

CONCLUSION

In this thesis, we have been interested in defining the uses of Enterprise Content Management Systems and Graph Theory to improve the innovation process at the ideation step.

The objective was to offer to creative teams a new approach to innovate more efficiently.

When creative teams participate in innovation activities to generate new ideas, they are willing to use their own knowledge. Providing them with a support tool that gives them access to information in different formats related to the challenge they are trying to solve is beneficial. But these creativity support tools could overwhelm the users and may slow them down. By taking Enterprise Content Management systems, we noticed that users would have access to possible thousands of contents loaded in the ECM. Creative teams using this tool will benefit from this range of valuable information. However, by performing a search using keywords related to the challenge they are trying to solve, the search result may display a long list of contents that requires much time to consult. Our approach was to display this search result as a graph. Using the Graph Theory, we decided the analyze the links between all these contents displayed in the search result and provide creative teams with a short list of the search result. So, we helped the team get more efficient search results related to their challenge, which resulted in being more creative by having a better ranking in an innovation event. We also worked on the generated ideas to define the links between them and develop new ideas using the bisociation.

The outcome of this thesis was four papers presented respectively in chapters 2, 3, 4, and 5.

In Chapter 2, we positioned our work by presenting a literature review about taxonomy and metadata, then a discussion about the importance of using ECM in an ideation session and presenting its limitations to end with a proposed approach. In Chapter 3, we documented the Graph tools and their potential utility for ECM search result analysis. In Chapter 4 we experimented with our proposed approach in an innovation competition and presented the results. In Chapter 5, we described a novel approach using bisociation in which our approach was improved by adding creative cues and it was tested in a second innovation event.

As with the enormous amount of data present within the organization today, the necessity of having approaches that help use them is crucial and especially benefits from its content to enhance creativity.

This research focused on teams of engineering students in an innovation competition with respect to all the competition rules. A future research would be to test our approach in an industry environment while engineering teams gather in a brainstorming session to find solutions to their current challenges in order to generalize it.

Also, our research used the analysis properties from the graph theory and explored the utilities of these properties in our context. In future research, we will be combining our approach with the use of machine learning algorithms and artificial intelligence (Like ChatGPT) in order to broaden our field of expertise.

Moreover, team composition could be considered. We can take into account the participants background, experience, personal skills, technical skills… then the team composition could be either random or making sure that we have equivalent teams.

One of the aspects that is worth exploring as well is the evaluation step since many biases could be linked to it. Looking at the evaluation criteria and the Jury's background could lead to interesting findings.

We also could investigate the steps to integrate our approach with a commercial ECM to benefit end users from the promising results we found.

ANNEXE I

APPROVAL OF THE ÉTS RESEARCH ETHICS COMMITTEE 1

ÉTS
Le génie pour l'industrie

Comité d'éthique de la recherche
École de technologie supérieure

21 mai 2019

Titre du projet : Définition des usages des outils de gestion de contenus pour améliorer le processus de créativité

Responsable : Mickaël Gardoni

Numéro de référence : H20190502 **Type de demande :** *Nouvelle*

APPROBATION FINALE

Monsieur Gardoni,

Nous accusons réception du formulaire d'information et de consentement modifié selon les recommandations émises par le Comité d'éthique de la recherche (CÉR) dans sa lettre du 17 mai 2019. Après révision, le dossier est conforme. J'ai donc le plaisir de vous informer que **votre projet peut aller de l'avant**.

Vous trouverez, jointe à la présente, une copie du formulaire d'information et de consentement **approuvé par le CÉR** (*version PDF datée du 21 mai 2019*). Veuillez utiliser cette version du document pour le recrutement de vos participants.

L'approbation éthique de votre projet est valable pour une année à compter de la date d'approbation finale. Si vous envisagez de poursuivre vos travaux de recherche au-delà de la date d'échéance mentionnée ci-bas, vous devrez présenter au CÉR une demande de renouvellement de l'approbation éthique. Si votre projet se termine avant cette date d'échéance, vous devrez fournir au CÉR un rapport de fin de projet.

