RIGA TECHNICAL UNIVERSITY

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PERSONAL KNOWLEDGE MANAGEMENT SYSTEMS DEVELOPMENT

Summary of Doctoral Thesis

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RIGA TECHNICAL UNIVERSITY
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DOCTORAL THESIS
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APPROVAL

I confirm that I have developed this thesis submitted for the doctoral degree at Riga Technical University. This thesis has not been submitted for the doctoral degree in any other university.

Kaspars Osis ……. (signature)

Date: ……

The doctoral thesis is written in Latvian and includes introduction, 4 sections, conclusions, bibliography, 5 appendixes, 26 figures and 10 tables, 174 pages. The bibliography contains 272 references.

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INTRODUCTION

There is a historic transition from industrial age to information age in recent decades. Some researchers assure that we already live in information age [2]. Information and knowledge based organization needs a larger amount employee than it is a case with industrial age organization. In addition these employees are located in organization operations level rather than in administrations level. These employees should have ability to identify missing knowledge and to acquire it if needed in a short time. They should be creative in all areas of their work, should be able to convert received non-standard information into knowledge in order to perform their work duties successfully.

Motivation of the research

Motivation of the research is related with substantial decisions and documents of European Union (EU), which are binding to EU states and thus which influence economy of Latvia. High knowledge value and its usage in business and in everyday life situations create demand for well educated individuals, which can handle non-standard situations and large volumes of information. Thus there are required on information age technologies based education and everyday task fostering systems. European Community commission in March of 2000 worked out the Lisbon strategy [91], which contains a number of very essential EU growth fostering settings for the next decade: 1) Europe should become the most competitive and dynamic knowledge based economic in the World, 2) Europe education and training systems should adapt to knowledge based society supporting several age groups. Lisbon strategy was followed up by the European lifelong learning memorandum, which was accepted in the fall of the same year [15]. There one of the main goals is to provide availability to acquire and to update necessary skills for prolonged participation in knowledge based society and economy. As a contributing factor towards reaching this goal, in memorandum is pointed out the usage of information and communication technologies (ICT). However, based on survey done in 2007, it turns out that adults (age 25 till 64) participation in lifelong learning activities in EU more are stagnating than progressing [16]. Thus there are needed new additional solutions for individuals support to be sustainable participant in knowledge based society and economy.

The usage of knowledge management in business environment is one such solution for knowledge worker support. On individual level knowledge worker support is relatively less researched area. So far developed personal knowledge management solutions contain several separate tools such as: time schedulers, to do lists and personal knowledge repositories. These

personal knowledge management supporting tools are not integrated with each other. Thus they do not provide complete gain from synergy and from united usability point of view in comparison with that if these tools' functionalities are united in one common system, where they supplement each other rather than overlap. There are developed more or less well designed knowledge management systems from technological aspect for successful implementation of knowledge management in organizations.

In knowledge worker individual level there is a lack of personal knowledge management (PKM) supportive technological solutions or systems, which would support individuals in their work duties, in education acquisition, and in solving everyday life tasks, and which are scalable and adjustable for needs of particular user. Personal knowledge management system is a complex system, and contains technological, social and psychological aspects [5]. It performance is closely tied with individuals perception, believes, emotions, goals, surrounding environment and society. Thus in addition to technological solution there are important social and psychological aspects in personal knowledge management context. In addition such systems should be accessible to knowledge worker in the right time and right place, if there is a need for such support.

Mobile and agent technologies are fosterers for exactly such requirements fulfillment, because today usage of mobile phones, smart phones and palmtops for work and private tasks is very wide spread. Even there is available the basis of mobile and agent technology and personal knowledge management supportive tools, though so far there is not developed a united personal knowledge management system. Also there are not available such systems based on usage of mobile and agent technologies.

The goal of the thesis

The goal of the thesis is to develop a personal knowledge management system (PKMS) conceptual development approach, which would combine technological, social, psychological aspects, and such system's an architecture solution, which uses mobile and agent technologies for support of learning environment.

The tasks of the thesis

There are following tasks set for achieving the goal of the thesis:

- to perform research and analysis about knowledge, knowledge and personal knowledge management approaches and systems;

- to perform research and analysis about available information and personal knowledge management supportive tools and systems, and their development approaches;
- to develop combined personal knowledge management system's conception including in addition to technological aspect also support for social and psychological aspect;
- to analyze personal knowledge management potential contribution to learning environment support in context of mobile learning;
- to summarize and analyze available mobile technology and wireless communication options in the context of personal knowledge management;
- to analyze a usage of agent technology in personal knowledge management systems context;
- to develop personal knowledge management system's architecture, which is based on usage mobile and agent technologies and contains a functionality for learning environment support.

Research object

Research object of the thesis is personal knowledge management, its tools and systems.

Research subject

Research subject of the thesis is a development of personal knowledge management systems.

Research methods

Theoretical research is based on analysis of available information sources, and on found out incompleteness and drawbacks of personal knowledge management tools and systems. Research contains classification and systematizing. The prototype creating approach, programming engineering methods, methodology for multi-agent system development [73], and principles of graphical user interface development for mobile software are taken into account and used during development of the thesis work.

Scientific novelty of the thesis

Scientific novelty of the thesis is:

- developed conception for combined personal knowledge management systems development, which is based on in the thesis offered trinity model, which contains technological, social and psychological aspects;

- developed adaptable personal knowledge management architecture, which is based on usage of mobile and agent technologies, and which contains technological, social and psychological aspects;
- defined nine processes of personal knowledge management and developed the model of personal knowledge management processes;
- created personal knowledge management skills, types of tools, and real tools representatives overview and summary based on previously defined nine PKM processes;

Theoretical value of the thesis

Theoretical value of the thesis contains:

- is given definition of knowledge substance and its elements;
- five principles are defined for fostering knowledge element acquisition for knowledge worker in the PKMS social and psychological aspect;
- is developed robust framework for creation and development of scalable, modular PKMS;
- is developed PKMS aspects general development approach and PKMS three aspects unification solution, and given its visualization;
- is developed the personal knowledge cone-spiral (PKCS), which describes nowadays individuals additional knowledge and skills acquisition stages;
- is given a definition of the knowledge utility quotient (KUQ) and its determination formula.

Practical value of the thesis

Practical value of the thesis contains developed adaptable personal knowledge management systems architecture, which is based on usage of mobile and agent technology. Also it contains prototype of specific system's specialization module for learning environment support in Vidzeme University of Applied Sciences, and which can be used also in other academic institution.

Approbation of the obtained results

Five presentations on the main results of the thesis were made in 5 international scientific conferences (3 of them in foreign countries, i.e. in Portugal, Greece, and 2 in Latvia):

- International Conference on Knowledge Management. Madeira, Portugal, October 6-8, 2009;

- RTU 50. Starptautiskā zinātniskā konference, Rīga, Latvija, 2009. gada 12.-16. oktobris.
- Inaugural Conference Meeting of the ESREA Network on Adult Educators & Trainers. Thessaloniki, Greece, November 6-8, 2009;
- 3rd WSEAS International Conference on Visualization, Imaging and Simulation. University of Algarve, Faro, Portugal, November 3-5, 2010;
- Annual International Conference on "Virtual and Augmented Reality in Education" (VARE 2011), Vidzeme University of Applied Sciences, Valmiera, Latvia, March 18, 2011.

The main results of the thesis are reflected in 9 papers (7 of them have been already published, 1 has been accepted, and 1 is submitted for publication). In fact, the submitted paper is a chapter in ascendant monograph "Knowledge Management", which will be published by InTech.

- Osis, K., Grundspenkis, J. Perspectives on usage of agents in personal knowledge management. In KMIS'09 International Conference on Knowledge Management. Madeira, Portugal, 2009, pp. 332-337. Citation indexed: dblp.uni-trier.de.
- Osis, K., Cakula, S., Ose, B. Quality adult learning in perspective of advancing modern technologies and personal knowledge management. In ESREA-ReNAdET'09, Inaugural Conference Meeting of the ESREA Network on Adult Educators & Trainers. Thessaloniki, Greece, 2009, pp. 859-868. Citation indexed: ERIC Index.
- Osis, K., Grundspenkis, J. Perspectives of Integration of M-learning and Personal Knowledge Management. In iCERI'09 International Conference of Education, Research and Innovation. Madrid, Spain, 2009, pp. 6723-6733. Citation indexed: IATED Digital Library.
- Osis, K., Grundspenkis, J. Advancements in Smartphone Technology and Applications in Personal Knowledge Management. In INTED2010 International Technology, Education and Development Conference. Valencia, Spain, 2010, pp.4840-4851. Citation indexed: IATED Digital Library.
- Cakula, S., Osis, K. Knowledge Management in Course Content Development and Teaching. In EduLEARN'10 International Conference on Education and

New Learning Technologies. Barcelona, Spain, 2010, pp.87-96. Citation indexed: IATED Digital Library.

- Osis, K., Grundspenkis, J. Agent and Mobile Technologies and Their Usage in Development of Learning Environment Supportive System. In 3rd WSEAS International Conference on Visualization, Imaging and Simulation (VIS'10). University of Algarve, Faro, Portugal, 2010, pp.58-63. Citation indexed: ISI, SCOPUS, ACM Digital Library.
- Osis, K., Grundspenkis, J. Modular personal knowledge management system and mobile technology cross-platform solution towards learning environment support. Annual International Conference on "Virtual and Augmented Reality in Education" (VARE 2011), Vidzeme University of Applied Sciences, March 2011, Valmiera, Latvia, pp.114-124. Citation indexed (submitted): Web of Science, SCOPUS, EBSCO.
- Osis, K., Grundspenkis, J. A different view to knowledge and personal knowledge management system. 12th European Conference on Knowledge Management (ECKM 2011), University of Passau, Germany, September 2011 (accepted for publication). Citation indexed (submitted): Thomson Reuters, Google Books, Google Scholar, EBSCO.
- Osis, K., Grundspenkis, J. „Agent based personal knowledge management system supported by mobile technology cross-platform solution", in (Hou, H., T. ed.), Knowledge Management, InTech, 2011 (chapter proposal accepted). Citation indexed (submitted): Mendeley, WorldCat, Google Scholar, SCIRUS, INTECHopen.

Structure of the thesis

The thesis includes introduction, 4 chapters, conclusions, bibliography and 5 appendixes.

In the introduction the motivation of the thesis, research goals and tasks are defined. Applied scientific methods, novelty, theoretical and practical value of the thesis and approbation of the main results are described as well.

In Chapter 1 is described research and analysis about knowledge, knowledge and personal knowledge management approaches and systems; are given definitions of knowledge substance and its elements, knowledge utility quotient. So far identified PKM processes are researched, summarized and classified from different view points, and is given a new view in

this context by defining nine PKM processes. These nine processes contain a maximum incorporating range of PKM related operations and functions. There is given PKM processes model which has been accordingly described based on view developed within this work.

Chapter 2 describes research and analysis about available information and personal knowledge management supportive tools and systems, and their development approaches.

Chapter 3 is devoted for development of united PKMS conception by in addition to technological aspect including also support for social and psychological aspect in the context of PKM. In addition the analysis of PKM potential contribution to learning environment support with focus on mobile learning is included in this chapter.

In Chapter 4 is described research in areas of agent and mobile technologies, wireless technologies, their summary, classification, systematization and analysis in the context of PKM. Also is described the developed adaptable PKMS architecture, which is based on usage of mobile and agent technologies, and contains a support functionality for learning environment support.

