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Domain analysis of the research in professional competences, technology and engineering cluster

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Abstract

Objective, The paper aims to apply scientific domain analysis and network analysis to research in professional competences and its relationship to technology and engineering. **Methodology,** Network analysis is a tool of scientific domain analysis. Nowadays it is supported by technology and computer sciences, which allow the generation of network maps in order to process the information. **Results,** The models of competences proposed for professionals in information technologies have been analyzed together with the importance of developing competency management systems and the support of computer technologies to this field. **Conclusions,** Domain analysis facilitates the structuring and organization of information, which is very useful to the analysis of competences and its relation with technology and engineering, being a new subject of study.

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Keywords: domain analysis; professional competence; engineering; technology

1. Introduction

Knowledge domain analysis is a tool focused on analyzing bibliographic records from relevant publications. This methodology maintains that scientific developments can be traced by studying their footprints revealed in its academic publications (Khun, 1962). It is in this way that its use allows for identifying important information. For this article, the field of study is focused on the visualization of the research structure of professional competences in order to identify their basis, development and evolution over time, providing greater emphasis on the cluster of Technology and Engineering (Guerrero, Martinez Almela & La Rosa, 2012).

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The database has considered titles published between 1973 and the present year (2014). The softwares used were: Vosviewer and CiteSpace II. Making use of different tools and functionalities provided by these programs, 6 different graphics have been obtained which show the information related.

2. Methodology

2.1. Traditional bibliographic analysis

Consist in reviewing publications related to the scope of the study with the aim of obtaining concepts and keywords necessary to the following steps of the analysis and as support for further interpretations.
The main background is the article "Professional Competences: Intellectual Structure of Research" (Guerrero et al., 2012), which, after analyzing professional competences, proposes a classification for these. Eight categories were detected, one of which is related to Technology and Engineering, the target of study.
Among the main authors that have been considered are (Berio & Harzallah, 2007; Draganidis & Mentzas, 2006; Frank, 2012; Garcia-Barriocanal, Jansma & Jones, 2006; Sicilia & Sánchez-Alonso, 2012).

2.2. Source selection

Elsevier's Scopus has been selected as the source of information. This is the largest abstract and citation multidisciplinary database of peer-reviewed literature: scientific journals, books and conference proceedings. It also features smart tools to track, analyze and visualize research. All these characteristics show it to be an adequate selection to obtain relevant information.

2.3. Search settings

One of the most accepted is the one given by HR-XML Consortium Competencies Schema, which defines it as: "A specific, identifiable, definable and measurable knowledge, skill, ability and/or other deployment-related characteristic (example: attitude, behavior, physical ability) which a human resource may possess and which is necessary for, or material to, the performance of an activity within a specific business context" (2006). This definition makes evident the complexity of the concept which, applied to an engineering and technological context, defines greater search limits, as well as special features. Considering the above, a series of descriptors and exclusions have been developed:

Table 1. Search Descriptors

Detailed search descriptors					
"competenc*management"	"model* competenc*"	skill*	learn*	"system*engineer"	"human resourc*"
"competenc*systems*"	"competenc* model*"	competenc*	engine*	"computer*support*"	
"competenc* ontolog*"	"models of competence"	know*	acqui*	techno*	
Terms exclusions					
Health, Children, Government, School, Biology, Tourism, Space					

2.4. Selection of Visualization Software

The importance of visualization of domain analysis lies in the fact that it allows representation of the numerous intellectual connections within a dynamic and changing system such as scientific knowledge. (Börner, Chen & Boyack, 2003).

Currently, there are programs that perform graphics based on the units of analysis (authors, documents, words). However, the quality of the graphics depends closely on the quality of the information obtained from the databases in previous steps.

Based on investigations of the same kind (Cobo, Lopez-Herrera, Herrera-Viedma & Herrera, 2011; Guerrero & La Rosa, 2013), and taking in consideration the accessibility and adequacy of the programs to the goals, the following softwares were selected:

CiteSpace II (Version 3.8. R1) (Chen, 2014): This is a free application designed to answer questions about knowledge domains that are represented by a set of bibliographic records. For better visualization, the Pathfinder method has been used as a pruning method, which selects a subset of the original links to form a simplified representation of the network by extracting its most outstanding patterns.