En acceptant le présent certificat éthique, vous vous engagez à :

- Observer une **conduite responsable** tout au long de vos travaux de recherche;
- Informer dès que possible le CÉR de **tout changement** apporté au projet ou **tout évènement imprévu** qui surviendrait au cours d'une expérimentation;
- Respecter les **conditions de confidentialité et de protection des renseignements et des données**, telles qu'énoncées dans le dossier et approuvées par le CÉR.

Veuillez agréer, Monsieur Gardoni, l'expression de mes sentiments les meilleurs.

Laurence Marck
Coordonnatrice, Comité d'éthique de la recherche

ÉCHÉANCE DE L'APPROBATION
21 mai 2020

REMISE DU RAPPORT FINAL
Au plus tard le 31 décembre 2020

cc : Claire Samson, Doyenne de la recherche
Mathias Glaus, Président du CÉR

p.1/1

ANNEXE II

APPROVAL OF THE ÉTS RESEARCH ETHICS COMMITTEE 2

Le génie pour l'industrie

Comité d'éthique de la recherche
École de technologie supérieure

21 avril 2021

Projet :	**Définition des usages des outils de gestion de contenus pour améliorer le processus de créativité**
Chercheur responsable :	**Mickaël Gardoni, professeur au département de Génie des systèmes – École de technologie supérieure (ÉTS)**
Co-chercheure :	**Ma-Lorena Escandon-Quintanilla, Professeur au département de *Creative Industries* – Ryerson University**
Étudiant :	**Houcine Dammak, Étudiant au doctorat au département de Génie des systèmes – ÉTS**
Référence :	**H20210303** *Demande :* ***Nouvelle***

APPROBATION FINALE

Monsieur Gardoni,

Nous accusons réception du dossier modifié et des documents demandés selon les recommandations émises par le Comité d'éthique de la recherche (CÉR) dans sa lettre du 8 avril 2021. Après révision, le dossier est jugé conforme aux exigences éthiques. J'ai donc le plaisir de vous informer que **votre projet est approuvé et que vous pouvez procéder au recrutement de vos participants**.

Vous trouverez, jointe à la présente, une copie des formulaires d'information et de consentement **approuvés par le CÉR** (*version PDF datée du 21 avril 2021*). Veuillez utiliser ces documents pour le recrutement des participants.

L'approbation éthique de votre projet est valable pour une année à compter de la date d'approbation finale. Selon l'état d'avancement de votre projet à la date mentionnée ci-dessous, vous devrez fournir au CÉR un rapport de suivi annuel pour demander le renouvellement de l'approbation éthique ou la fermeture du dossier.

En acceptant la présente approbation éthique, vous vous engagez à :

- Observer une **conduite responsable** tout au long de vos travaux de recherche;
- Informer dès que possible le CÉR de **tout changement** apporté au projet ou **tout évènement imprévu** qui surviendrait au cours d'une séance de collecte de données;
- Respecter les **conditions de confidentialité et de protection des renseignements et des données**, telles qu'énoncées dans le dossier et approuvées par le CÉR;
- Conserver cette approbation éthique **valide au moins jusqu'à la publication des premiers résultats** de la recherche.