Main results of research and conclusions are presented in the last part of the thesis.

1. KNOWLEDGE MANAGEMENT AND PERSONAL KNOWLEDGE MANAGEMENT

While information acquisition is evolving, the amount of processing information is rapidly increasing. Work environment equipment [110], and everyday household devices become more complex. That requires additional information and skills, which later on turns into knowledge, in order to handle all necessary tasks. That in turn encourages to recognize that knowledge has become the most important asset as well for organizations as for individuals. Knowledge has become a significant value. Increasing value of knowledge has served as a reason for beginning of „knowledge work".

The goal of this chapter is to define knowledge and its related notions, knowledge management and personal knowledge management.

1.1. Knowledge and knowledge management

By conducting knowledge analysis in the thesis is determined, that knowledge consists of several *parts*, *divisions*, *categories*, knowledge is classified and knowledge has *characteristics*. There is notion of *knowledge object* [62] and notion of *knowledge element* [116]. It is determined that knowledge is divided in several groups which forms square of *all*

known and unknown. Based on latter mentioned characteristics and notions author of this work defines new notion of *knowledge substance*.

By conducting knowledge management (KM) analysis within this work it is determined that it has several definitions, which are *divided based on three aspects*, there are several KM views, there are three KM *basic processes*, there is notion of *knowledge velocity* and *knowledge viscosity*, there are several *knowledge communication obstacles*. It is determined that there are several KM implementation principles. In the context of knowledge usage author of this work defines new notion of knowledge utility quotient (KUQ).

Knowledge forming parts are: *experience*, *intuition*, *basic values*, *believes*, *assumptions*, and *intelligence*. About intelligence speaks in cases, when knowledge with split second decision is used in the right time and in the right place to create better processing and results. To rephrase Wiig, the goal and main idea of information is its ability to describe, but the goal and main idea of knowledge is geared towards action [110]. Grundspenkis is even more laconic and defines knowledge as "operable" information. Grundspenkis adds that knowledge is the ability to interpret and to operate [35]. In the same time knowledge is divided [110] as follows: *towards activity geared knowledge*; *passive knowledge*. Knowledge is divided in categories. Kirikova and Grundspenkis categorize knowledge by focusing on requirements engineering [52]. They propose to distinguish *natural knowledge* inherently represented in human brains, and *artificial knowledge* represented by some natural or artificial knowledge carrier. Most popular knowledge categorization includes two categories [19,76,99]: tacit knowledge and explicit knowledge. Tacit knowledge belongs to a person and it is difficult to clearly express this type of knowledge in words, written or visual form. The location of tacit knowledge is in knowing individual's heads. Explicit knowledge can be codified and can be shared with others in such clear cut ways as expressed in writing, schemas, audio or video records. Knowledge is classified. For example, Scheler classifies knowledge as instrumental, intelligent, and mental [94]. Altogether there are identified 24 several (more or less detailed) knowledge classifications, which are summarized in thesis in table 1.1.1. (which contains a year, an author, a reference and a classification itself) in a chronological order.

By conducting knowledge analysis it is determined that there are several knowledge element and knowledge object definitions. Within this work as *knowledge element* is perceived a tacit or explicit knowledge atomic particle, which should not be or can not be divided in other knowledge related items, but which can be of different sizes and forms, and

can contain conceptual and technical context. Such knowledge element (KE) consists of information items, which can not be disjoined from each other by not loosing meaning of this knowledge element and its describing meta-data. There is also a notion of *knowledge object* [62], which by itself is not knowledge, but a depiction of knowledge within an individual, for example, a painting or a transcript of knowledge sharing speech.

Similarly as material objects knowledge has several characteristics which are rather unusual if to compare with ones describing material objects [19]:

- after usage of knowledge it is still not consumed;
- after transfer of knowledge it is still not lost;
- there is plenty of knowledge, but the ability to use it is scarce;
- in organizations much of their valuable knowledge walks out the door at the end of the day.

So far a lot of attention has been focused towards knowledge, which we know and which we know that we do not know. Though there still remains such unknown knowledge about which we do not know that we know, and such knowledge about which we do not know that we do not know (see figure 1.1.1.). Thus there exists knowledge that is outside and exists independently of human consciousness. Also Polanyi asserts that humans know more than they can tell [90]. Thus individuals already have a lot of such knowledge in their heads which they do not realize that they have it. As follows, the potential of human knowledge is considerably larger than the amount of used knowledge.

	Have it	Do not have it
Know it	Know that know	Know that do not know
Do not know it	Do not know that know	Do not know that do not know

Fig. 1.1.1. The square of known-unknown [29]

Previously noted knowledge characteristics and the wealth of knowledge based on the square of known-unknown (Figure 1) incite to define a concept of knowledge substance. This concept encompasses a breadth of all knowledge all around humans and around the environment individuals live in as a community by communicating and interacting with each other. The knowledge substance is integrity of all knowledge, and it is not further dividable in knowledge sub-substances but only in KE-s. Thus the breath of all known and unknown KE-s is forming the knowledge substance. It can be described with formula (1), where M_Z is knowledge substance, Z_E is KE and n is the number of all KE-s [80].

$$M_Z = \sum_{i=1}^{n} Z_{Ei} \tag{1}$$

In addition knowledge an individual is striving to acquire in the context of knowledge substance can not be viewed only as a dichotomous item (or items) as it is in the case of knowledge domain stated in knowledge space theory [22, 53]. It means that there exist such KE-s which can not be fully cognizable or can not be identifiable at all. However they are part of knowledge substance. Based on previously noted knowledge characteristic (i.e. after usage of knowledge it is still not consumed) one can derive also the opposite – the amount of knowledge in our environment we live in has not increased, that is, the amount of knowledge within knowledge substance is constant. Only amount of knowledge acquired by humans is changing which is relatively the same as the concept of World brain nailed by Wells in the beginning of 20th century [108]. By discovering new knowledge or coherence the amount of people-acquired-knowledge accordingly is increasing. However we can not say that a coherence described by just-acquired knowledge did not exist before it was discovered because this coherence existed and described people environment also before it was discovered. This once again underlines that the amount of knowledge within knowledge substance is constant. For an individual it is important to find the right approach for learning to spot, acquire and use unknown elements of knowledge substance (i.e. those KE-s which individual knows that he or she does not know; those which deep inside individual are known, but he/she does not realize that yet; and also those which individual does not know that he/she does not know). More details about the way to acquire knowledge substance elements are given in the third chapter of this work.

Knowledge management (KM). Similarly as it is in case of knowledge definition also KM is not an unambiguous notion. There are a large number of KM definitions, which are divided in three aspects [35]. These are: *systemic and formal* aspects, *process* aspects, and *organization* aspects. In addition there are several KM views [34,92,99]: from *business perspective* focused view, from *technology perspective* focused view, and from *human knowledge perspective* focused view KM view.

There are three basic processes which describe KM. They are: knowledge acquisition, knowledge sharing and knowledge usage [99]. There are distinguished two characterizing concepts in the context of knowledge transfer or sharing [20]:

- *knowledge velocity* – it is the speed of transfer with which knowledge moves through an organization or through an informal group of individual, having common interests, and how quickly and broadly particular knowledge is available;
- *knowledge viscosity* – it refers to the richness or density of the knowledge transferred..

In other words knowledge viscosity means how much of communicated knowledge is actually absorbed and further applied by a receiving individual. Author of this work proposes to define a notion of knowledge utility quotient (KUQ) in the context of knowledge usage. KUQ describes (see formula 2) the proportion between amount of useful knowledge Z_L possessed for performing a certain task in particular setting and all the necessary knowledge Z_V required to accomplish a given task [80].

$$Z_K = Z_L / Z_V \tag{2}$$

Such KUQ measurement can be very useful when performing a knowledge audit also in the case of PKM. However it is important to point out that KUQ is applicable only in specific environments such as m-learning task where all KE-s required can be identified ahead of time. There still have to be done further work to improve this formula so that it can be applicable for broader set of tasks and situations.

Knowledge communication obstacles, their identification and overcoming is one more important research area, which strongly influences all three KM basic processes. They are such obstacles as bad feedback, communication preconception, played incompetence,

hostility, information overload, invented “not here”, difficulty to come up with a question in particular problem domain and lack of common understanding [25].

There are several principles which should be followed for successful KM implementation. They contain such principle as awareness that knowledge is located in human brain, as well as such as that in knowledge sharing process is required trust and for starting this process encouragement and involvement is required. Successful KM implementation also includes a necessity for quantitative and qualitative KM initiative measurements [20].

1.2. Personal knowledge management from knowledge worker’s perspective

Personal knowledge management (PKM) is one of knowledge management (KM) sub-areas. KM research area exists already for a while, though PKM as a sub-area is not well enough researched one [88]. Thus PKM has been chosen as one of basic research objects of this work.

Table 1.2.1. Personal knowledge management process overview

PKM processes	**Apshvalka** [4]	**Tsui** [101]	**Jarche** [45]	**Moghe** [70]	**Frand** [28]	**Frei** [30]
1. Composition or new ideas recital / creation					1	5
2. Searching / discovery	1	1				
3. Acquisition / aggregation		2		1	2	1
4. Processing / sorting			1	2		
5. Classification / organizing / categorizing		3	2	3	6	3
6. Reviewing / evaluation / analysis				4	3; 4	2; 4
7. Storing / codification	2	4	3		5	
8. Retrieving	4	5	4		7	
9. Connecting or socializing / dialogue creating			5			8
10. Contributing / usage	3		6			
11. Sharing / publicizing / presentation	5		7			6; 7

By conducting research in this area it is determined that PKM includes series of *processes an individual has to accomplish*. In addition, analysis of this area has led to identification of several sets of such processes, which are summarized and systematized in table 1.2.1. As in different sets several of these processes are very kindred or their essential is the same just each of them having a different name, then within this summary a number of processes (i.e. names of processes) are combined and should be considered as one. Accordant

order of processes within each set (i.e. based on accordant researcher provided definition) is given by using numbers. In the same time these numbers indicate that particular PKM process is included within accordant researcher's given PKM definition.

Author of this work provides a new view within PKM process context by taking into account summarized PKM processes in table 1.2.1. and Barth information processing skills and tools description [8]. Author distinguishes nine PKM processes, which include in PKM context comprehensive set of actions or functions to do. The nine PKM processes are: *creation*, *access*, *processing*, *organizing*, *analyzing*, *retrieving*, *collaboration*, *usage and sharing*, *security*.

Based on nine PKM processes, authors have developed a PKM process model as seen in figure 1.2.1. (see below), which pictures processes to be used for knowledge element development and usage in PKM context. In process designating squares is an area in blue. It is a process sub-level, which if needed can omit particular process actions and to pass control to the next process. Dotted lines in context with security process means, that accordant security action can or can not be applied during particular PKM process action(s). Also in PKM process model can be observed that security process is parallel to all other PKM processes.

