KNOWLEDGE CODIFICATION – THE KNOWLEDGE MANAGEMENT SYSTEMS PERSPECTIVE

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Abstract:
Knowledge Management Systems (KMS) are software solutions. Their main feature is knowledge codification. From a technological perspective information technology (IT) can only process data and produce information for decision-makers. The way knowledge is codified and stored using contemporary IT differentiates KMS from other information systems. The paper reviews representative ways of knowledge storage to clarify how knowledge codification changes the focus of IT, not only to process data but to support knowledge management (KM) processes.

Keywords: knowledge codification, knowledge storage, knowledge management system, knowledge management, information technology

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1. INTRODUCTION – FROM DATA AND INFORMATION TO KNOWLEDGE

KM is an evolving discipline which examines knowledge through two distinctive approaches: personal (tacit) knowledge and codified (explicit, written) knowledge. Knowledge codification involves IT (Alavi & Leidner, 2001, Becerra-Fernandez & Gonzales & Sabherwal, 2004, Dalkir, 2011, Gomez & Perera & Manning, 2012, Hislop, 2009, Jashapara, 2011, Leonard, 1998, Nonaka & Takeuchi, 1995, Nonaka & Toyama & Hirata, 2008).

Alavi and Leidner describe a KMS as an IT supported information system to support KM processes: the creation, exchange and application of knowledge (Alavi, 2001). Wang explicitly expands KMS processes with knowledge storage and knowledge search (Wang, 2008).

IT supported knowledge processes are not possible without knowledge codification. IT can only process data. The meaning (semantic) result is information (Laudon, 2016). The usable (pragmatic) result is knowledge (Valacich & Schneider, 2014), see Figure 1. Data is typical organised and stored in a form of rows and columns forming a data matrix, using keys to identify and link logical records of entity and stored in operational databases (e.g. Store & regional sales database in Figure 2). Similarly, raw data can be stored in an Excel type of spreadsheet if no formulas are used. Operational applications capture and store data to produce information for decisions together with knowledge and experience of decision-makers. It does not mean that there is no knowledge in data or information, but data is stored for data processing results (information) and not in a way of expressing knowledge.

Picture 1: From Data and Information to Knowledge

Data	Information	Knowledge
465889727	465-88-9727	465-88-9727 → John Doe
Raw Symbols	Formatted Data	Data Relationships
Meaning: ------------ ???	Meaning: ------------ SSN	Meaning: ------------ SSN → Unique Person

Source: Valacich & Schneider, 2014, p. 49

When information is linked with theory and experience, we recognise it as knowledge (Lagemaat, 2015, Smith & Lyles, 2011). The semantic interpretation of data and information is processed in a human brain or IT algorithm to produce usable knowledge. The knowledge produced can be stored for further use. Frequently knowledge is captured and stored using IT. From the KMS perspective the process is known as knowledge codification, which is a very important step in developing KMS. From the IT perspective knowledge codification must satisfy the technological requirement of capturing, storing and processing data. From the KM perspective (semantic and pragmatic) it must satisfy the human way of thinking and decision-making using IT.

Picture 2: Example of data, stored in Store & Regional Sales operational Database.

Store & Region Sales Database

II	Store N	Sales Regio	Item N	Item Descriptic	Unit Pric	Units Sol	Week Ending
1	1	South	2005	17" Monitor	$229.00	28	10/27/2014
2	1	South	2005	17" Monitor	$229.00	30	11/24/2014
3	1	South	2005	17" Monitor	$229.00	9	12/29/2014
4	1	South	3006	101 Keyboard	$19.95	30	10/27/2014
5	1	South	3006	101 Keyboard	$19.95	35	11/24/2014
6	1	South	3006	101 Keyboard	$19.95	39	12/29/2014
7	1	South	6050	PC Mouse	$8.95	28	10/27/2014
8	1	South	6050	PC Mouse	$8.95	3	11/24/2014
9	1	South	6050	PC Mouse	$8.95	38	12/29/2014

Source: Laudon & Laudon, 2016, p. 27

2. KNOWLEDGE CODIFICATION – HOW KMS SUPPORT KNOWLEDGE STORAGE

2.1 KMS – Overview

There is no KMS exclusive IT. KMS are really supported by all the known IT (Liebowitz, 2006). A company can develop a content management KMS based on File Management System or even Office or collaboration IT tools. Furthermore, data mining technology is suitable for knowledge discovery of valuable data patterns (e.g. customer behaviour). E-mail of collaboration IT tools supports knowledge sharing. Formulas in spreadsheet tools describe relations between variables, thus enabling business modelling and simulations as important business knowledge.

Becerra, Gonzales and Sabherwall classify KMS based on KM processes and KM mechanisms (Becerra & Gonzales & Sabherwall, 2004). The paper uses the list of KM Technologies as a starting point to review how contemporary IT supports knowledge codification/storage (see Figure 3). The list is further extended and organised around the SECI model of knowledge creating process (Natek & Zwilling, 2016).