ANNEXE III

OTHER PUBLISHED CONFERENCE AND JOURNAL ARTICLES

A Future Eco-Design Framework Based on TRIZ's Contradictions and Bio-Inspired Design Process

Marouane Mouatassim[1,2(✉)], Mickael Gardoni[1,3], Arlindo Silva[2], Denis Cavallucci[3], Houcine Dammak[1], and Abdellatif Dkhil[1]

[1] École de Technologie Supérieure, Montréal, Canada
{marouane.mouatassim.1,houcine.dammak.1, abdellatif.dkhil.1}@ens.etsmtl.ca, mickael.gardoni@etsmtl.ca
[2] Singapore University of Technology and Design, Singapore, Singapore
arlindo_silva@sutd.edu.sg
[3] Institut National des Sciences Appliquées, Strasbourg, France
denis.cavallucci@insa-strasbourg.fr

Abstract. In the products development process, innovation is prescribed as a key parameter for technological evolution. It describes itself as a complex process that exploits different ways of transforming an idea into a reliable product. However, its way of resolution tends to amplify the conflicts of technical systems called technological contradictions. In this paper, was used the contradiction solving methods based on TRIZ Matrix in order to extract an ideal inventive principle which basically requires the existence of at least one contradiction to be eliminated. Then we will explore the potential of Bio-Inspired Design process that seeks, from ecosystem elements to extract conflicting functions that can be technologically transferable. Taking in account the aforementioned reasoning, we will discuss how the technical contradictions and their causalities can interrogate biomimetic databases to improve the innovation process by designing new environmental-friendly products that are more reliable. The aim of this work is to introduce new "eco-principles" by analyzing analogies between technical and biological solutions. The main objective is to analyze the possibilities to optimize an eco-inventive process for the next new technological generations. Based on this vision, the endpoint is to provide designers and engineers with the ideal eco-inventive methodology.

Keywords: Contradiction · TRIZ matrix · Bio-inspired design · Biomimetics · Eco-design

1 Introduction

At the development stage of a new or improved product (new technology, device or industrial process), innovation is often a complex parameter to manage. As a process, it requires several dimensions of apprehension (economic, operative, cognitive, etc.). Among these, systemic approach is defined as a complex multidimensional space used

Published by Springer Nature Switzerland AG 2020
D. Cavallucci et al. (Eds.): TFC 2020, IFIP AICT 597, pp. 183–195, 2020.
https://doi.org/10.1007/978-3-030-61295-5_15

International Journal on Interactive Design and Manufacturing (IJIDeM) (2022) 16:627–642
https://doi.org/10.1007/s12008-022-00846-9

ORIGINAL PAPER

A new approach to ideation based on linkography combined with graph theory

Abdellatif Dkhil[1,2] · Houcine Dammak[1] · Marouane Mouatassim[1] · Mickael Gardoni[1,3]

Received: 10 May 2021 / Accepted: 19 January 2022 / Published online: 10 March 2022

Abstract

Creativity is important in today's fast changing world. Creative idea generation is essential to novel concept development and ultimately innovation. In several studies, it has been shown that the rate of idea generation decreases slowly during ideation session. In some cases, a state of impasse is noted. In the many proposed approaches, the ideas are usually inspired by the use of external resources to help ideators teams during the impasse state. The main objective of this paper is to improve and stimulate the ideas generation during ideation session by using previous proposed ideas in order to create new ones. To achieve this goal, we propose an approach composed of three steps. At first, we propose the use of Linkography method to identify the previous proposed ideas. The aim of the second and third steps is the use of the previous ideas in order to propose a new one. With a view to illustrate this contribution, a real case study is presented.

Keywords Ideators · Impasse state · Graph theory · Linkograph · Bissociation

1 Introduction

Idea generation belongs to the fuzzy front-end of the development process, recognized as a key leverage point for a firm [1]. Idea generation is the fundamental step of the innovation process [2]. Participants from different domains or areas of expertise can work together during idea generation (ideation) sessions, to exchange and create knowledge, usually for a specific aim. The purpose of ideation sessions is to set an environment and implement creativity methods or techniques that will help participants generate, express and combine ideas. Another advantage of idea generation sessions is that the ideas of others sometimes stimulate the creation of ideas [3].