For the interpretation of visualizations, the following should be taken into account:

- The centrality of the nodes (graph-theoretic property) quantifies the importance of the position of the node in the network and its capacity to generate connections with other nodes. It is represented by a fuchsia ring around the node, which indicates high centrality, while a white ring symbolizes the opposite.
- The thickness of each ring represents the number of times the article is cited (thicker nodes, higher citation), and the color refers to the year. The same considerations apply to the links among nodes.
- Is important to highlight that relevant information appears at the upper leftmost of the graphic. For example: the density is the proportion of the relationships that have been originated against all the possible relationships within the graphic.

Vosviewer (Version 1.5.7) (van Eck & Waltman, 2010): This software allows the construction and visualization of bibliometric maps. Pays attention to the graphical representation of the maps and it is especially useful for displaying large bibliometric maps in an easy-to-interpret way. The visual capacities of Vosviewer depend on the use of the colors. It offers different types of views for maps. In this study, the cluster density view has been selected. This one is particularly useful for obtaining an overview of the assigning of terms to clusters and the way they relate to each other. One important consideration is the distance between two items, which reflects the strength of the relationship between them (small distance indicates high relationship).

2.5. Data treatment

Before the registers can be used as an input for the visualization software, the quality of the data obtained from the previous step must be verified (this at the same time allows a guarantee of the quality of the results). For this purpose, it was necessary to use different computer programs for the elaboration of records (code assigning and normalization of references, among others). It should be noted that this step has also a manual part, as it was necessary to verify the homogeneity of titles, authors, etc., as well as to check the right format of the records.

2.6. Visualization of the Scientific Domain

As mentioned in the previous sections, the chosen softwares provide options that allow for selecting units of analysis to obtain the desired graphics. However, it is necessary to know previously the techniques that are going to be used to analyze the information:

- Co-citation: this refers to the relationship that is given between two scientific articles when they appear simultaneously in the references of a third one. This type of analysis allows the discovery of the most relevant authors or papers of a field of study, through the empirical consensus established by the hundreds of citations of those authors or papers (Olmeda-Gómez, Perianes-Rodríguez & Ovalle-Perandones, 2007).
- Co-authoring: this involves the participation of two or more countries in the development of a study. It is mainly an indicator of collaboration, and two approaches based on this exist: the first is related to the reasons and consequences of the collaboration, and the second to the analysis of the maps of collaboration created between countries.
- Co-occurrence: this is the joint appearance of two terms in a given document. The higher the frequency of joint appearance of the words, the higher is the conceptual linkage (Miguel, Caprile & Jorquera-Vidal, 2008).
- Bibliographic Coupling: two documents are bibliographically if they share one or more references. With this, a relationship of "similarity" is created between both publications (Kessler, 1963).

3. Results

3.1. Analysis of most relevant authors and their contributions based on references

Figure 1 has been obtained from the software Citespace II, applying the document co-citation. In this, the bibliography that has been cited the most by articles considered within this study can be identified. The first consideration is the colors of relationships (connections). In that way, the research related to the issue addressed has been developed in greater proportion since the year 1995, which coincides with the major technological and engineering development that has been presented in recent times. On the other hand, the density has a small value (0.0086). This can be interpreted as a little-existing connection between the bibliography considered in the study of technological and engineering competences, which gives a glimpse of the different trends followed by each of the authors. An example of this is the citation of the authors that provided the first guidelines in competences: those guided by the theory based on people's behaviour (Boyatzi, 1982; Mcclelland, 1973) and those guided by the business strategy based on competence (Prahalad & Hamel, 1990).

The document that appears as the most cited is "Competence at work: models for superior performance" (Spencer, 1993), in which the methodology of McClelland is continued. This document provides a dictionary of competences and a methodology for the evaluation and application of competences at work. Following this aspect, (Lucia D. & Lepsinger, 1999) design and implement competence models for different areas of a company.

With regard to the aspect of business strategy, the core competences are presented as a key resource that allows the company to develop its competitive advantages within themselves without depending on the environment or the industry. As a complement, (Barney, 1991) put forward his concept of "sustainable" competitive advantages. Later, "The knowledge creating company" (Nonaka & Takeuchi, 1995) focused on knowledge (component of competences) and urged the development of creating companies using this as a competitive advantage.