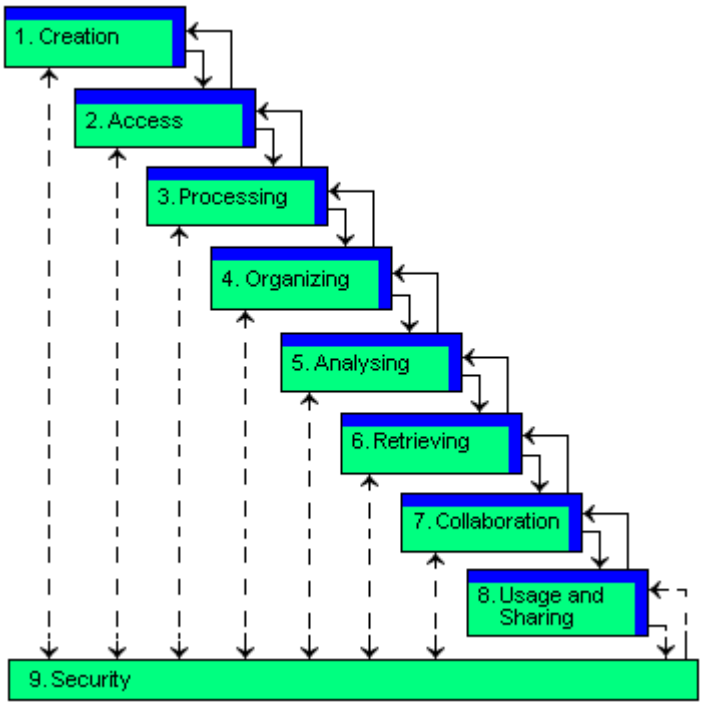

Fig. 1.2.1. Personal knowledge management process model

With Barth words PKM in essential is to be responsible about what you know, who you know, and what they know [8]. PKM cultural and collaboration edge is included in essential of this laconic definition. That points that PKM is not just focusing on individual as such. Rather it also focuses on cultural, collaborative and social aspects among knowledge workers.

PKM fosters creation of communities of practice (CoP) [13,64](Cakula & Osis, 2010; Martin 2006), which serves as a fertile ground for knowledge acquisition, sharing and usage, and as follows also for knowledge creation.

It is necessary to follow trends of own work areas and to continuously supplement own knowledge. In order for an individual to successfully manage these challenges authors see PKM as a solution and as a support provider for knowledge worker and for an individual towards their growth and improvement. Thus it is also important that for knowledge worker is available personal knowledge management system's (PKMS) support for simple information management tasks as well as for more intellectual activities.

1.3. Conclusions

Within this chapter is done report on knowledge, KM, PKM and related to it areas from traditional view. Main conclusions are:

- so far PKM and PKMS is less researched KM area;
- knowledge workers tend to think that knowledge is power which makes them more unique than other colleagues in work or academic environment; thus they have a wish to keep knowledge by themselves and not pass them over to others. This does not foster successful PKM implementation and usage;
- personal knowledge management has a potential to provide support to knowledge worker in order that he / she could follow dynamic development in surrounding environment related with individuals several areas of life such as professional, academic and personal.

The new theoretical result within this chapter is an introduction and definition of new notion of "knowledge substance" and new notion of KUQ. There is defined a set of personal knowledge management processes for maximum ambient to-do tasks and functions in context of PKM and accordant model of these PKM processes.

2. PERSONAL KNOWLEDGE MANAGEMENT TOOLS AND SYSTEMS

Within this chapter is described in thesis performed analysis of PKM tools, systems and their development approaches with the goal to identify so far accomplished PKM related tools and systems, and to obtain conclusions about deficiencies in this area.

2.1. Tools and systems

By conducting PKM tools analysis within this work it is established that they contain as well as several technologies as physical equipment for personal knowledge and information processing. Barth points out that for an effective PKM it is vitally necessary to use accordant technology [8]. It is also established in thesis that PKM tools are divided in several groups or categories. In online resource point KM Magazine is given a list of PKM tools by dividing them in six categories: “indexing and searching”, “associative links and searching”, “organizing, sharing and creation of knowledge mutual connections”, “meta-searching”, “collaboration services” and “web storing” [53]. In this case these tools are to be considered as personal information management (PIM) tools. As PIM is part of PKM then also this division of tools is described in context of PKM tools. Barth [9] categorizes PKM tools in five parts similar to KM Magazine case. They are [9]: indexing and searching tools, associative links and searching tools, online meta-searching tools, web storing tools, organizing and creation of knowledge mutual connections tool. Apshvalka bases her division of PKM tools on three knowledge processes: knowledge creation, knowledge codification, and knowledge sharing [4].

By taking into account Barth [] PKM tools division approach, and based on within this work previously developed PKM process model (figure 1.2.1.), the author of this work has developed a detailed PKM tools and skills overview in context of nine PKM processes. Thus created PKM tools and skills overview is divided in nine parts, where each of them denotes one of previously mentioned 9 PKM processes: *creation*, *access*, *processing*, *organization*, *analysis*, *retrieving*, *collaboration*, *usage and sharing*, *security*. In the same time this tools division is divided in to three parts: skills, tools and tools representative [84]. Part “Skills” contains a list of skills necessary for particular PKM process operation or functioning. Part “Tools” contains particular PKM process related types of tools, but part “Tool representative” contains example of particular type of tool according to particular PKM process.

Overview of tools in context of PKM tools division in nine parts shows the wide array of tools for knowledge worker to get done with actual tasks and problem solving. In addition there should be pointed out knowledge workers accordant skill set meaning and importance as the same skill set may not fit for solving different type of problems and tasks. Successful performance of knowledge work is tightly related with mixture of individual's education, social skills, culture and intuition.

By conducting knowledge management **systems** (KMS) analysis in thesis there is established that such systems are looked at in context of organization. They contain such functionality as *communication*, *document management*, *access* or *retrieving*, *searching* and *visualization*. There are different type of KMS and differently targeted KMS. For example, Maier divides KMS in three large groups based on which organization level do these groups represent [63]: *whole organization amplitude KMS*, *group or community KMS* and *individual KMS*. To be more laconic KMS in organizations support [102]: finding knowledge objects, acquisition, creation and sharing with knowledge objects; fosters decision making; fosters environment creation in order to support knowledge sharing among knowledge workers.

Thus KMS mainly focus on organization learning, awareness of existing knowledge and its usage for fulfilling business goals. KMS also focus on knowledge gap identification and acquisition of missing knowledge so that organization stays as a competitive participant or leader within its market niche. Within view of such systems mainly is an organization level knowledge. As stated above Maier points out a separate category "individual KMS" [63]. However usually in context of these systems PKM appears very seldom or not at all.

By conducting personal knowledge management systems (PKMS) analysis in thesis is established that research in this area has started rather recently. Till now PKM and PKMS is a less researched KM area [88]. As PKMS definition in thesis is chosen a view of Apshvalka and Grundspenkis [5] which states that PKMS is a complex system and it contains social, psychological and technological aspects. Its operation is closely tied with knowledge workers perception, emotions, believes, surrounding society, environment, desires and goals. Technology in context of PKMS has an important role as well. Goal of PKMS is to support as much as possible system's owner to make decisions and perform actions.

It is determined that similarly as in case of KMS also PKMS support finding knowledge objects, acquisition, creation and knowledge object sharing. They also support decision making and creation of environment so that individual could do knowledge sharing with other knowledge workers or with CoP acquaintances. Miller states that PKMS from practical point

of view encompasses how individual can find personal information sources in his / her computer or mobile device, and how to adjust this information to particular situation in order to create intellectual and knowledge values to foster success at work and in life [68]. In addition PKMS focus not only on individual's personal information sources, but also on sources outside latter mentioned set of sources.

Till now observed PKM research areas can be divided in two directions. One of them looks at PKMS mainly as a part of whole organization wide KMS [105] and how it mutually interacts. Other research direction focuses on PKMS or PKM tools usage in context on an individual and less attention is geared towards organization KMS factor [44,60].

2.2. Personal knowledge management tools and systems development approaches

By conducting PKMS analysis it is determined that there are several types of PKMS based on their structure. So far more known and developed PKMS are based on desktop approach [23], for example, Google Desktop, Windows Search, Apple Spotlight and Copernic Desktop Search [18]. Other PKMS are based on web technologies such as wiki, for example, WikiPad [111], or web blogging [60]. There have been attempts to combine latter mentioned approaches [51], thus trying to come up with such system, which would allow its user to avoid information doubling by using both desktop and wiki environment.

By conducting PKMS analysis it is also determined that there are several PKMS development approaches, for example, Maier's pier-to-pier KMS [63] with focus on individual level, Apshvalka's developed one based on brain functionality PKMS conceptual model [4], Smedley's conceptual PKMS [96] based on theoretical models in KM [75] and in learning [55], Wright conceptual PKMS [113,114] based on four mutually connected scopes (analytical, information, social, learning). In the case of Smedley conceptual PKMS very important ns knowledge sharing process is the trust factor [96], but in Wright's approach very important is tight collaboration and networking [113,114].

2.3. Conclusions

Within this chapter is conducted overview of PKM tools and their categorization based on previously defined nine PKM processes. As well as notion of PKMS as such and PKMS and PKM tools development approaches are explored. Main conclusions are:

- there are number of available PKM tools used by knowledge workers;
- there are simple PKM tools and also ones with broader functionality;
- there is no one common definition of PKMS in PKM research area;
- there are crested several PKMS development approaches based on desktop and on web social software;
- there are several PKMS conceptual development approaches which better encompasses PKM basic values.

So far created PKMS development approaches based on desktop and on web social applications are applicable in PKM. However these approaches only partially support PKM requirement and conditions, and they do not combine all three PKMS aspects: social, psychological and technological. These PKMS are not scalable and / or are not adjustable to particular knowledge worker and to his / her knowledge work and area of interest. Current PKMS can be considered as only a bit more than PKM productivity tools. Based on [47] there are needed systems with ability to adjust to individual style and working methods. By evaluating available information, we have to conclude, that so far are not known wholesome PKMS development approaches, which would focus directly on systems development and would combine previously mentioned three PKM aspects.

3. PERSONAL KNOWLEDGE MANAGEMENT SYSTEM'S CONCEPTION

This chapter contains description of PKMS conception developed in thesis which encompasses all three PKM aspects – social, psychological and technological. There is defined notion of mobile learning in context of PKMS with a goal to focus on this system's specific area module "m-learning" in addition to basic module and frequently used modules.

3.1. Personal knowledge management system in context of individual needs

An appearance of innovations and new ideas in the knowledge worker (KW) level happens in all environments and in all moments over individual's time frame. For KW it is important to have a PKMS support. PKMS from technological aspect only will not make a successful system's integration and usage for backing KW task supporting process. It is important that individual himself / herself is willing to use PKMS and is willing to stick with

PKM guidelines. Here stand out the social and psychological aspects of PKMS. It is important to realize individual's everyday needs, motivation and task accomplishing satisfaction.

A well-known hierarchy of needs was published more than fifty years ago [65]. Maslow proposed that individual's needs are hierarchically ordered in five levels: biological and physiological, safety, belongingness and love, esteem, and self-actualization. This hierarchy usually is depicted in the form of pyramid where at its basic level are positioned biological and physiological needs. Later on hierarchy of needs was extended with cognitive and aesthetic needs levels, and also there was added transcendence needs level.

Hierarchy of needs theory has been also criticized being subjective and the order of needs levels being not appropriate [12]. However from PKMS perspective the Maslow hierarchy order is not important. More essential is to realize that such individual needs exist and they clearly have an impact on KW. Thus these needs have to be taken into account when developing a PKMS.