Picture 3: KM Processes, Mechanisms and Technologies

KM Processes	*KM Systems*	*KM Sub-Processes*	*Illustrative KM Mechanisms*	*Illustrative KM Technologies*
Knowledge discovery	Knowledge discovery systems	Combination	Meetings, telephone conversations, and documents, collaborative creation of documents	Databases, Web-based access to data, data mining, repositories of information, Web portals, best practices and lessons learned
		Socialization	Employee rotation across departments, conferences, brainstorming retreats, cooperative projects, initiation	Video-conferencing, electronic discussion groups, e-mail
Knowledge capture	Knowledge capture systems	Externalization	Models, prototypes, best practices, lessons learned	Expert systems, chat groups, best practices, and lessons learned databases.
		Internalization	Learning by doing, on-the-job training, learning by observation, and face-to-face meetings	Computer-based communication, AI-based knowledge acquisition, computer-based simulations
Knowledge sharing	Knowledge sharing systems	Socialization	See above	See above
		Exchange	Memos, manuals, letters, presentations	Team collaboration tools, Web-based access to data, databases, and repositories of information, best practices databases, lessons learned systems, and expertise locator systems
Knowledge application	Knowledge Application Systems	Direction	Traditional hierarchical relationships in organizations, help desks, and support centers	Capture and transfer of experts' knowledge, troubleshooting systems, and case-based reasoning systems; decision support systems
		Routines	Organizational policies, work practices, and standards	Expert systems, enterprise resource planning systems, management information systems

Source: Becerra & Gonzales & Sabherwal, 2004, p. 41.

2.2 Text oriented codification of knowledge

Storytelling is an ancient way of knowledge retention and exchange (Jashapara, 2011). In the digital age a lot of knowledge is written as text using IT. If text is structured, its content can be more precise. Today the main challenge is to derive knowledge from plain (ordinary) text. There are numerous examples of application with text codification of knowledge e.g. social networks, forums, communities of practice, e-mail, chat groups, blogs, good & bad practice, questions & answers, yellow pages, electronic bulletin boards, intranets, web portals, etc. Different applications use different forms of entering and presenting a text. Knowledge can be derived from reading the relevant and usable content or using an advanced technique of knowledge discovery (e.g. text mining).

A wiki is a website application that provides collaborative modification of its content and structure in a web browser using wiki mark-up – links to another part of a wiki (https://en.wikipedia.org/wiki/Wiki). A text is more structured so it is usually easier to get usable knowledge comparing to plain text (Figure 4).

Picture 4: Wikipedia text example

Knowledge management

From Wikipedia, the free encyclopedia
(Redirected from Knowledge management systems)

Not to be confused with Content management or Information management.

Knowledge management (KM) is the process of creating, sharing, using and managing the knowledge and information of an organization.[1] It refers to a multi-disciplinary approach to achieving organizational objectives by making the best use of knowledge.[2]

Source: https://en.wikipedia.org/wiki/Knowledge_management (6. 2. 2017)

Case-based reasoning (Jashapara, 2011) is an application for solving new problems, based on the solutions of similar problems from the past using analogy. There are examples in different areas (e.g. lawyer precedents, project management, etc.). The problems, solutions and corresponding information are codified in a form of structured text depending on specific application (Figure 5).

Picture 5: Case based reasoning example good & bad experiences

Experience Information

Destination	Comments
Tampa Florida	Had a great time at Disney and Sea World. Good relaxation.
St. Paul Minnesota	Mall of America was neat, but trip was rushed, hectic
Columbus Ohio	Sea World was wonderful, not much else to do - good time. Had to meet Bill at the airport - difficult meeting - expensive
Dallas Texas	Crowded and busy, hot and humid, lots to see Tom is easy going and accomplished alot, would like to go back
New York New York	Hot, humid, busy - Expensive Most interesting City I've ever been in

Source: https://engineering.purdue.edu/~engelb/abe565/cbr.htm (6. 2, 2917)

The biggest application using knowledge as text are web browsers (e.g. Google). Users enter one or several keywords to search for relevant information or knowledge. Web browsers use complex algorithms and data centres infrastructure to process large amounts of data in different formats (including text) to obtain relevant and useful knowledge (Laudon & Laudon, 2016). There are numerous applications on the internet which also share data (if useful, also knowledge) through XML forms (Figure 6).

Picture 6: XML example

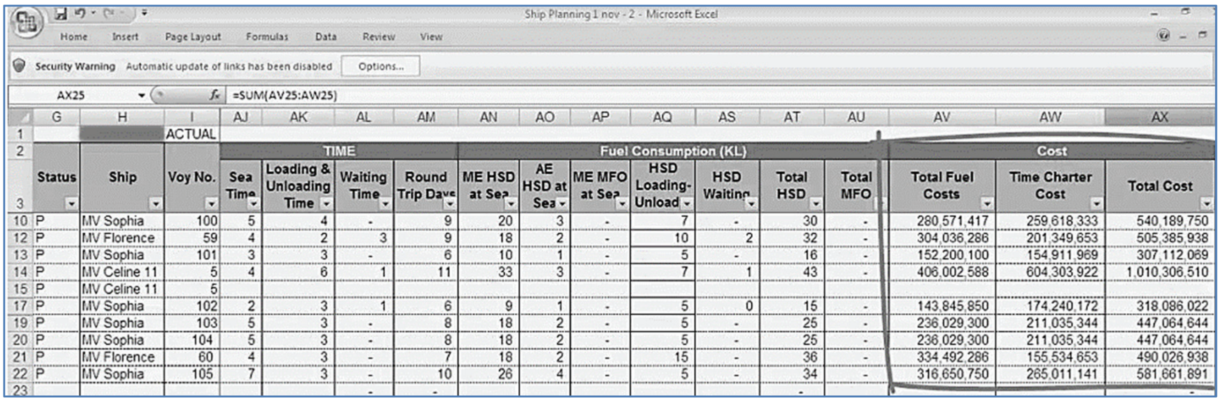
PLAIN ENGLISH	XML
Subcompact	<AUTOMOBILETYPE="Subcompact">
4 passenger	<PASSENGERUNIT="PASS">4</PASSENGER>
$16,800	<PRICE CURRENCY="USD">$16,800</PRICE>