In technology, there are authors who introduce it as an important tool for storing, communication and knowledge management, given its availability and accessibility (Davenport, Prusak & Lawrence, 2000).

It also appears in "Competency based management: a review of systems and approaches" (Draganidis & Mentzas, 2006), where the technology is shown as a tool for competence management. Likewise, it presents the efforts made currently to develop software that allows the interoperability with other systems of the organization and the competence data.

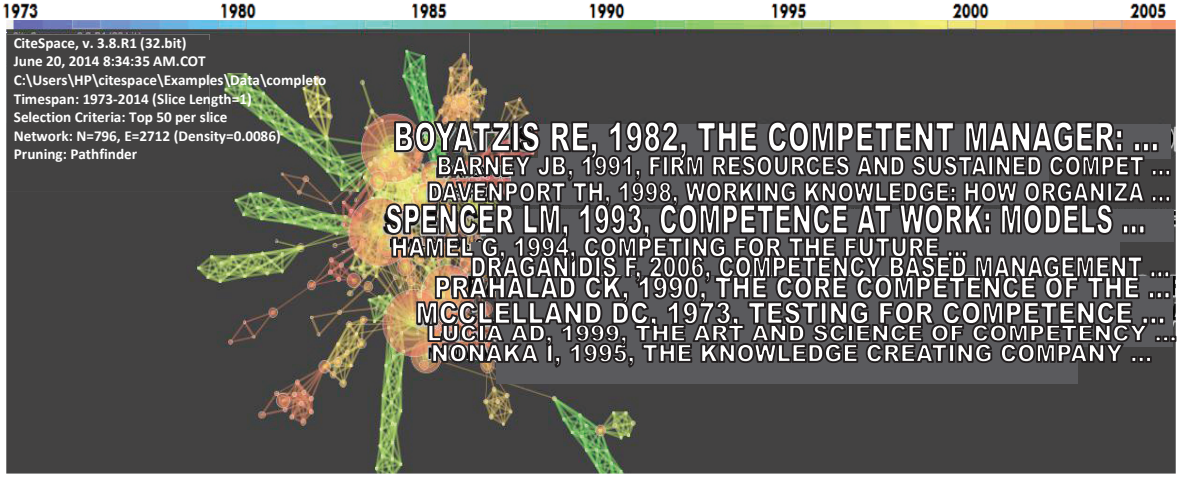

Fig. 1. Documents Co-citation

In order to complement the above graphic, a map of author's co-citation was made. In Figure 2, the results were similar with regard to the low density and the colors of the relationships. All authors who have been shown in the first graphic also appear in this second one, and the four most cited authors in the first figure are the most relevant in this one. However, two new authors are named: Harzallah, M., and Lindgren, R. Their appearance in this graphic is due to the numerous occasions that they have been cited but makes mention of different articles published by each

of them (not considering only one document as is the case with the first map). Both agree in showing competence management systems as a tool that allow managing these at an individual and organizational level, as well as the role of technology in this process (Harzallah & Vernadat, 2002).