Maslow realized the existence of attitude problems regarding workers such that they have certain human basic needs and that they have the rights for self-actualization. There are also some other problems KW-s have to deal with. KW-s have to identify problems within themselves and should be willing to tackle them. Thus they can improve PKMS performance from all of its three aspects.

Important traits of KW about the done task are also motivation and satisfaction. In regard of satisfaction a considerable research is done by Herzberg developing theory of two factors [39] which can be directly referred also to KW-s. Regarding motivation a valuable research effort is done by McClelland who developed a theory of motivation and researched individuals' needs for achievements [66]. Thus it is considered that individual's needs are developing during his / her life. Haslam states that individual's motivation is dependent on his / her self-categorization [38].

3.2. Personal trinity model – an approach to PKMS development

Author has proposed a PKMS development approach taking into account several individuals influencing factors [80]. This approach is named personal trinity model (PTM) approach. It has three views:

- whole-human imitation point of view;
- individual needs point of view;
- PKMS development point of view.

Whole-human simulation point of view of PTM is described first. A personal knowledge is not a set of notifications, settings, expressions or actions that are stored for later use. “As organic beings we are embedded in situations and culturally formed, and we developmentally acquire and extend the learned activities that come to constitute our being in the world”. As follows individuals act on behalf of their experience according to their surrounding customs and habits. An individual is developing as an oak tree which grows out of acorn with its encoding (i.e. having roots, trunk, branches and leaves). While growing it is affected by surrounding environment – sun and amount of warmth, precipitation and seasons. Similarly it is with individuals with their own initial “encoding” and further development influenced by surrounding environment. Thus the PTM can be considered as a symbolic simulation of human entirety in direct and indirect meaning. There are three basic parts: head, hart and body. Head part relates to human cognitive and exploring aspect. Hart part relates to human social, emotional and cultural aspect, while body part relates to human physiologic aspect.

From whole-human simulation point of view author gears his attention more closely at the head part. Johnson talks about innovation and new ideas. He states that at the beginning there is a hunch [49] in the mind of an individual. There it incubates. A new idea has not born yet. After a while another hunch appears in the mind of this individual. In the process of exchanging thoughts two or more hunches create a base for creation of new idea or directly foster it [49]. A thoughts exchange can take place within individual herself / himself or among several individuals in the process of knowledge sharing. A hunch can be located in the mind of one individual or the same hunch can come up in the minds of several individuals [80]. This is depicted in figure 3.2.1. below.

In first chapter of thesis author has defined knowledge substance concept [80] related notion of knowledge element. Regarding this concept author has proposed five knowledge acquisition principles [80] to support PKM and knowledge elements acquisition.

1st principle: a KW has to posses an intuition to come to verity about those KE-s, which in a foreseeable time manner can not be find out or known, for example, NP complete problems [26], or which can not be known at all thus leaving them in semi-find-out state (i.e. even they are found out in a hunch level (see figure 3.2.1 below) though they stay as tacit knowledge, which further can not be explicated).

2nd principle: an individual does not need to strive to find out and to pierce each and every surrounding KE till the last detail. They are too many. Instead one has to strive to

common understanding about particular knowledge area to a certain level and to get additional knowledge how to acquire more detailed knowledge about this area in case it is needed later.

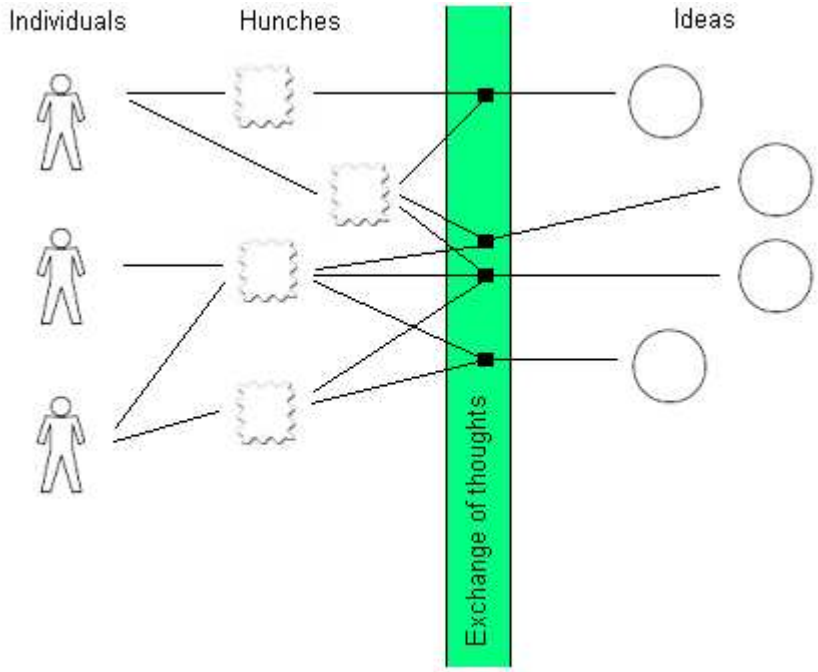

Fig. 3.2.1. Individuals – hunches – ideas

Nowadays regarding knowledge element acquisition a KW is facing an increasing intensity tempo of acquiring new knowledge in particular time frame. Earlier individual obtained knowledge and all the main skills for his / her life during childhood or young adulthood. Once becoming an adult individual usually also possessed a craftsmanship to be relied upon for entire life. However nowadays there are much more dynamics in economics. Similarly as before much of knowledge is acquired in childhood or young adulthood. However it may turn out to be not good enough in our current world. Thus individual might have to be forced or stimulated to change occupation or to retrain pressed by economics, society or by other means. That means to learn substantially new knowledge and skills (i.e. vertical growth) as depicted in figure 3.2.2. (see below) based on proposed personal knowledge cone-spiral (PKCS).

For nowadays individual such additional knowledge and skills acquisition stages or spiral twines are more than if to compare with people centuries before. In order to be competitive in job market KW has to acquire a qualitatively new knowledge even in shorter periods of time if to compare that with previous knowledge acquisition cycles or PKCS twines. That is similar to the coherence described by Moor's law regarding computer

development. This pattern of even shorter spiral twines bears a potential side effect. Such pattern can indicate the potential of KW burn-out. Thus PKCS not only describes nowadays the common pattern of even shorter periods of knowledge acquisition, but also may serve as warning signal built in PKMS for KW to adjust his / her learning intensity in order to avoid potential burn-out symptoms. Thus this serves as an example that by using PTM in development process and in execution of PKMS a KW has a support to voluntary leverage his / her life areas.

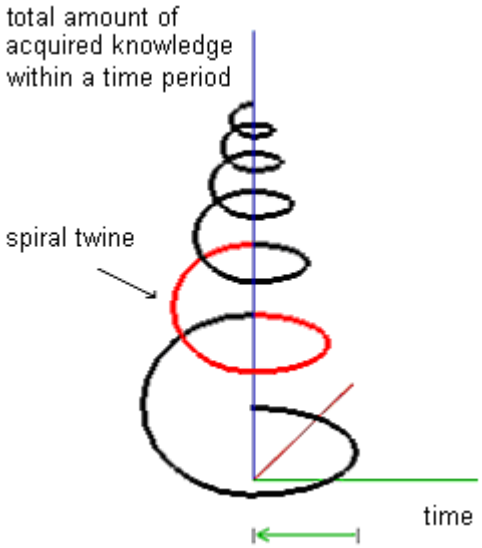

Fig. 3.2.2. Personal knowledge cone-spiral

Regarding PTM heads part there are proposed three more principles [80] related with knowledge sharing and acquisition.

3rd principle: in order to successfully acquire new knowledge elements an individual has to work out a desire to acquire them and to strive for this knowledge.

4th principle: there is a better chance to acquire new knowledge elements by collaborating (e.g. within communities of practice) rather than to try it alone. It is easier to maintain ones knowledge level by being within a group and by collaborating while by being alone knowledge gradually fades unless much more effort is applied to prevent that.

5th principle: sharing tacit knowledge is best accomplished by using analogies and similarities. Thus it is possible to transfer not only the direct meaning of knowledge but also the spirit of knowledge.

PTM - individual needs point of view. The PTM is projected on eight-level Maslow needs hierarchy described above. Accordingly individual needs are grouped into three parts, which correspond to the PTM three views (i.e. head – cognitive needs; heart – transcendence,

self-actualization, esteem needs, aesthetic needs, belongingness and love needs; body – safety needs, physiological needs).

Usually it is important for a KW to reach needs stated in self-actualization level within hierarchy of needs. In this regard Maslow states that it is important to strive for specific set of fifteen values in order to be happy and to reach self-actualization [65]. However Boeree does not agree with this proposition. Rather he argues that individual being in such critical situations as war or economic crisis his / her desire to strive for this set of primary values will not exist due to more primary needs as food, warmth and home [12]. By taking into account these arguments author proposes that a knowledge workers should strive for other super-set of individual improving values [17,80] encompassing love for others and for themselves (LFO-FT): meekness and not being hot-headed; politeness and not being rude; wishing well and not being envious; simplicity and not being flatulent; low-keyed and not being indecent; unselfish and not being selfish; not being angry; forgiveness and not to remember/remind mischief; joy about truth and not joy about falsehood.

By taking into account human weaknesses, lust, etc. it is clear that this super-set is a running target which will never be reached. However the important point for an individual is to start to strive for this super-set of values and constantly to try to achieve them. Then that will be the real gain for knowledge worker from the individual perspective and even more valuable from collaboration with others perspective. Especially that applies to the 5th principle stated above.

3.3. Robust framework for PKMS development and advancement

Within this chapter is described robust framework for PKMS development and advancement. In chapter 2 reviewed PKMS are based on ready-made architecture and all functionality. In contrary author of this thesis has developed PKMS modules approach general architecture based on modularization principle (see figure 3.3.1. left side – “technological PKMS aspect”) by adding necessary module on need basis from pre-created supplemental modules repository. There is compact fixed system basic module. To this basic module there are to be added pre-created other particular system supplementing modules depending on specifics of knowledge worker performed work and his / her actual needs [84]. Thus PKMS is scalable accordingly to its particular chosen hardware device, for example, tablet pc or smart phone.

There are available two levels of PKMS configuration. 1st level PKMS configuration is connected with architecture whole-point-of-view creation in PKMS level, which provides availability of particular modules (i.e. based on functionality). That can be done by PKMS developer or also by its user. 2nd level adjustment is done by PKMS user where configuration (i.e. adjusting several settings) takes place in particular module level. This robust framework and two level PKMS configuration option ensures that PKMS is adaptable to particular knowledge worker needs.

During development of PKMS modules identification takes place to pin point in which previously defined nine PKM process or processes this module might be involved / used [83] (see figure 3.3.1. left side and middle part). Thus it is known that, for example, module A is used to perform actions connected, for example, with PKM organizing and analyzing processes.

PTM - PKMS development point of view is described next. PKMS general development approaches based on robust framework and PTM are dividable into two directions. First one focuses development principles and PKMS aspects including following the PTM approach guidelines. This direction is dividable into two more parts – PKMS social aspect and psychological aspect, and technological aspect.

PKMS social aspect and psychological aspect based on PTM focuses directly on knowledge worker himself / herself. Partially they are connected with technological aspect (note: this partial connection is true in opposite direction as well) by using previously defined 9 PKMS process as a transition link. As a solution basis for these two aspects is previously described LFO-FT set of characteristics and 5 knowledge elements acquisition supporting principles. PKMS technological aspect has a modular approach. Agent and mobile technologies are a solution basis for technological aspect. In more details it is described in the 4th chapter this work. PKMS general development approaches are depicted in figure 3.3.1. [83].