Source: Laudon & Laudon, 2016, p. 228

2.3 Formula-oriented codification of knowledge

Spreadsheet applications have changed office work (Laudon & Laudon, 2016). They combine data organised in tabular forms with basic and advanced calculations using formulas – functions (Figure 7). As an "electronic document" spreadsheets and similar applications support knowledge codification. Introducing formulas means transformation of data to decision support systems, supporting business modelling and business simulation (Turban & Sharda & Delen, 2011). As a replacement of paper documents, spreadsheets are valuable, powerful, widespread and a relatively easy way of knowledge codification.

Picture 7: Excel data & formula example

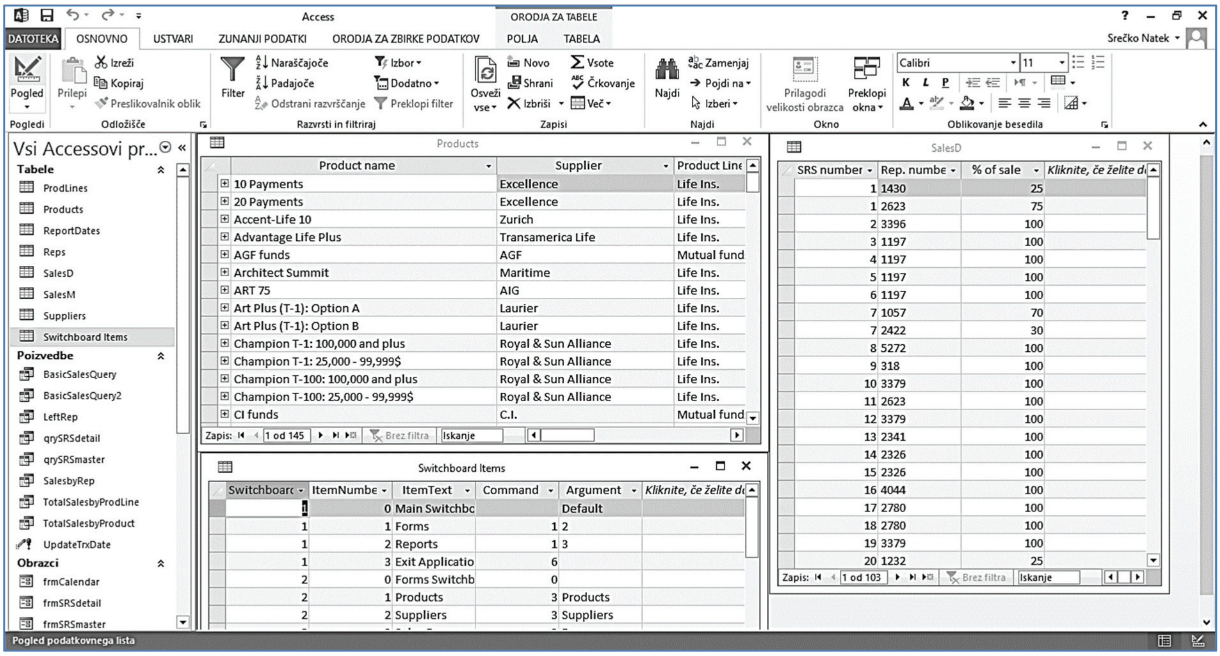


Source: https://i.ytimg.com/vi/Zc96kDS1Aqg/maxresdefault.jpg (6. 2. 2017)

2.4 Data-oriented codification of knowledge

Data processing is the core activity of IT from the very beginning. It is clear that knowledge is hidden in data. If we look at raw data (Figure 2), we do not see knowledge (Natek & Lesjak, 2013). At best we see some very small pieces of specific knowledge which are rarely useful for our decisions. The development of databases with corresponding theory and IT tools supports knowledge discovery from raw data in an easy, systematic and productive way. Contemporary database management systems incorporate solid data management where data is organised and normalised to suit a corporate or individual need. Databases are equipped with many features for fast and easy data processing and of course also simple knowledge discovery as shown with desktop Access database example for sales application (Figure 8).