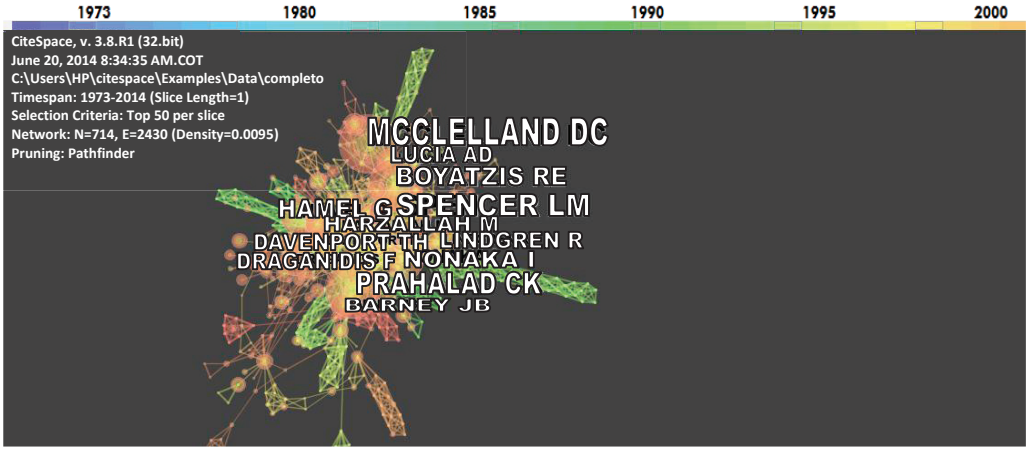

Fig. 2. Author's Co-citation

3.2. Analysis of authors and their contributions based on document authoring

Figure 3 has been obtained from Vosviewer software, applying authors' bibliographic coupling, obtaining in this way documents that have more similarity in the light of common references they cite.

From the graphic, a clear proximity between four authors can be seen. They develop topics related among themselves, such as the management of competences and knowledge, ontologies and models.

The first is Albert, D., who, starting from management concepts of the human resource and knowledge, characterizes competences as a key factor in predicting performance in the workplace through The Competence Performance Theory (Albert et al., 2008).. This approach supported by ontology and Semantic Web technologies is presented as an alternative to the dynamic nature of business.

Next, Frank, M., determines the necessary competences for systems engineers, highlighting within them the capacity for engineering systems thinking (CEST- Capacity for Engineering Systems Thinking). This is the capacity that allows for seeing the "whole", without getting stuck in the details (Frank, 2012). From this competence is derived a competence model called CEST Competence Model (2012). In this, systemic thinking is referred to as a capacity composed of elements that can be evaluated separately (Frank & Kasser, 2010).

Fazel-Zarandi, develops an ontology for competence management that allows representing, validating and evaluating competences in the companies (Fazel-Zarandi & Fox, 2012). His ontology is an extension of the Process Specification Language (Gruninger & Menzel, 2003), which uses predicates and axioms for its representation.

Finally, Bonjour, E. focuses his work on the articulation between competence and knowledge, as well as on the creation of models to develop and manage competences for project designers, because of their impact on innovation and product development. He also seeks to optimize task assignment to the staff according to their competence levels (Bonjour, Belkadi & Dulmet, 2007).

On the other hand, there are two authors who appear separated from the previous group and from each other. The first is Afsarmanesh, H., who is in charge of the management of competences in "Virtual Organizations Breeding Environments" (VBE). Competences for this type of organization are specified in the profiles of the members that integrate them. To support the management of the human resources, he develops the "Profile and Competency Management System (PCMS)" supported by an ontology (Afsarmanesh & Camarinha-Matos, 2005).

Finally, Guerrucci, D., who presents the work done in the Space European Agency with regard to knowledge management, and illustrates the tools and procedures established to capture and share it (Dow et al., 2012).