✉ Abdellatif Dkhil
abdellatif.dkhil.1@ens.etsmtl.ca

Houcine Dammak
Houcine.Dammak.1@ens.etsmtl.ca

Mickael Gardoni
mickael.gardoni@etsmtl.ca;
Mickael.Gardoni@insa-strasbourg.fr

1 École de Technologie Supérieure. Montréal, Québec, Canada

2 Institut Supérieur Des Sciences Appliquées Et de Technologie de Gafsa, Gafsa, Tunisie

3 Institut National Des Sciences Appliquées, Strasbourg, France

It has been shown in the review of several case studies, that the rate of idea generation during brainstorming decreases slowly and steadily after 30 min, with a dramatic decrease in idea quality after just 20 min [4, 5]. In some cases, a state of impasse is noted. In the creativity method TRIZ (Theory of inventive problem solving), Psychological Inertia is the term used to explain the impasse state in a particular way of thinking. According to Altshuller [6]," Psychological Inertia as a phenomenon refers to a natural tendency of individuals and communities to resist any changes, thereby delaying progress as much as possible". Psychological Inertia deals with resistance to change due to human programming. Also, the term fixation is often used to refer to situations where ideators limit their creative output because of an over-reliance on a pre-existing solution, or more generally, an over-reliance on a specific knowledge directly associated with a problem [7].

Recently, studies have focused on ways of overcoming this impasse state during ideation session. The objective of this is not only to support divergent thinking during ideation step but also to have a wide diversity of potential solutions, so as to identify an original or a novel proposition to solve a problem. It is necessary to support ideators to enable them to make unexpected combinations [8]. It is also accepted that creativity is not necessarily a natural-born talent, but something that can be encouraged, supported and trained [9]. A large wide of idea generation methods and tools are often

BIBLIOGRAPHICAL REFERENCES

Ackoff, R.L., 1989. *From data to wisdom*. Journal of applied systems analysis, 16(1), pp.3-9.

AIIM: Association for Innovation and Image Management. (n.d.). www.aiim.org

Alalwan, J.A., Thomas, M.A. and Weistroffer, H.R., 2014. *Decision support capabilities of enterprise content management systems: An empirical investigation*. Decision Support Systems, 68, pp.39-48.

Alalwan, J.A., 2013. *A taxonomy for decision support capabilities of enterprise content management systems*. The Journal of High Technology Management Research, 24(1), pp.10-17.

Audoux, K., Segonds, F., Kerbrat, O. and Aoussat, A., 2019. *Toward a customized multicriterion tool for product evaluation in the early design phases: the CMDET methodology*. International Journal on Interactive Design and Manufacturing (IJIDeM), 13, pp.981-993.

Bang-Jensen, J. and Gutin, G.Z., 2008. *Digraphs: theory, algorithms and applications*. Springer Science & Business Media.

Bridges, J.D., 2007. *Taking ECM from concept to reality*. Information Management, 41(6), p.30.

Card, M., 1999. *Readings in information visualization: using vision to think*. Morgan Kaufmann.

Chen, Y., Argentinis, J.E. and Weber, G., 2016. *IBM Watson: how cognitive computing can be applied to big data challenges in life sciences research*. Clinical therapeutics, 38(4), pp.688-701.

Cooper, R.G. and Edgett, S.J., 2009. *Generating breakthrough new product ideas: Feeding the innovation funnel*. Product Development Institute.

Dammak, H. and Gardoni, M., 2018. *Improving the innovation process by harnessing the usage of content management tools coupled with visualization tools.* In Product Lifecycle Management to Support Industry 4.0: 15th IFIP WG 5.1 International Conference, PLM 2018, Turin, Italy, July 2-4, 2018, Proceedings 15 (pp. 642-655). Springer International Publishing.

Dammak, H., Dkhil, A. and Gardoni, M., 2019. *Graph-based tools for ecm search result analysis to support the ideation step*. In Product Lifecycle Management in the Digital Twin Era: 16th IFIP WG 5.1 International Conference, PLM 2019, Moscow, Russia, July 8–12, 2019, Revised Selected Papers 16 (pp. 170-180). Springer International Publishing.