Picture 8: Access database example



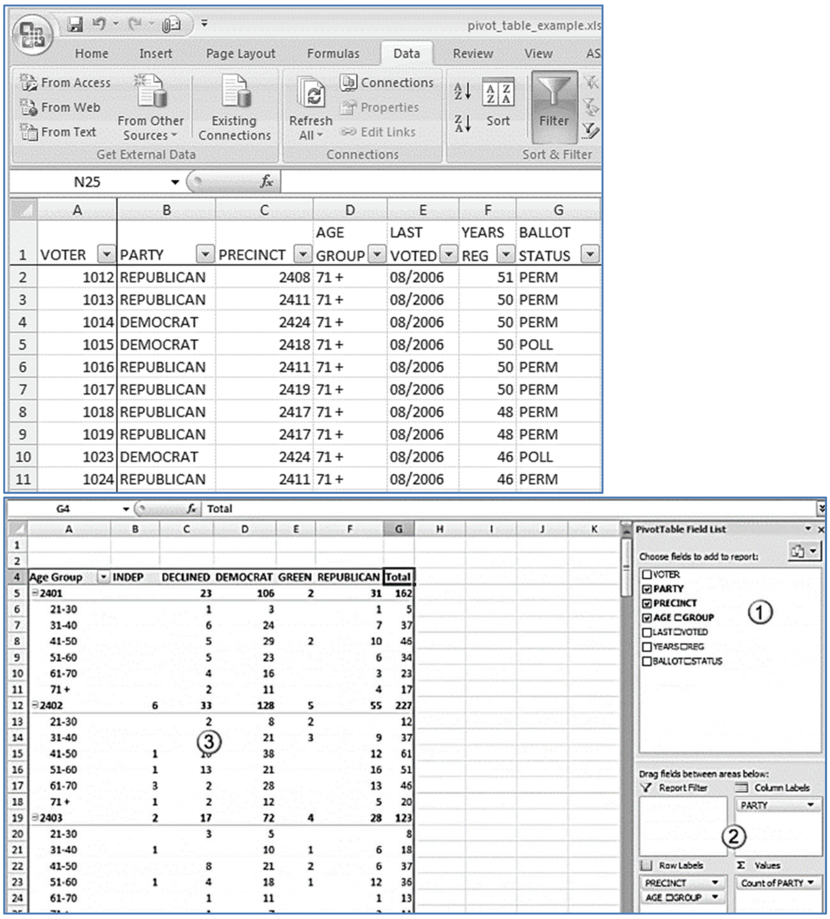
Source: http://www.ms-access2010.com/tutorials/download.html (6. 2. 2017)

Database management systems primarily support operational (transactional) applications to create, store and retrieve documents, e.g. ERP Enterprise Resource Planning, CRM Customer Relations Management, Supply Chains Management, Inventory, Sales, Marketing, etc. (Laudon & Laudon, 2016).

To meet management requirements for online, fast, easy to use, consolidated and summary data, data warehouses and analytical applications are the right solutions. Data in data warehouse are organised in a much more structured, dimensional and pre-processed way for summary data to suit only data analysis (trends, structure, comparison, different summary levels, etc.). If we look at data source, data is more understandable and free of unnecessary operational meaningless data. Data source presents detailed data but still closer to be used as knowledge source comparable with raw data in databases as shown in political parties data warehouse example (Figure 9).

To discover real, useful knowledge we need summary data representing useful knowledge for decision-making. Analytical solutions are capable of fast data analysis as shown in Excel Pivot table example result (Figure 9). As knowledge is content and learning sensitive it is important that the IT tool can instantly adapt (pivot, dimension change, level change) knowledge representation from well-organised tabular form of data sources.

Picture 9: Data source and Analytical solution example (Excel Pivot table)



Source: https://www.timeatlas.com/excel-pivot-tables/ (6. 2. 2017)

A lot of knowledge is deeply hidden in data. To discover rare rules, unusual patterns or behaviour of our customers, products, services on different markets, we need more sophisticated IT tools e.g. data mining. Data for data mining applications is usually stored in tabular or big data warehouse data sources as shown data mining input data example (Figure 10). Normally the data is further prepared (filtered) to contain only data (variables) for our goal data mining analysis (Natek & Zwilling, 2014). The way data is stored and organised is basically the same as shown in data warehouses.

Picture 10: Data mining input training data for Student data mining solution example

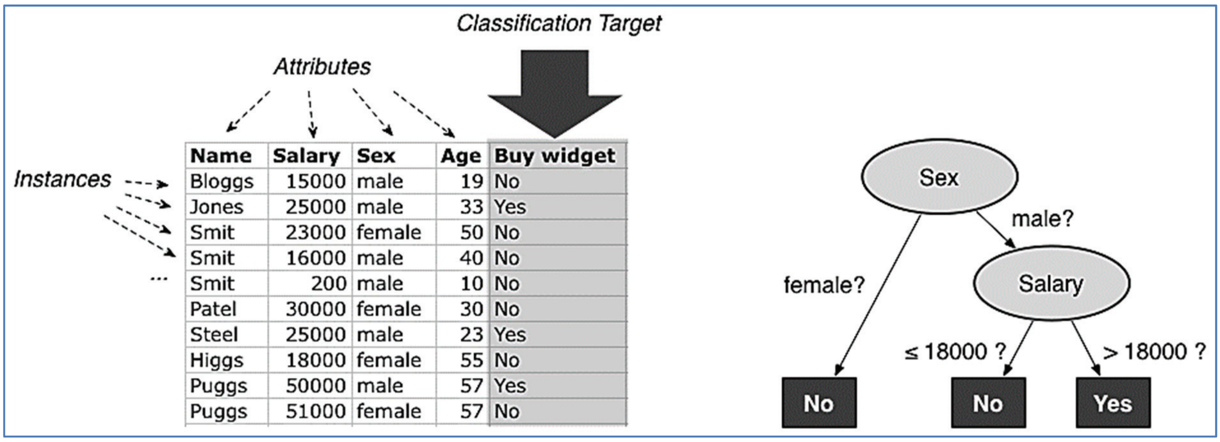
Examples of students data sets (attributes taken are: year of study, Student #, gender, year of birth, employment, status – taken sport course, registration status, Type of study either full-time/part-time, exam condition, points for activity participation, exam points, final points, Final grade out of 10).