Another development direction focuses on knowledge worker and his / her availability to further develop / customize PKMS by using 1st and 2nd level adjusting options. Thus knowledge worker can develop his / her individual PKMS and also trying to include PKM all three aspects – technical, social and psychological. These development approaches should be perceived as robust road maps for PKMS development.

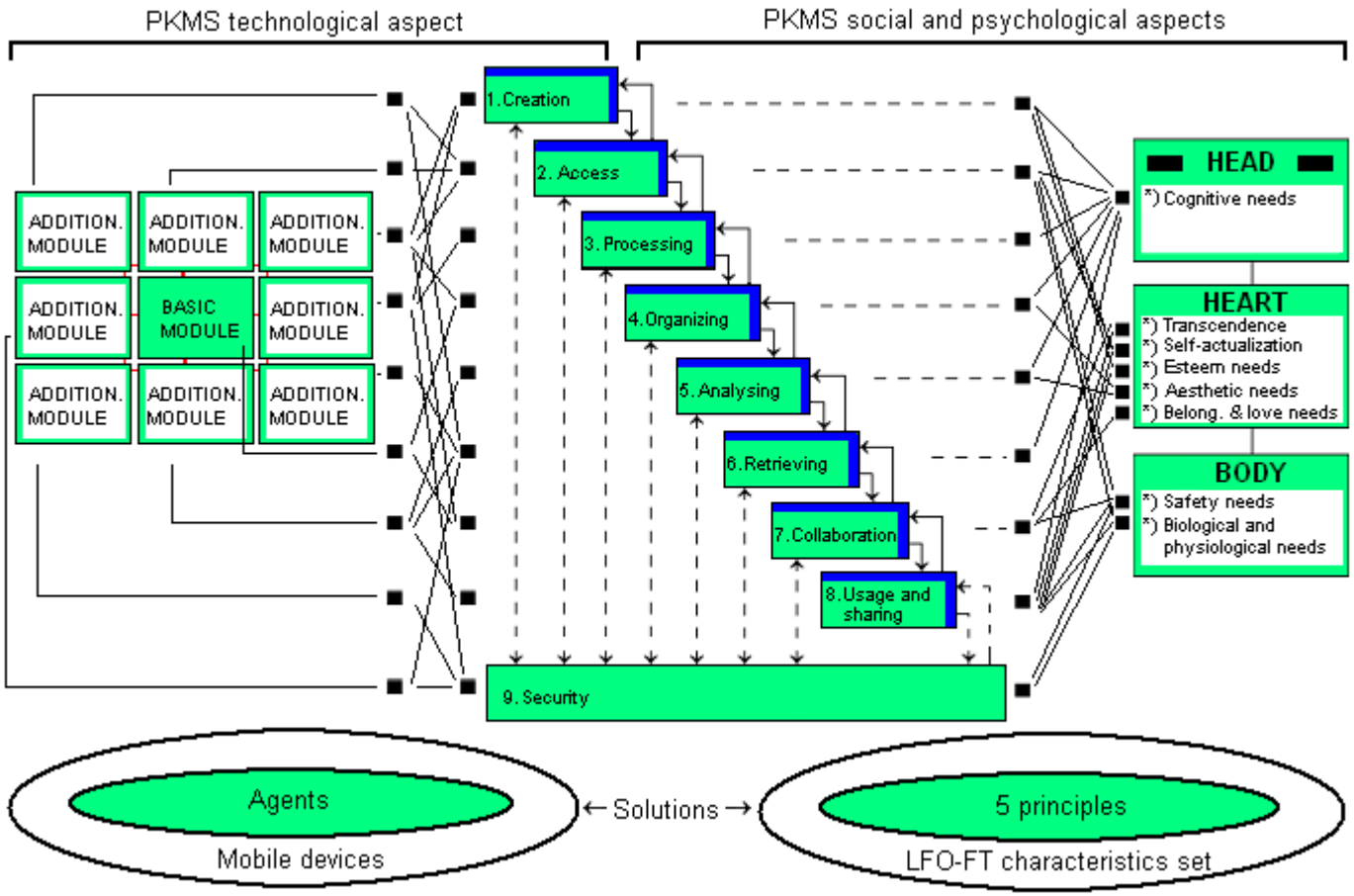

Fig. 3.3.1. PKMS aspects general development approaches

3.4. Modular PKMS

Modular PKMS architecture consists of basic module and several additional modules. Basic module consists of basic functionality, which supports PKMS basic processing. This module contains knowledge worker's, so called, *knowledge card* or *knowledge profile*, *user's card* or *user's profile*, *information and knowledge element searching*, *tacit knowledge elements externalization support tool*, *personal knowledge cone-spiral functionality*, as well as *time scheduling tool*.

Knowledge profile contains information about system's user: knowledge level, knowledge specifics, information about desirable knowledge and also knowledge sharing frequency. In addition it contains: knowledge development plan and knowledge element repository list. *User profile* contains particular knowledge worker: personal information, social aspect information, psychological aspect information. Both these cards are used by PKMS when there is collaboration with other knowledge workers and accordingly with their PKMS. PKMS basic module from architecture point of view is described in more details in 4th chapter.

PKMS additional modules are divided into two groups: frequently used modules and specific area modules. Frequently used modules contain modules suggested for minimal / small size PKMS while in the same time still maintaining scalability. Specific area modules contain such PKMS modules, which are considered for one or another group of knowledge workers with particular specifics of activities. For example, for ice cream development support (i.e. for example, for developing a new ice recipe, solving with quality connected tasks, external knowledge acquisition regarding competitors production development, and following development of European Union laws regarding diary area) in a milk processing company.

While keeping PKMS size as small as possible as frequently used modules are set the following ones: "goals and tasks management module" and "collaboration management module". Goals and tasks management module from goal perspective allows knowledge worker in a simplified way to set up personal goals, by using specific goals setting templates depending from chosen goal's type and specifics. From tasks perspective this additional module supports knowledge worker to set up to do tasks for himself / herself as well as for PKMS. Collaboration management module provides several communication type support (see

user card – social aspect part) for knowledge worker's collaboration with other individual or for PKMS collaboration agent with particular individual's PKMS representing agent. More detailed description about agent usage and frequently used modules from architecture and technical solution perspective is given in 4th sub-chapter of this chapter.

3.5. Mobile learning in context of PKM and specific area module „m-learning"

Each specific area module is intended for concrete group of knowledge workers with specific or partially specific tasks to do. As author's everyday work is connected with academic environment as a lecturer for professional bachelor study program in Vidzeme University of applied sciences, then as a specific area module is chosen m-learning module. As additional modules size should be kept as compact as possible, then this additional module is focused on providing learning environment support functionality by using mobile devices as the basis for PKMS. And thus it is not considered as a universal m-learning module. However if to particular company is necessary additional m-learning support then by supplementing modules repository with new modules it is possible to add other m-learning modules to PKMS. Thus previous m-learning PKMS functionality is supplemented by additional one. In more details particular specific area module is described also in 4th chapter. As part of a work on particular specific area module author has conducted research on mobile learning in PKM context.

Within this part of thesis is described performed researched regarding mobile learning in context of PKM. Based on Armstrong there are established effective learning pre-conditions [6]: *worker is motivated to study*; *learning worker receives some benefit*; *organization culture supports and fosters learning*; *learning value is higher if theory is applied in practice*; *learning ensures workers needs satisfaction*.

In addition it is determined that there are several psychological factors which partially are connected with latter mentioned effective learning pre-conditions, and which should be taken into account in order to foster workers training [6]: motivation and sense of a goal; possibility to make a mistake by not fearing to be punished; practical training; training should right on time; feedback; to ensure a possibility for worker to learn / study to him / her best suited time and place.

Armstrong stated effective learning pre-conditions and psychological factors in workers training are closely tied with within this par of thesis described individual's needs, motivation

and satisfaction aspects as well as with developed PTM PKM social and psychological aspect. Currently there are several types of learning and training used in organizations and in academic environments: *classical learning in classrooms, distance learning, e-learning, field trips*. M-learning can be seen as extension of e-learning with accent on usage of mobile devices (see figure 3.5.1.) [85].

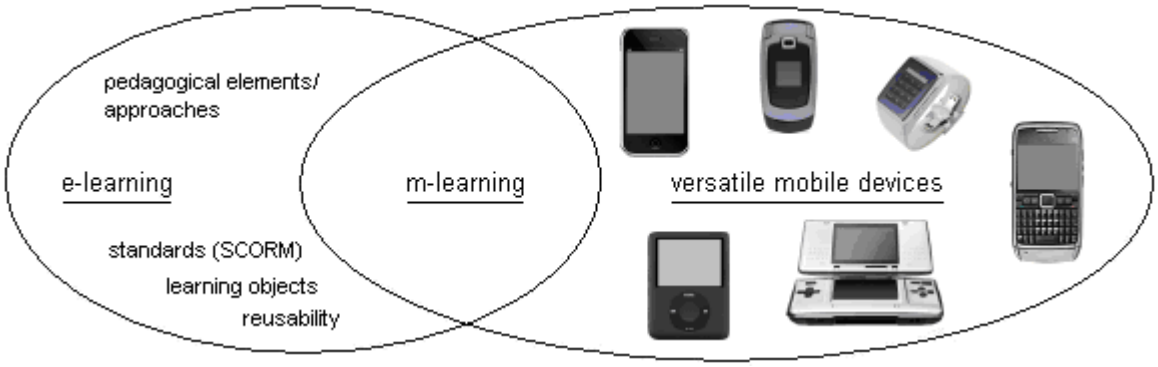

Fig. 3.5.1. Mobile learning in perspective of e-learning and mobile devices

Within this part of thesis there are researched m-learning definitions and determined that there are not one common broadly accepted definition of this notion. It is found that connection with e-learning is pointed out. However there also is pointed out that m-learning is much more than just e-learning with mobile devices. M-learning strives towards specific knowledge depending on geographical location, situation, device and on learner himself / herself [69]. It is determined that m-learning has further development options in regards with in thesis introduction mentioned lifelong learning strategy especially if it is based on powerful mobile devices. Modern mobile devices offer wider spectrum of different content and communication types. More in details about mobile devices characteristics, types of communication, strength and weaknesses in context of PKM is described 4th chapter of this work. . Ntloedibe-Kuswani suggests that there is a high possibility that if the potential benefits of using mobile devices in learning are realized then especially adult learners could invest in more sophisticated mobile devices that would provide them more functions rather than just use of SMS [77].

There are determined several PKM and m-learning contact points. For example, in context of PKM knowledge elements acquisition, classification and storing are important skills for every knowledge worker especially pointing out the skill to integrate found knowledge elements in a combined view and to use them for reaching the set goal. It is established that similarly to m-learners those are important skills to have as well. For

example, skill to find by himself / herself new knowledge elements or skill to retrieve or to understand the basic meaning of already available knowledge elements [79]. In addition there are pointed out Sharples approaches to effective learning in this context [95]: *learner centered approach*, *knowledge centered approach*, *assessment centered approach*, and *community centered approach*. Latter mentioned approaches coincide with PKM skills and processes. These are very helpful skills for a student participating in m-learning class. But he or she is not the only one benefiting from such skills – they are also highly beneficial for an m-learning instructor who develops learning content, gathers sources of information, and suggests the methods that could best suite particular m-learning environment [79].