Dammak, H., Dkhil, A., Cherifi, A. and Gardoni, M., 2020. *Enterprise content management systems: a graphical approach to improve the creativity during ideation sessions—case study of an innovation competition "24 h of innovation"*. International Journal on Interactive Design and Manufacturing (IJIDeM), 14, pp.939-953.

Day, M., 2001. *Metadata for digital preservation: a review of recent developments*. In Research and Advanced Technology for Digital Libraries: 5th European Conference, ECDL 2001 Darmstadt, Germany, September 4-9, 2001 Proceedings 5 (pp. 161-172). Springer Berlin Heidelberg.

De Brabandere, L., & Iny, A., 2013. *Thinking in new boxes: A new paradigm for business creativity*. Random House.

Dkhil, A., 2011. *Identification systématique de structures visuelles de flux physique de production (Doctoral dissertation, Strasbourg).*

Dove, G., & Jones, S., 2014. *Using Information Visualisation to Support Creativity in Service Design Workshops*. In ServDes. 2014 Service Future; Proceedings of the fourth Service Design and Service Innovation Conference; Lancaster University; United Kingdom; 9-11 April 2014 (No. 099, pp. 281-290). Linköping University Electronic Press.

Eades, P. and Tamassia, R., 1989. *Algorithms for drawing graphs: an annotated bibliography*. Providence^ eRI RI: Department of Computer Science, Brown University.

Escandón-Quintanilla, M.L., Gardoni, M. and Cohendet, P., 2016. *Big data analytics as input for problem definition and idea generation in technological design*. In Product Lifecycle Management for Digital Transformation of Industries: 13th IFIP WG 5.1 International Conference, PLM 2016, Columbia, SC, USA, July 11-13, 2016, Revised Selected Papers 13 (pp. 468-477). Springer International Publishing.

Escandon-Quintanilla, M.L., 2017. *Effects of data exploration and use of data mining tools to extract knowledge from databases (KDD) in early stages of the Engineering design process (EDP) (Doctoral dissertation, École de technologie supérieure).*

Escandón-Quintanilla, M.L., Gardoni, M. and Cohendet, P., 2018. *Improving concept development with data exploration in the context of an innovation and technological design course*. International Journal on Interactive Design and Manufacturing (IJIDeM), 12, pp.161-172.

Escandon-Quintanilla, M.L. and Gutierrez-Lopez, A., 2019. *Creative cues to Identify and Design Opportunities Driven by Artificial Intelligence Technologies.* In Proceedings of International Conference on Application of Information and Communication Technology and Statistics in Economy and Education (ICAICTSEE) (pp. 28-35). International Conference on Application of Information and Communication Technology and Statistics and Economy and Education (ICAICTSEE).

Everitt, B. S., Landau, S., Leese, M., & Stahl, D., 2011. *Cluster analysis*. John Wiley & Sons.

Fey, V. and Rivin, E., 2005. *Innovation on demand: new product development using TRIZ*. Cambridge University Press.

Fleming, L. and Szigety, M., 2006. *Exploring the tail of creativity: an evolutionary model of breakthrough invention*. In Ecology and Strategy (Vol. 23, pp. 335-359). Emerald Group Publishing Limited.

Freund, L., Toms, E.G. and Clarke, C.L., 2005, August. *Modeling task-genre relationships for IR in the workplace*. In Proceedings of the 28th annual international ACM SIGIR conference on Research and development in information retrieval (pp. 441-448).

Graph theory: Adjacency matrices. (2016, August 4). EMBL-EBI Train Online. https://www.ebi.ac.uk/training/online/course/network-analysis-protein-interaction-data-introduction/introduction-graph-theory/graph-0

Greenberg, J., Spurgin, K. and Crystal, A., 2005. *Final report for the amega (automatic metadata generation applications) project*.