Study year	Student	Gender	Year of birth	Employment	Status (sport...)	Registration	Type of study	Exam condition	Activities points (50)	Exam points (50)	Final points (100)	Final grade (10)
2010–2011	1	Female	1988	No	No	First	Full time	Yes	46	46	92	10
2010–2011	2	Male	1990	No	No	First	Full time	Yes	38	33	71	7
2010–2011	3	Female	1990	No	No	First	Full time	Yes	39	30	69	7
2010–2011	4	Female	1990	No	No	First	Full time	Yes	47	35	82	8
2010–2011	5	Female	1989	No	No	First	Full time	Yes	39	36	75	7
2010–2011	6	Male	1990	No	No	First	Full time	Yes	38	30	68	7
2010–2011	7	Female	1990	No	No	First	Full time	Yes	39	36	75	7
2010–2011	8	Female	1990	No	Yes	First	Full time	Yes	39	33	72	7
2010–2011	9	Male	1990	No	No	First	Full time	Yes	39	38	77	8
⋮												
2012–2013	106	Female	1990	No	No	First	Part time	Yes	44	30	74	

Source: Natek & Zwilling, 2014 p. 6401

The main benefit of data mining techniques is the way they present results of comprehensive data mining algorithms (Han & Kamber & Pei, 2012). If a decision-maker recognises results as meaningful and useful for their activities, and use them for real life decisions, the results can be defined as knowledge, which can sometimes be very different from knowledge obtained using other methods and IT tools. A classification tree is an example of such specific knowledge (Figure 11).

Picture 11: Data mining input data and classification tree result example



Source: http://fluxicon.com/blog/wp-content/uploads/2012/01/DM-Example.png (6. 2. 2017)

There are many different methods, techniques, statistics and IT tools using artificial intelligence algorithms to discover valuable, useful but deeply hidden knowledge from sometimes simple data inputs. Fuzzy sets example shows a tabular form of input data for fuzzy logical analysis (Figure 12) when using fuzzy (soft) logic to meet the requirements of the decision-maker better than with other hard logic techniques.

Picture 12: Fuzzy sets example

TABLE 7-1 Fuzzy Sets Tall, Statuesque, Short, and NBA Players

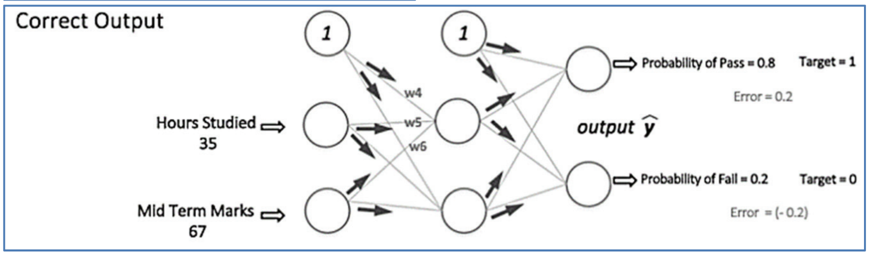
Tall		*Statuesque*		*Short*		*NBA Players*	
5′0″	0.00	5′0″	0.00	5′0″	1.00	5′0″	0.00
5′4″	0.08	5′4″	0.08	5′4″	0.92	5′4″	0.04
5′8″	0.32	5′8″	0.32	5′8″	0.68	5′8″	0.08
6′0″	0.50	6′0″	0.50	6′0″	0.50	6′0″	0.18
6′4″	0.82	6′4″	0.82	6′4″	0.18	6′4″	0.32
6′8″	0.98	6′8″	0.98	6′8″	0.02	6′8″	0.50
7′0″	1.00	7′0″	1.00	7′0″	0.00	7′0″	0.75

Source: Becerra & Gonzales & Sabherwal, 2004, p. 125

When we want knowledge to predict a future case based on knowledge in data from previous well-known cases, and need a system capable of learning from case to case, neural networks can be valuable solutions (e.g. credit card type, sales, insurance risk, etc.). The concept of neural networks follows a well-known concept of "machine learning" (Negnevitsky, 2011). Input data is organised in a tabular form, each row representing one past case. Data is normally derived from data warehouses, so the way it is written in data source (input data) is not different from previous examples. In the student pass probabilities neural networks the graphical results of neural network analysis are a different presentation of useful knowledge, capable of predicting the new student pass probability and learning with every new student case (Figure 13).

Picture 13: Neural network input data and Neural network output example

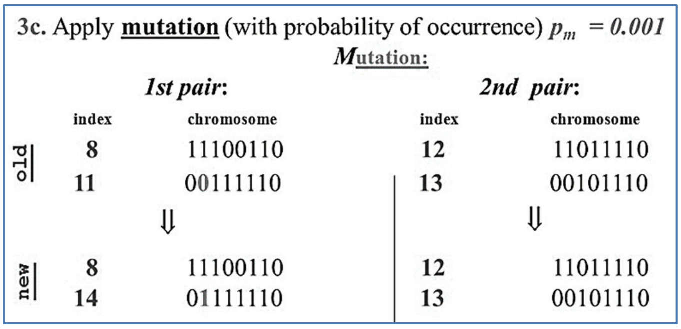
Hours Studied	Mid Term Marks	Final Term Result
35	67	1 (Pass)
12	75	0 (Fail)
16	89	1 (Pass)
45	56	1 (Pass)
10	90	0 (Fail)



Source: https://ujjwalkarn.me/2016/08/09/quick-intro-neural-networks/ (6. 2. 2017)

Thera are a lot more examples of using data for specific but complex analysis. For example, genetic algorithms usually use specific binary data input as shown in genetic chromosome chart (Figure 14). The algorithm can also be used for solving development business problems (by replacing chromosomes with business variables).