Of course, it is very advisable and beneficial for an m-learner to have all the above mentioned PKM skills. Unfortunately it is quite difficult for an individual to posses or to develop all these skills. Many times just a subset of these skills is present when an individual decides to acquire new knowledge using m-learning approach. In this case PKM as such and author proposed three PKM aspects combining PKMS (which from technological aspect is based on agent and mobile technologies) provides knowledge worker with the necessary m-learning support. From technological aspect on agent environment based PKMS helps to eliminate learners and instructors knowledge gaps, supports creation of learning communities and serves as a bridge for legacy systems involved in m-learning environment. Thus gathering, storing and retrieving of knowledge elements located in different systems and repositories could be done possible. More in details about PKMS technological aspect are located in 4.3. and 4.4. sub-chapters of this work.

3.6. Conclusions

This chapter of thesis contains PKMS conception from social and psychological aspects (i.e. individuals' needs, motivation and satisfaction, PTM, five principles for knowledge element acquisition support, LFO-FT super-set of individual values) as well as from technological aspect.

Main conclusions are:

- there is defined personal trinity model (PTM) which contains PKMS development approaches three point of views: whole-human imitation point of view, individual needs point of view and PKMS development point of view. Thus there is described a new PKMS development approach by combining all three PKM aspects – social, psychological and technological;

- within PTM - whole-human imitation point of view:

  (*) there is developed personal knowledge cone-spiral (PKCS) which depicts individual's vertical knowledge growth. This PKCS is a new view on individual's knowledge and skill acquisition process. It provides a possibility to warn individual to lower knowledge learning speed in order to avoid so called "burn-out" if PKMS recognizes that particular individual's PKCS approaches in figure 3.2.3. depicted PKCS form. The "approaching level" in PKMS can be set by systems user himself / herself;

  (*) there are defined five principles for knowledge worker for knowledge element acquisition support in context of PKMS social and psychological aspect;
- within PTM - individual needs point of view;

  (*) there is defined LFO-FT super-set of values for knowledge worker to be strived for in order to have successful collaboration with other individuals in context of PKMS social and psychological aspect;
- within PTM - PKMS development point of view;

  (*) there is developed robust framework for creation of adaptable PKMS which provides availability for knowledge worker to configure PKMS in two levels;

  (*) there is developed PKMS modules approach general architecture;

  (*) there is defined PKMS basic module and supplemental modules;

  (*) there is defined PKMS supplemental modules division in frequently used modules and in specific area modules;

  (*) there is given a set of frequently used modules with their basic functionality description;
- frequently used modules and specific area modules individual composition creates basis for development of better adjusted PKMS for particular knowledge worker specific needs;
- there is given brief description of specific area module m-learning and perspective of mobile learning in context of PKM.

4. DEVELOPMENT OF PERSONAL KNOWLEDGE MANAGEMENT SYSTEM

This chapter contains PKMS technological aspects more detailed description in context of PKMS development. Within this chapter are stated mobile device characteristics, strengths and weaknesses, as well as smart phone and agent integration in context of PKM. Also is provided description of PKMS basic module, frequently used modules and specific area module “m-learning” architecture.

4.1. Mobile devices and personal knowledge management

By researching available information sources online and available literature it is determined that so far there have not done research exactly about PKMS development approaches based on mobile devices platform. Agnihotri and Troutt are even more categorical. They point out, that research about role of technologies in PKM is only at its beginnings [1]. Thus within this work is conducted mobile device overview and evaluation in context of PKM.

One of the most important knowledge worker tasks is developing collaboration with other individuals, for example, as it is in case of Wright conceptual PKMS [113]. Developing collaboration contains: *ability to communicate*, *to do* explicit and tacit *knowledge element sharing*, to do *collaboration in any time and in any place*.

It is important for knowledge worker to adjust mobile device from all PKMS aspects to his / her needs and requirements in order to conveniently and handy carried out everyday functions. It is also important so that this device (i.e. device physical shape) and within it available work environment is acceptable aesthetically (see PTM and individual needs). Device’s shape based on it usage convenience (i.e. does it comfortably fit in palm, is there available convenient information input functionality) is one more mobile device characteristic. Based on PKM security process and on safety needs level (see PTM whole-human imitation point of view – body part) as one more important characteristic can be named mobile device security functionality from not authorized access to device itself point of view. It is also important one from PKMS ability to function on different mobile devices point of view, i.e. reducing PKMS dependence from one particular mobile device model or even platform.

Author has conducted mobile device summary and analysis, and have determined that currently there are available many different mobile devices. That included many different mobile device platforms. Each of them represents one mobile device operating system. As most used operating systems can be named Android, Symbian, iPhone OS, RIM and Microsoft developed mobile device operating systems [31]. Mobile device platforms and application development environments are also researched. Also within this aspect there is large diversity. Often development environments are specifically suited for particular platform. However in addition to mobile device basic platform no matter what operating system it runs on frequently there is provided support for Java environment. This is one of the reasons, which fosters to choose Java application developing environment for PKMS development based on mobile devices. Thus in thesis appendix are also described main Java mobile environment elements.

One of actual mobile devices features is their ability to provide wireless communication and data transfer. Nowadays mobile devices usually are used for communication and data transfer with other mobile devices, for web access or data synchronization with personal computer or notebook computer. Within our work we have determined and systematized mobile device communication and data transfer types in different parts of the World. In table 4.1.1. author depicts these communication and data transfer types by focusing on European region.

Table 4.1.1. Wireless communication and data transfer types in European region context

Type, generation	**Communication and data transfer types**	**Data transfer speed - download**	**Specifics and constraints**
Basic-types	Wi-Fi (802.11n)	600 Mb/s	Operation range in indoors is till 46m, outdoors till 92m. Mobile device requires wireless network adapter.
	Bluetooth 2.0	2.1 Mb/s	Operation range till 10m.
	IrDA	115.2 Kb/s	Short range operation; required direct visibility.
2G	GSM	9.5 Kb/s	Operation range till 35km. Limited data transfer options.
	GPRS	53.6 Kb/s	GPRS is GSM extension (not available without GSM).
	EDGE/EGPRS	384 Kb/s	Mainly is used as transition standard from GSM to UMTS.
3G	UMTS	1920 Kb/s	Data transfer rate 384 Kb/s for mobile phones.
	HSDPA	8-10 Mb/s	Only for download; upload not supported.
	CDMA2000	3.1 Mb/s	Limited amount of parallel connections – i.e., if a tight number of clients, then someone will be left without a service.
	WiMAX	75 mb/s	Currently a comparably expensive service.
4G	3GPP LTE	100 Mb/s	Not widely available yet.
	UMB	275 Mb/s	Unclear future perspective can be discarded.

Usually knowledge worker conducts its work in company premises or in open air company territory. Assuming company is located in populated area or within its vicinity and evaluating communication and data transfer ranges, then majority of 2G and 3G connections provide communication to mobile devices for conducting knowledge work. Data transfer basic types such as Bluetooth and IrDA operate in very limited range (till 10 meters). In addition IrDA requires direct visibility connection. There is also service coverage that can considerably differ from country to country. It is determined that Wi-Fi operation range allows its usage both in company premises and in open air company territory.

An important aspect in knowledge worker's work is data transfer rate. From this point of view currently available best download rate is on 802.11n standard based Wi-Fi, which is 600 Mb/s. Though latter mentioned data transfer rate is dependent on company used 802.11 standard versions. In many places there still is used one based on 802.11g which supports data transfer rate till 54 Mb/s. Also 3G technologies support a good data transfer rate, for example, WiMAX standard supports data transfer up to 75 Mb/s.

Additional aspect is based on costs of particular communication and data transfer rate. Bluetooth and IrDA are free of charge types of data transfer. However due to their limited operation range their usage to support PKMS is not suitable. WiMAX data transfer type is suitable based on its operation range (till 50 km) and data transfer rate (up to 75 Mb/s). It is determined that it is rather expensive service and, for example, in Latvia it is not available yet even though for a testing time it was available in Lattelecom network. Also it is determined that there neither is a wide range of mobile devices supporting WiMAX. Even there are a number of commercial Wi-Fi hot spots though there are also available quite a few places (including company indoor and outdoor territories) with free of charge Wi-Fi hot spots as well. By evaluating latter mentioned aspects it is concluded that for knowledge worker and PKMS support the most appropriate one is Wi-Fi communication and data transfer type.

Strength and weaknesses of mobile devices in perspective of PKMS. By conducting mobile device strength and weaknesses analysis within this work it is determined that there are number of strength and weaknesses, which are related with mobile devices and which should be considered when involved in knowledge work. As weaknesses can be mentioned [85]: small and different size screens, small keyboards, small icons on touch screen displays, difficulties to access information and explicit knowledge elements (where add-ons are required), general navigation difficulties, diversity of mobile devices brands and each brand products diversity, mobile devices operating systems diversity (which creates difficulties for

development of multi-platform PKMS applications), limited memory and processing power, limited buttery processing time, text messages and e-mail size limitations, difficulties to access web content (originally designed for desktop computers screens sizes). Also several mobile devices strengths have been determined in the context of knowledge worker and PKM which are actual both for m-learning and for mobile device based PKMS. They are [67,97]: *portability*, *individuality*, *linking*, *context sensitivity*; *flexibility in a sense of time, place and new knowledge acquisition speed control*; *usage of technology, which is attractive to knowledge worker* (i.e. from PKMS social and psychological aspects) and *convenient*.

By evaluating mobile devices strengths and weaknesses it is concluded that modern mobile devices have several considerable strengths, which makes them especially attractive for use as a development basis for PKMS. They are ubiquity, personalization, and localization functionality interaction characteristic. In addition it is determined that mobile devices supplemented with specific hardware obtain universal technical applicability characteristic. For example, accordingly supplemented mobile devices serves as a camera, pocket torch light, bicycle speedometer or mini-projector for providing slide shows [7] to support such PKMS process as usage and sharing, and to satisfy individual's safety needs (see PTM individual needs point of view - body part).

Smart phone characteristics. By evaluating mobile devices strengths and weaknesses in context of PKM in addition there are also established mobile devices characteristics. Smart phone has been chosen as a representative of different mobile devices as it contains broad functionality, its characteristics overpass regular mobile devices characteristics and smart phones are sold with increasing intensity [31]. For research purposes are chosen 5 smart phones based on statistics companies Gartner [32] and Canalys [14] market reviews as well as based on GSM Arena [37] available statistics.

In boundaries of performed research smart phone characteristics are divided in three groups or views – *technological* view, *functionality* view, and *human-smartphone interaction* (HSI) view [81]. This division in three groups is adapted from Economides [24] offered mobile device evaluation framework. First group – technological view contains smart phone technical characteristics such as internal memory size, type of processor and supported types of network (26 characteristics all together). Functionality view contains smart phone functionality characteristics such as additional software types (26 characteristics all together). HIS view is the highest level view in such sense that it contains end user experience when mobile device is being used. This view contains such characteristics as graphical user

interface (GUI) ease of use, readability in direct sunlight and audio quality (12 characteristics all together). As characteristics information resources are used GSM Arena [36], Lets Go Mobile [59] and accordant mobile device brand names [74,11,42,41,93] home pages detailed information about particular mobile devices.