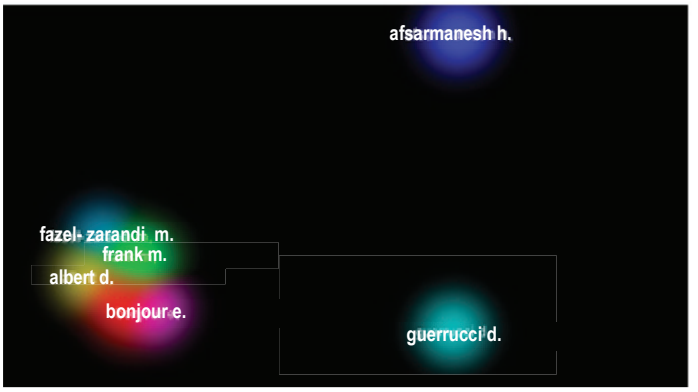

Fig. 3. Bibliographic Coupling

3.3. Identification of thematic fronts of research

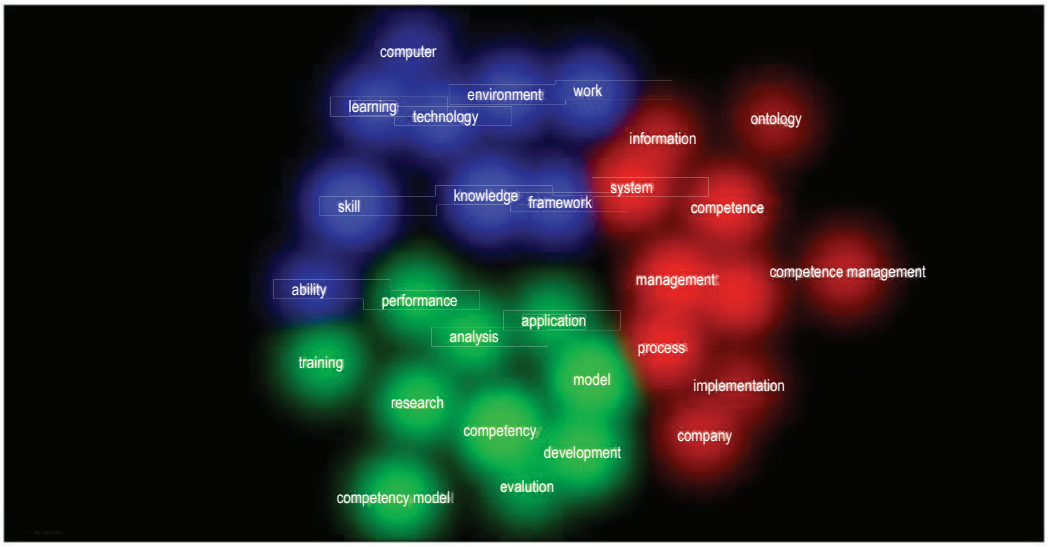

Fig. 4. Terms Co-occurrence

In order to create Figure 4, Vosviewer was used, applying terms co-occurrence. According to the graphic, three clusters were identified, these determine the main axis in which the information has been distributed.

- Red cluster – Competence management: the **management of competences** is an important factor for good performance of an **organization**. In the last decades, it has become a crucial element in companies, due to the increasing need to be agile and quick enough to adapt to market changes and reorient business plans. In this situation, **competence management systems** has become the main tool of human resources (Draganidis, Chamopoulou & Mentzas, 2006) given that, currently, the acquisition of new competences is a central objective of any educational or knowledge management **process**.

  The management of competences supported on computer tools requires models able to represent them and the flexibility of their components. The aim is to develop generic models for the different competence frameworks, which implies finding a common semantics. To that end, it is resort to the **ontology**, defined as shared conceptualizations of specific domains, based on languages and logic descriptions (Nardi & Brachman, 2003).

The use of this allows the development of automated tools for competences **information systems**. Within this context, different ontologies have been proposed, such as those developed by (Maniu & Maniu, 2009; Schmidt & Kunzmann, 2006; Sicilia, 2005).

- Green cluster – Competence Models: these are an integrated set of competences required for an excellent performance (Lucia D. & Lepsinger, 1999), derived from observing the satisfactory **performance** of an employee in their specific workplace. These have different purposes: **personal selection, training, succession planning, and performance management** (Heneman & Greenberger, 2002).

  Among the main competence models for systems engineers, there are: INCOSE UK SE Competence Systems, Model of Competences of Systems Engineering MITRE, SPRDE-SE/PSE Competence Model, APPEL Competence Model, among others. Every model should have an operational definition for each competence. With these definitions should exist **observable and measurable performance indicators or standards** in order to **evaluate** workers.

  Competence models are focused on the worker (how objectives are achieved and how works are met), as opposed to the old **work positions analysis** approach, which focuses on the tasks or work (what is performed).
- Blue cluster – Systems Engineering and Computer Support: the development of competences also takes place within the process of "experience in networks", understanding this to mean the competences that arise from **social interaction, knowledge exchange and collective solving problems.** These are integrated in the communities and organized groups of professionals (Hakkarainen, Palonen, Paavola & Lehtinen, 2007).

  Information exchange among groups of people is supported by the use of **computers**. In this way, CSCL **"Computer-Supported Collaborative Learning"** was born, which studies how collaborative learning supported by **technology** can improve the interaction between pairs and **work** in groups. Also, **collaboration and technology facilitate the distribution and exchange of knowledge and experiences among the members of a community.** Learning in networks also presupposes the application of Web technologies within this scope. This is called **e-learning.** It is worth noting that learning through the Web within organizations eases the acquisition of knowledge.