Picture 14: Genetic algorithm example

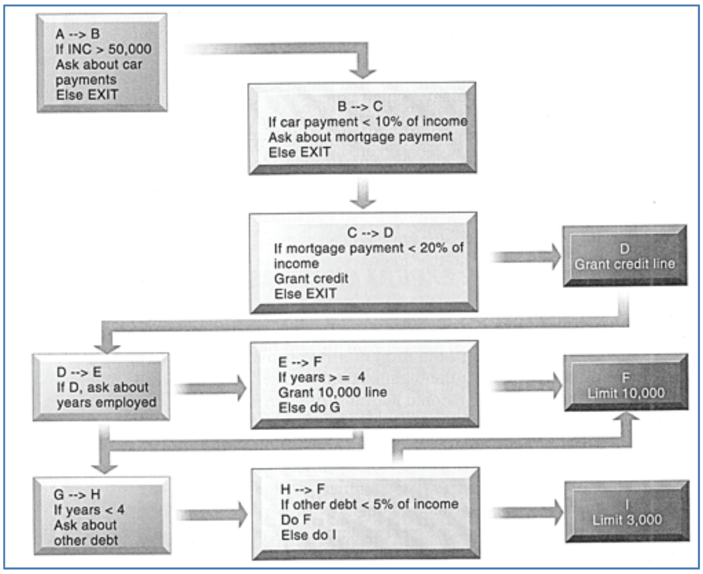


Source: http://images.slideplayer.com/16/4989293/slides/slide_40.jpg (6. 2. 2017)

2.5 Rule-oriented codification of knowledge

Expert systems and some intelligent agents do not use only data as input to provide an expert or intelligent task. The main feature which distinguishes expert systems from other KMS is knowledge base. Knowledge in expert systems is codified by rules (Figure 15) or sometimes frames (Figure 16).

Picture 15: Rules in an expert systems knowledge base example



Source: Laudon & Laudon, 2016, p. 476

Knowledge is codified in several inter-connected and logically organised sets of rules or frames as defined by experts using expert systems shell (Figure 17.)

Picture 16: Frame knowledge base example

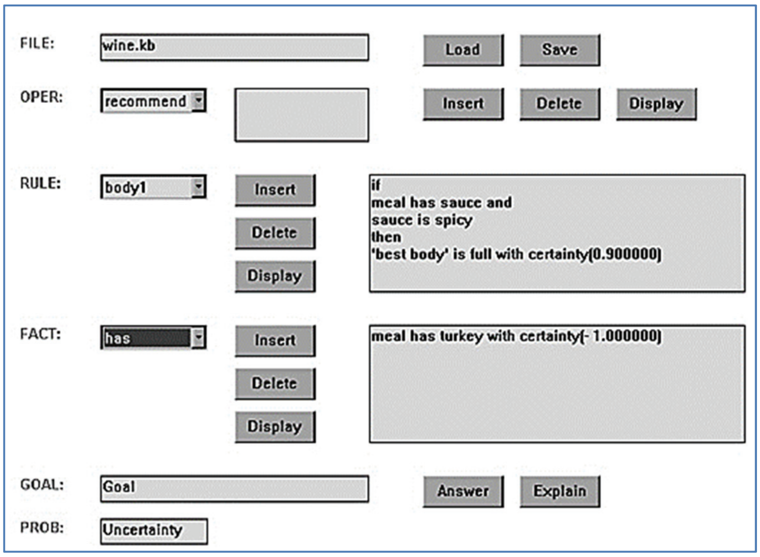
TABLE 8-1 Basic Frame for Avelino's New Mustang

Frame: Mustang
Manufacture: Ford
Country of manufacture: USA
Model: Mustang GT
Number of wheels: 4
Number of doors: 2
Year: 2002
Engine size: 4.6L-V8
Transmission: Standard
Reliability: Medium
Body style: Convertible
Color: Red
Miles per gallon: 19.7
Serial number: 12345A67890B
Owner: Avelino

Source: Becerra & Gonzales & Sabherwal, 2004, p.140

Expert systems are unable to learn from using their expert advice to solve problems. If an upgrade of the knowledge base is needed, the expert team must run the process of expert system development again. Using rules as a way of codifying knowledge is a less flexible solution compared to other described ways of knowledge codification. But it can be very effective and useful in specific areas when the replacement of the expert is needed.