Greenberg, J., Spurgin, K. and Crystal, A., 2006. *Functionalities for automatic metadata generation applications: a survey of metadata experts' opinions*. International Journal of Metadata, Semantics and Ontologies, 1(1), pp.3-20.

Grimaldi, M. and Rippa, P., 2011. *An AHP-based framework for selecting knowledge management tools to sustain innovation process*. Knowledge and Process Management, 18(1), pp.45-55.

Harel, D. and Koren, Y., 2006. *Graph drawing by high-dimensional embedding*. J. Graph Algorithms Appl, 8, pp.195-214.

Herman, I., Melançon, G., & Marshall, M. S., 2000. *Graph visualization and navigation in information visualization: A survey*. IEEE Transactions on Visualization and Computer Graphics, 6(1), 24–43.

Hicks, B. J., Culley, S. J., Allen, R. D., & Mullineux, G., 2002. *A framework for the requirements of capturing, storing and reusing information and knowledge in engineering design*. International Journal of Information Management, 22(4), 263–280.

Hossain, M. I., & Rahman, M. S., 2015. *Good spanning trees in graph drawing*. Theoretical Computer Science, 607, 149–165.

International Patent Classification (IPC). (n.d.). Retrieved April 26, 2020, from https://www.wipo.int/classifications/ipc/en/index.html

Jacobs, A., 2009. *The pathologies of big data*. Communications of the ACM, *52*(8), 36–44.

Kabir, N., & Carayannis, E., 2013. *Big data, tacit knowledge and organizational competitiveness*. 220.

Kim.W, 2005. *On Metadata management technology: Status and Issues*. Journal of Object Technology

Koestler, A., 2020. *The act of creation*. University of California Press.

Kunstová, R., 2010. *Enterprise Content Management and Innovation.* IDIMT-2010 Information Technology–Human Values, Innovation and Economy, Linz, Trauner, 49–56.

Les 24h de l'innovation / The 24h of innovation. (n.d.). Retrieved April 26, 2020, from https://24h.estia.fr/fr/

Lourens, R., 2016. *Strategic corporate innovation factors affecting the transitioning from Chief Information Officer to Chief Innovation Officer*.

Manyika, J., 2011. *Big data: The next frontier for innovation, competition, and productivity. Http://Www. Mckinsey. Com/Insights/MGI/Research/Technology_and_Innovation/ Big_data_The_next_frontier_for_innovation*.

Mor, O., & Mor, D., 2008. *Anti-slip overshoe* (United States Patent No. US20080022555A1). https://patents.google.com/patent/US20080022555A1

Mouatassim, M., Gardoni, M., Silva, A., Cavallucci, D., Dammak, H., and Dkhil, A., 2020. *A Future Eco-Design Framework Based on TRIZ's Contradictions and Bio- Inspired Design Process*. In International TRIZ Future Conference, pages 183–195.

Munkvold, B. E., Päivärinta, T., Hodne, A. K., & Stangeland, E., 2006. *Contemporary issues of enterprise content management*. Scandinavian Journal of information systems, 18(2), 4.

Nassisi, B., 2020. *Oblique Strategies for Graphic Design, Behance*. https://www.behance.net/gallery/91849093/Make-Your-Own-Oblique-Strategies

Nonaka, Ikujiro., 1990. Chishiki-Souzou no Keiei (A theory of organizational knowledge creation). *Nihon Keizai Shimbun-Sha: Tokyo (in Japanese)*.

Nonaka, Ikujiro, Byosiere, P., Borucki, C. C., & Konnot, N., 1994. *Organizational knowledge creation theory: A first comprehensive test*. International Business Review.

Nonaka, I., & Takeuchi, H., 1995. *The Knowledge Creating Company*: Oxford University Press. New York, 995.

Nonaka, Ikujirō, & Takeuchi, H., 2007. *The knowledge-creating company*. *Harvard Business Review*, *85*(7/8), 162.