PKM means to know what knowledge do we posses, how can we organize it, mobilize, continue to create new knowledge and to apply it for reaching own goals [64]. By reviewing latter mentioned mobile devices platforms, wireless communication and data transfer types, mobile devices weaknesses and strength, mobile devices characteristics, their ever increasing processing power and number of users [40] is acquired a base for confidence about mobile platform validity and conformity for PKMS development.

4.2. Mobile devices and agent technology in perspective of PKMS

Research was conducted regarding software agent application areas in context of PKMS. It was determined that software agent can be used in a rather wide range of different areas such as explicit knowledge materials local searching within PKMS, fostering collaboration among knowledge workers and their representing PKMS, information searching in web resources, supporting actions of knowledge worker in communities of practice and PKMS hardware operation monitoring and supporting.

Regarding software agents, their characteristics and communication it is determined that first of all agent is an environment existing computer system, which can carry out autonomous operations within this environment in order to reach set goals [48]. Agents ability to perform autonomous actions is one of the most important ones also due to that majority of researchers agree that agents should possess it [107]. Agents' autonomy is compared as equivalent characteristic to humans' free will [104].

Agents possess abilities or characteristics [48]. They are [112,103,87]: autonomy, social abilities, ability to react, pro-activity, mobility, truth, benevolence, rationality. Based on Bradshaw [3] some other agent characteristics include: temporal continuity, personality and adjustment.

An important area in agents' collaboration context is their ability to communicate. In case of humans in order to communicate they choose communication language which is understood by all involved parties. Similarly is used Agent Communication Language (ACL), which is based on [3]: vocabularies, Knowledge Interchange Format (KIF), and on Knowledge Query Manipulation Language (KQML). It is determined that a common

vocabulary should be defined so that agents could mutually communicate. In addition communication is supported by using common ontology, which defines particular domain concepts and relations among them. Common ontology is used to design communication protocols. Also a common ontology is a support for vocabulary usage in agent communication. Agents should not be forced to use only one communication protocol in such a wide many sided environment as the Internet. Instead their collaboration must be regulated by using number of ontology protocols [115].

There are distinguished several types of agents. For example, there are collaboration agents, interface agents, information agents, reactive agents, hybrid agents, mobile agents and intelligent agents [78]. Within context of this work more attention is geared towards mobile and intelligent agents as the set of their characteristics is suitable for development of mobile device based PKMS.

Mobile agent is an execution unit which can autonomously migrate to another execution place by transporting along with it its code and execution status. Then it dynamically installs it code and seamlessly continue its execution in the new environment [78,57,58,50,56]. Mobile agents use three types of messages [50]: proposal, knowledge based, and mobility message. There are several reasons to use mobile agents [58]: they decrease network load (by traveling themselves to data), they over come network latency, they encapsulate protocols, they execute asynchronously and autonomously, they dynamically adjust, they are naturally heterogeneous (by naturally adapting legacy system), they are robust and fault tolerant.

Intelligent agents perceive their environment, make deliberate decisions based on their perception and react accordingly. Intelligent agents perceive their environment in different ways depending on environment characteristics. Agents obtain information about their environment by using sensors. Intelligent agent is a software component, which can operate autonomously by perceiving/understanding environment, by evaluating options, and making action decisions by not having communication with user (i.e. agent owner) [21].

Within this work also is determined notion of multi agent systems (MAS). They are distributed and based on definition their operations are disseminated over many agents. Each agent usually operates within its own thread thus operation is undoubtedly simultaneous. Many systems allow agents to join and leave them in their run-time [61].

Lightweight agent platform for mobile device based PKMS. Mobile devices get more popular and individuals become more demanding regarding available mobile device based services. For knowledge workers even more important becomes to find the right

information in the right time. More, in some cases it is desirable that software in mobile devices can act on behalf of their users. It is especially important in frequently changing and unpredictable environments. Koch and Rahwan [54] point out that this is the area where usage of agent technology is a promising solution to develop modern mobile devices based software.

As a basis for agent and mobile technology integration serves created standards in this area. Such are Foundation for Intelligent Physical Agents (FIPA) developed agent based systems standards. FIPA specifications comprise a set of standards to facilitate collaboration of heterogeneous agents and their services [27]. Thus FIPA focuses not only on communication, but also on general meaning services such as standard approach to agent life cycle management [10].

Several world level companies such as Motorola, Siemens, British Telecom, Telecom Italia, etc. have realized the importance of this area and by joining effort they have started Lightweight Extensive Agent Platform (LEAP) project. That is the first attempt of a kind to develop a FIPA agent platform that can run both on mobiles and on regular devices such as personal computers and using wireless and land line networks. Main goal of the LEAP project is to develop FIPA compliant agent platform, which is enough lightweight to run on mobile devices with limited resources, and is enough open and scalable to become a solution for devices with no particular resource limitations such as corporate servers [10].

There are several development platforms for software agent development on mobile devices. One such platform is MicroFIPA-OS [98]. One of the most popular one is Java Agent DEvelopment Framework (JADE) [46,106,109]. It is a software platform fully realized in Java. It facilitates multi-agent systems development by using middle-ware, which is compliant with FIPA and combines several graphical tools for debugging and implementation phases. Agent platform can be distributed over several computers which not necessarily need to have the same operating system; configuration can be controlled using remote GUI. Configuration can be changed during run-time by moving agents from one computer to another whenever it is necessary. Agent communication is based on passing messages by using FIPA ACL as a communication language [46]. There is developed platform based on JADE agents for mobile devices called JADE-LEAP. It is based on FIPA standards and on latter mentioned LEAP project. This is also frequently used agent platform, which is well documented and has active developers' community. By considering latter mentioned it is

determined that JADE-LEAP is suitable as a development platform for mobile device based PKMS with built-in software agent support.

4.3. Architecture of personal knowledge management system

Based on latter mentioned PKMS general architecture, it is scalable and consists from modules combining basic module and several supplemental modules. Basic module contains knowledge worker's knowledge profile and user profile. Knowledge profile contains information about system's user: knowledge level, knowledge specifics, information about desirable knowledge and also knowledge sharing frequency. In addition it contains: knowledge development plan and knowledge element repository list. Within this work as a specific area module is chosen m-learning module, which provides learning environment support functionality.

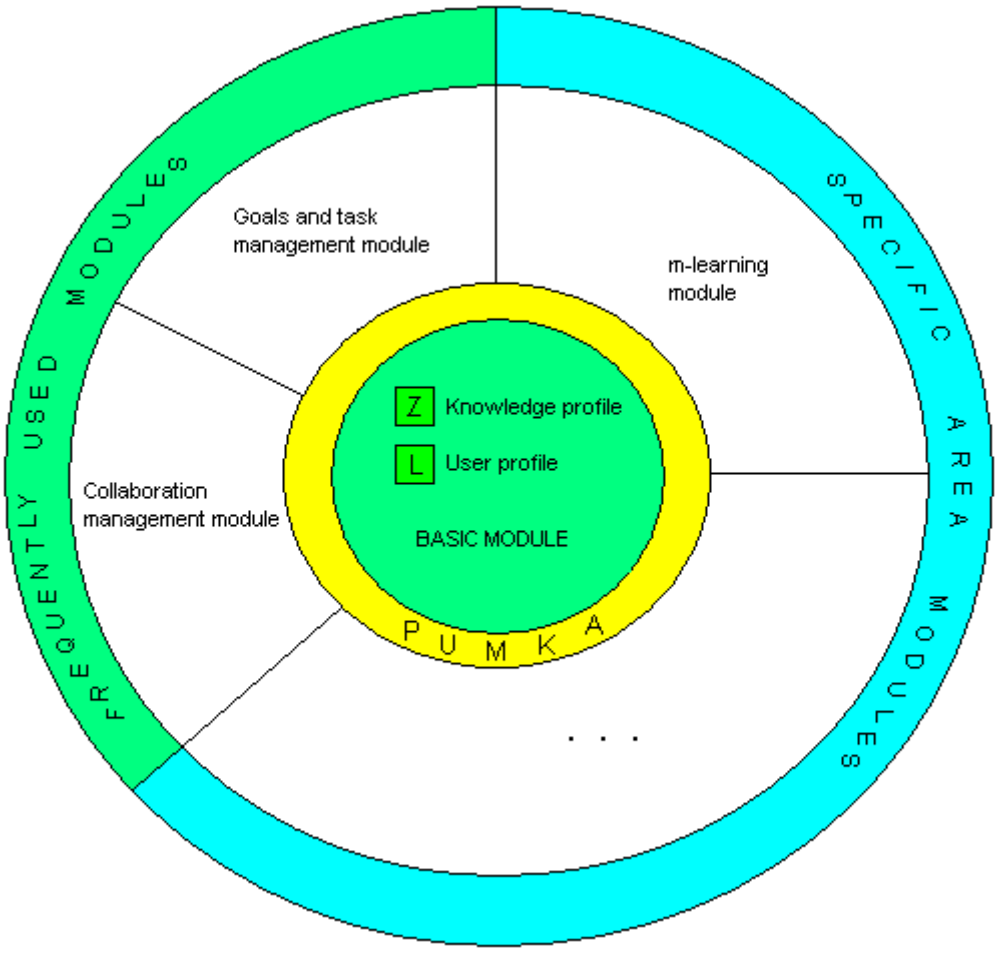

Fig. 4.3.1. PKMS basic module, frequently used modules and specific area modules

When there are developed new PKMS supplemental modules for inclusion in repository of supplemental modules, then there is updated also special supplemental module list. This list is transferred to PKMS basic module along with installation of a new upgrade package. Based on this list PKMS recognizes additional supplemental modules. In order to add frequently used module or specific area module to PKMS there has to be used special PKMS settings and module configuration area called PUMKA (see figure 3.4.1). Knowledge worker uses PUMKA area only for PKMS configuration purposes and this area is not used during his / her everyday task processing. PUMKA combines following functionality [83]: adding frequently used modules or specific area modules to PKMS, and PKMS (i.e. basic module) default settings configuration.

There is needed an intellectual support for knowledge worker everyday to-do tasks in context of PKMS. Solution for this is an intelligent agents' community (see middle part of figure 4.3.2.) which creates a base for knowledge worker environment. First of all agents can serve as hard work performers – as a driving force in so called "engine room". In basics it is hardware, software and technology integrated area to support knowledge acquisition, processing, storing and representation as it is mentioned in Grundspenkis approach [33] in companies' context. In this work it is used in context of PKMS [86]. Secondly, they are agents supporting communication. And finally they are personal agents, which are tightly connected with knowledge worker.

"*Engine room*" agents idea is that nowadays a number of to-do tasks are connected with technical solutions, which should done by knowledge worker in order to streamline his / her everyday actions. These agents can appropriately react on changes in "engine room" environment. Such "engine room" environment consists, for example, from local network, wireless network, Internet and from knowledge worker used hardware. It is especially difficult and time consuming for majority of individuals to work with such environment. Other intelligent agents group is *communication agents*. They are responsible for communication support. Communication is an important aspect for an individual in multi-agent environment in order to perform knowledge creation, acquisition, sharing and distribution. *Personal agents*, which are directly influenced by knowledge worker, support interaction with particular hardware device as well as provide support in knowledge work.

Knowledge worker and PKMS three group of agents environment in context of PKMS modules is depicted in figure 4.3.2. middle part. In green are agents connected with PKMS basic module. In grey agents connected with PKMS frequently used modules.