Picture 17: Expert system shell – rule entry example

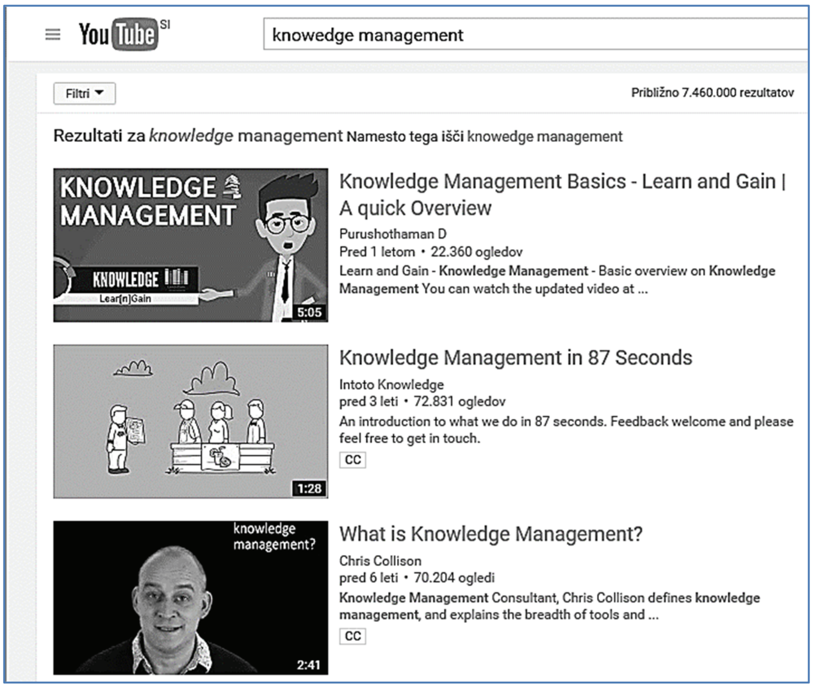


Source: http://www.ictlounge.com/Images/expert_system_rules_large.jpg (6. 2. 2017)

2.6 Multimedia-oriented codification of knowledge

There are numerous multimedia applications capable of knowledge codification by using video, audio, image or animation formats (Laudon & Laudon, 2016). Multimedia applications with corresponding libraries are a very effective way of knowledge retention and accelerate global knowledge sharing. Multimedia applications are most useful in codifying "how to" knowledge. YouTube, Facebook, Snapchat, Instagram etc. are good examples of powerful usage of contemporary multimedia and social networks IT (Figure 18).

Picture 18: YouTube multimedia example



Source: https://www.youtube.com/results?search_query=knowedge+management (6. 2. 2017)

2.7 Concept-oriented codification of knowledge

When we want to codify conceptual knowledge, cognitive mapping tools, knowledge maps, conceptual maps and similar KMS are available (Figure 19).