Table 2. Cluster distribution

Blue cluster – Systems engineering and computer support	Red cluster – Competence management	Green cluster – Competence models
Computer	Ontology	Training
Learning	System	Performance
Technology	Information	Analysis
Environment	Competence	Application
Work	Management	Model
Skill	Process	Research
Ability	Implementation	Competency
Knowledge	Competence Management	Development
Framework	Company	Evaluation
		Competency Model

Figure 5, can be seen the chronology of the main keywords, for complements and supports the information obtained above.

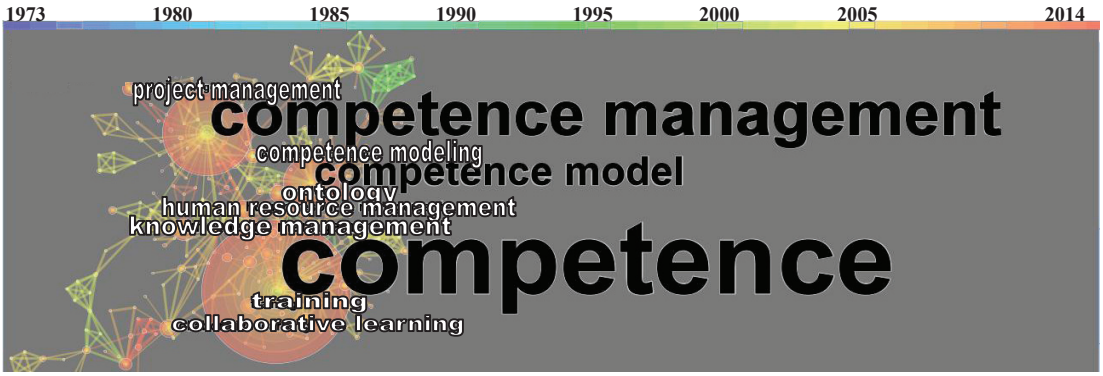

Fig. 5. Keywords co-ocurrence

The most commonly used terms are the words “competence” and “competence management”, which is observed in the size of its nodes. The word “competence”, oriented to technology and engineering, appears in the late 90s and the term “competences management” in the beginning of 2000. The validity of the rest of the terms is the same.

Among the emerging concepts are “ontology” and “collaborative learning”. They both are linked to the appearance of the computer. This, therefore, explains its emerging development.

3.4. International Contribution

Figure 6 was developed to identify the source of the articles considered in this study. According to the color of most of the rings (from yellow to red), the addressed topic has acquired more relevance in recent decades. This coincides with the developments/improvements that have occurred in technology and engineering. Also, there can be identify the countries with high centrality: the United States, England and Germany.

United States, is the country that also shows high frequency. Its first contribution occurred in 1983 with Madeline Weiss in “The human side of systems: an experimental approach", which addresses the importance of interpersonal orientation in information systems professionals. The first guidelines are presented with regard to the capacities/qualities of the person for the best job performance.

For China, although the frequency is high, its centrality is zero due to its lack of collaboration with others.

Brazil is the only country from Latin America that appears in this chart. Its first appearance was in 2002 with “Developing Competencies in Different Organizational Arrangements: The Case of the Plastics Industry in Brazil”, by Maraia Teresa Leme Fleury, in which the contribution provided by competences in the management of production chains and development networks is analyzed.

Fig. 6. Co-athoring of countries

4. Conclusions

Tools such as scientific domain analysis are very useful for the study of large volumes of information, owing to the fact that they allow the identification of relevant information in a scope of study such as: the main representatives and their contributions, the clusters in which the information is grouped and the collaboration taking place among countries. The concept of competences is very wide and includes several approaches. From an engineering and technological point of view, is oriented to the behaviors, knowledge, capacities and abilities that the professional of a company should have in order to ensure an optimal performance that would allow reaching the objectives of the organization. In this way, companies support themselves in the advances of technology to ease and optimize processes that involve the management of competences.

Within the scope of this research, three large clusters are identified in which the information is organized: competence management systems, competence models, and systems engineering and computer support.

The competences within a technological and engineering approach are a new issue that continues developing, having currently a great deal of validity. The research focuses on the future of enhancing the use of systems and technological tools such as the Internet to support the training and development of competence processes, as well as facilitating their management through logic and a common language defined in an ontology.

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