Park, S. and Nam, T.J., 2015. *Product-personification method for generating interaction ideas.* International Journal on Interactive Design and Manufacturing (IJIDeM), 9, pp.97-105.

Pearce, R. J., 2001. *Driveway, walkway and roof snow and ice melting mat* (United States Patent No. US6184496B1). https://patents.google.com/patent/US6184496B1

Peffers, K., Tuunanen, T., Rothenberger, M.A. and Chatterjee, S., 2007. *A design science research methodology for information systems research*. Journal of management information systems, 24(3), pp.45-77.

Petrov, V., 2019. *TRIZ. Theory of Inventive Problem Solving: Level 1*. Springer.

Polanyi, M., 1958. *Personal Knowledge: Toward a Post-Critical Philosophy University of Chicago Press Chicago*.

Provost, F., & Fawcett, T., 2013. *Data science and its relationship to big data and data-driven decision making*. Big Data, 1(1), 51–59.

Reamy, T., 2007. *Taxonomy development advice*. AIIM E-Doc Magazine, 21(6), 35-37.

Roy, R. and Warren, J. P., 2019. *Card-based design tools: A review and analysis of 155 card decks for designers and designing*. Design Studies, 63:125–154.

Sieloff, C. G., 1999. *"If only HP knew what HP knows": the roots of knowledge management at Hewlett-Packard*. Journal of Knowledge management.

Smith, H. A., & McKeen, J. D., 2003. *Developments in practice VIII: Enterprise content management*. The Communications of the Association for Information Systems, 11(1), 41.

Soliman, F., & Youssef, M., 2003. *The role of critical information in enterprise knowledge management*. Industrial Management & Data Systems.

Stark, W., 1969. *Non-skid attachment for the ground-engaging end of canes, crutches, and the like* (United States Patent No. US3448749A). https://patents.google.com/patent/US3448749A

Szyk, B. and Czernia, D., 2021. Combination Calculator. https://www.omnicalculator.com/statistics/combination

Terninko, J., Zusman, A. and Zlotin, B., 1998. *Systematic innovation: an introduction to TRIZ (theory of inventive problem solving)*. CRC press.

Thönssen, B., 2010. An enterprise ontology building the bases for automatic metadata generation. In Research Conference on Metadata and Semantic Research (pp. 195-210). Springer, Berlin, Heidelberg.

Tisbo, T. A., & Whitehead, S. P., 1999. *Ice scraper* (United States Patent No. US5983504A). https://patents.google.com/patent/US5983504A

Uhl, A., & Gollenia, L. A., 2016. *Business transformation essentials: Case studies and articles*. Routledge.

Usman, M., Muzaffar, A. W., & Rauf, A., 2009. *Enterprise content management (ECM): needs, challenges and recommendations.* In 2009 2nd IEEE International Conference on Computer Science and Information Technology (pp. 283-289). IEEE.

Video Challenges 2019 24h ENG 190516—YouTube. (n.d.). Retrieved May 4, 2020, from https://www.youtube.com/watch?v=8feeXuuNMb8

Vom Brocke, J., Seidel, S., & Simons, A., 2010. *Bridging the gap between enterprise content management and creativity: A research framework*. In 2010 43rd Hawaii International Conference on System Sciences (pp. 1-10). IEEE.

Von Krogh, G., Nonaka, I., & Aben, M., 2001. *Making the most of your company's knowledge: A strategic framework.* Long Range Planning, 34(4), 421–439.

Watanabe, K., & Nagai, Y., 1997. *Road snow melting system using a surface heating element* (United States Patent No. US5605418A). https://patents.google.com/patent/US5605418A

W. Hughes, 1875 *Improvement in devices for distributing ashes on icy sidewalks* (United States Patent No. US164562A). https://patents.google.com/patent/US164562A

Yim, B., 2018. *Metadata-Driven Information Security Model for Enterprise Content Management (Doctoral dissertation)*.