Picture 19: Knowledge map example

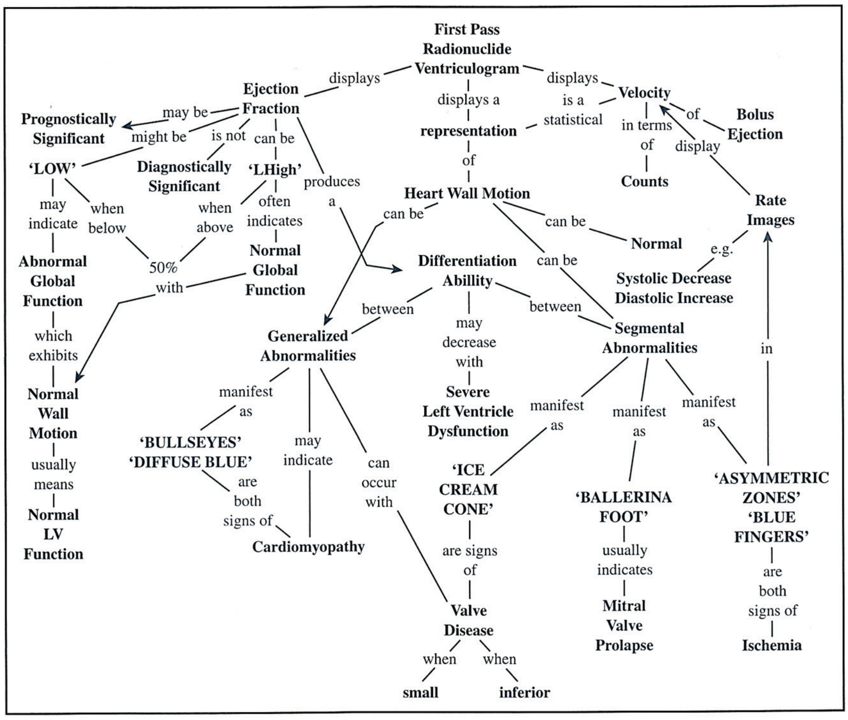


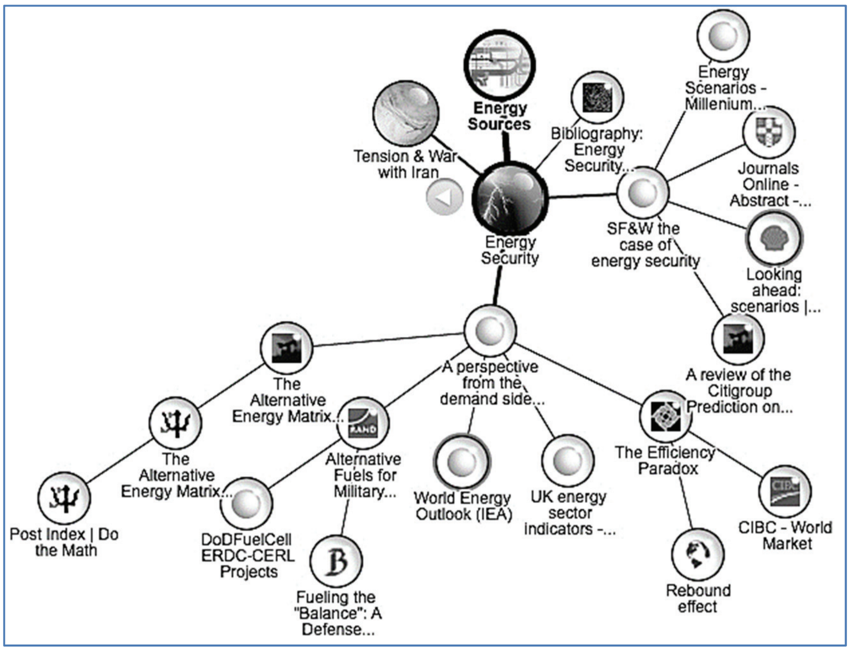
FIGURE 14-2 A Segment of a Concept Map from the Domain of Nuclear Cardiology

Source: Ford et al. [1996].

Source: Becerra & Gonzales & Sabherwal, 2004, p.287

Knowledge is usually codified in a form of structure or network, also supporting active web links to another "piece of knowledge". A good example is pearltrees.com tool with support of collaborative work and knowledge source sharing.

Picture 20: Pearltrees »place of interests« example

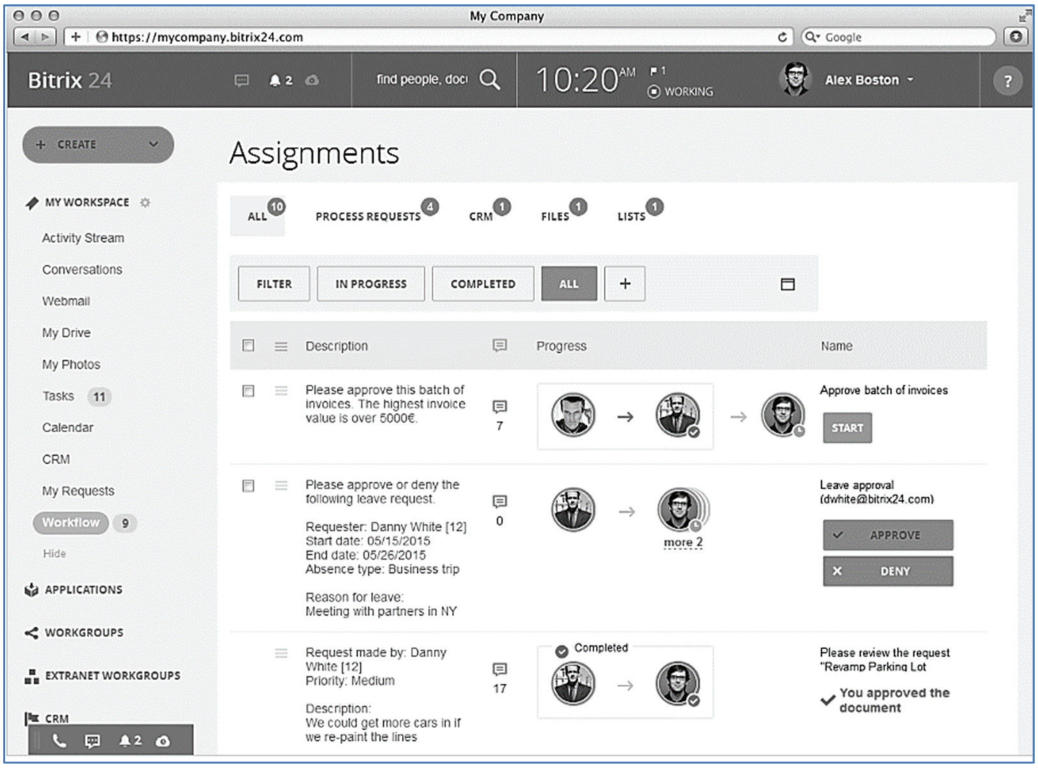


Source: https://www.redanalysis.org/wp-content/uploads/2012/04/energy-security-tree-1.jpg

2.8 Process-oriented codification of knowledge

An important type of knowledge is process "how-to", "who-what" and "when-to" knowledge (Laudon & Laudon, 2016). Specific content requires specific knowledge codification, usually as a combination of text and graphic task sequence. There are several workflow systems, business process management, project management, document management and similar applications which support the codification of the described type of knowledge (Figure 21).

Picture 21: Workflow system example



Source: https://www.bitrix24.com/images/content_en/bp_list.png (6. 2. 2017)

3. CONCLUSION

Students, practitioners and managers need a practical but systematic review of different ways to codify and store knowledge as the core of KMS. Knowledge codification distinct the operational and analytical information solutions from KMS. The paper reviews KMS and IT literature from a perspective of how knowledge is stored by IT and how to differentiate between data, information and knowledge.

The resulting review is precise and practical enough to guide students, practitioners and managers in distinguishing KMS from comparable information systems, thus helping them to choose the appropriate IT to develop usable KMS, and thus proves to be an important KMS managerial tool.

The review is not exhaustive. The selected examples are just representatives of well-known KMS. Thus, the list is open to additional IT/KMS examples to support different users, experts or managers, to become a valuable tool for understanding and managing the implementation of KMS.

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