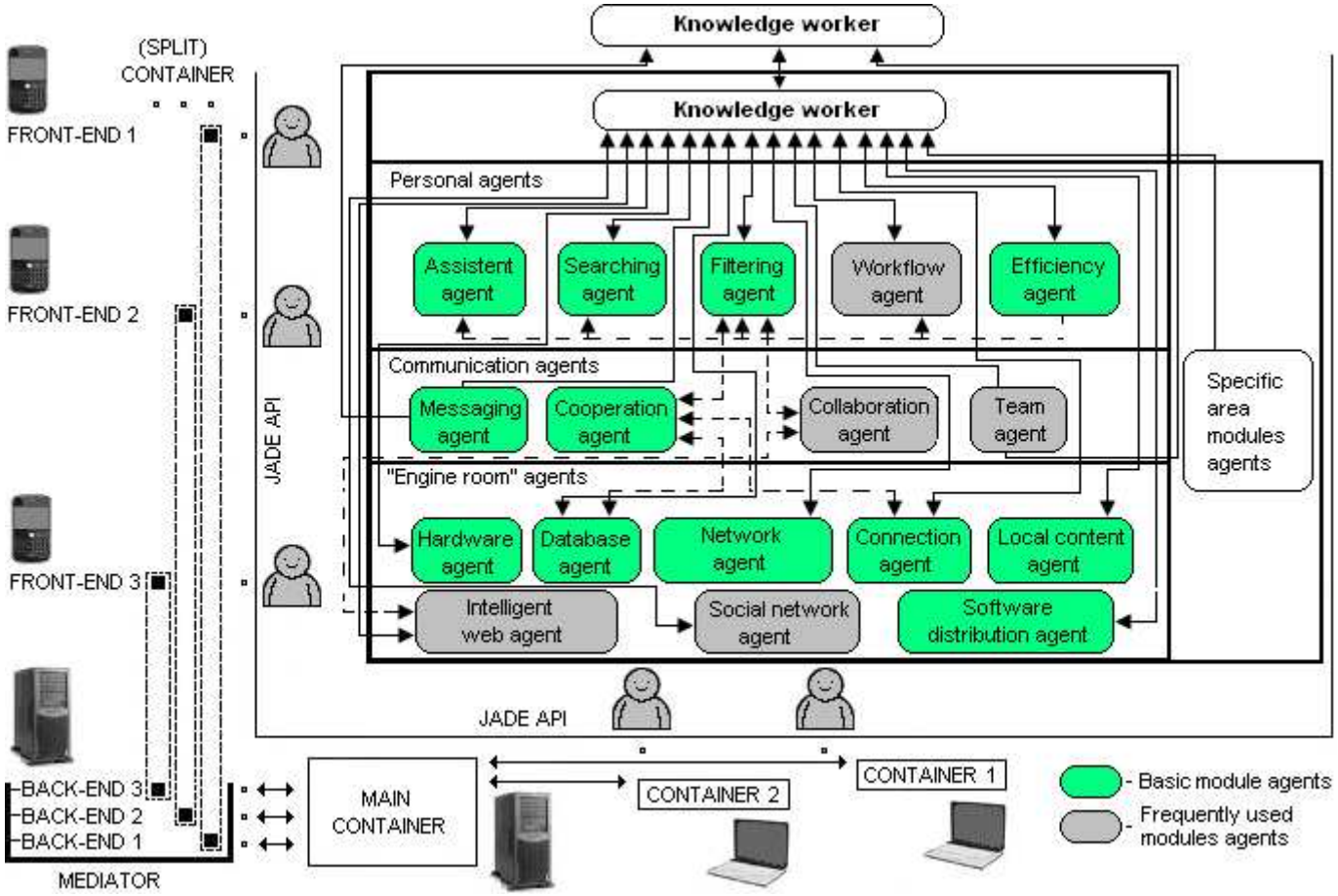

Fig. 4.3.2. PKMS three group agent environment in context of mobile devices and agent development environment JADE-LEAP

Meaning that workflow agent intelligent web agent is connected with PKMS goal and task management module, but remaining grey-colored agents are connected with collaboration module. In addition should be mentioned specific area modules agents. However they are should not be showed in details before accordant specific area module is not created and added to modules repository.

Solid lines in middle part of figure 4.3.2. (i.e. three group agents environment in context of PKMS modules) denote data, information and knowledge flow, but interrupted lines denote possible collaboration between accordant agents. PKMS three group agents' environment in context of mobile devices is depicted in figure 4 entirety. It depicts PKMS architecture by combining agent technology view, mobile device technology view, agent development environment JADE-LEAP view and five knowledge workers using notebook computers and smart phones accordingly as a basis for PKMS.

4.4. Specific area module "m-learning" architecture

PKMS specific area module "m-learning" is focused on learning environment support. As basis for this module architecture development is chosen a learning environment support functionality provision at Vidzeme University of Applied Sciences. There were evaluated a number of undergraduate level courses within Faculty of Engineering. Undergraduate level course "Accounting / resource-planning systems" was chosen. It has the following items: home works (250 points), short quizzes (40 points), research paper (110 points), research paper presentation (25 points), active participation in class (75 points), final exam (250 points). In total a student can receive 750 points. The further grading is done based on accumulated points. Next these points are turned into percentages and then accordant percentage intervals are assigned to a final mark (see table 4.4.1).

Table 4.4.1. Point percentage alignment with final mark

Percentage	**Mark**	**Percentage**	**Mark**
>= 93% (697 p.)	= 10	>= 78% (585 p.)	= 6
>= 90% (675 p.)	= 9	>= 74% (555 p.)	= 5
>= 87% (652 p.)	= 8	>= 70% (525 p.)	= 4
>= 82% (615 p.)	= 7	< 70% (525 p.)	= 3

Evaluation item called "active participation in class" means collecting "pluses" for each constructive activity such as asking questions, solving exercises on the blackboard, and so on

during a time frame of whole semester. Then these “pluses” are summarized and a curving is performed – meaning that the student who has received most of all “pluses” receives 75 points, the next highest amount receives accordingly less points based on percentage difference, and so on. So far during the course all records are kept in an Excel file by an instructor. Thus student on his own even can not know his or her current standing. Instead instructor has to be approached in person to this find out. It is especially so because item “Active participation in class” can be calculated just by knowing the “pluses” of all students and thus it can not be calculated by a student himself or herself. Another feature of course grading system for all courses is that students can appeal the received marks. Especially it is so for the final mark. An appeal can be done only within certain amount of days after the mark has been set. After the time has passed and a student wishes to appeal or to enhance a mark, then he or she first has such option. But before that a processing fee to university has to be paid in order, for example, to re-take a final exam. This turned out to be a problem. Some students missed these deadlines and they had to pay a processing fee. Also it seemed to be rather difficult for some students to follow their own status during a course at a given time. Thus this module was designed to provide a support for these activities.

PKMS specific area module m-learning architecture from agent technology perspective is depicted in middle part of figure 4.3.3. Solid lines denote communication within specific area module m-learning, but interrupted lines denote communication with PKMS. This module has four main agents types: instructor agent, operator agent, student agent and audit agent. JADE-LEAP agent environment is used. There are included some more FIPA standard management agents. PKMS specific area module m-learning architecture in context of mobile devices and agent development environment JADE-LEAP is depicted in figure 4.3.3. entirety. In particular solution m-learning module has the Main-Container (located on a server or can be located on a notebook computer) and five other containers: Container 1, Container 2 and three split Containers. The Main-Container contains audit agent and operator agent. It also has FIPA standard management agent Directory Facilitator (DF) and FIPA agent platform’s mandatory component called Agent Management System (AMS). Containers 1 and 2 are located on notebook computers having regular Java environment. Other three split containers are located on smart phones (i.e. their front-ends). All back-ends of these split containers are located on a server (or can be located on a notebook computer). Automatic management of back-ends of all three front-ends is performed by the JADE-LEAP architectural unit called a mediator as depicted in figure 4.3.3.

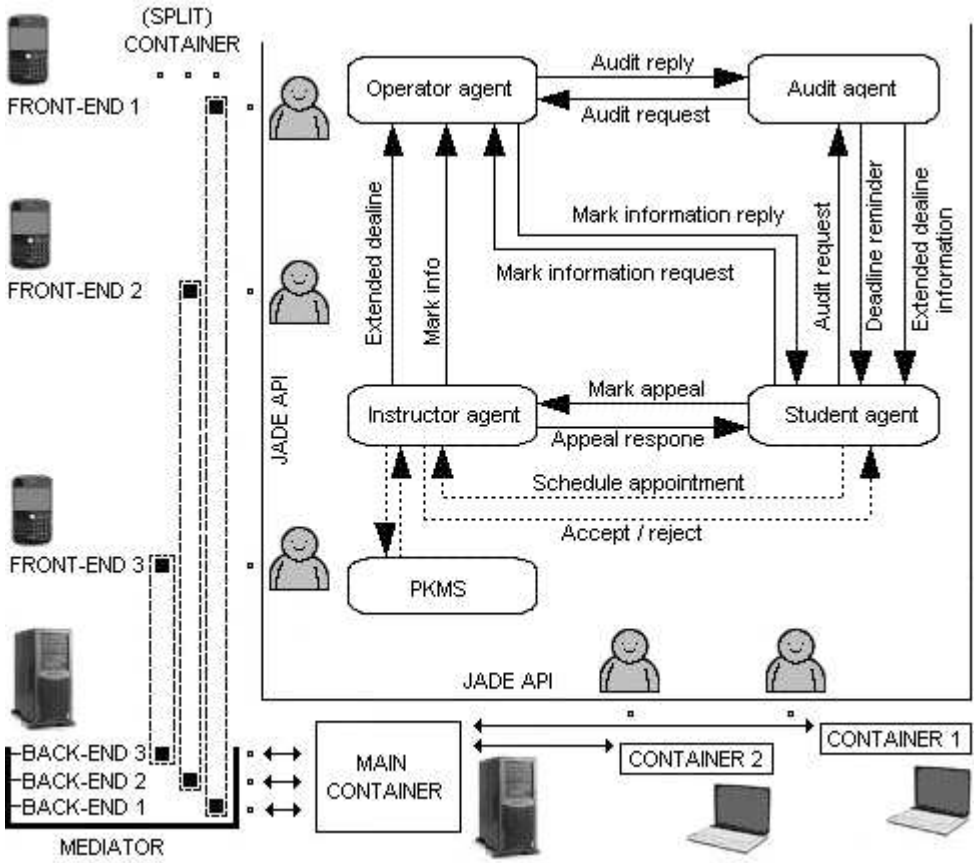

Fig. 4.3.3. PKMS specific area module m-learning architecture in context of mobile devices and agent development environment JADE-LEAP

Specific area module m-learning has several scenarios. They are as follows: setting a mark, appealing, extending a deadline and scheduling an appointment. (1) *Setting a mark scenario* begins when instructor has corrected, for example, a home work and assigns points. Instructor agent provides option to create a batch collection of the student ID, a single item of points, and the exercise ID. Next it sends this batch collection to operator agent. Then operator agent saves that information. It uses help of DF agent (i.e. it is a JADE framework internal agent) and broadcasts this information accordingly to each student agent. In addition if student agents specifically request then they can receive a total summary status of assigned points at a given time. Meanwhile audit agent keeps track of done and not-yet-done exercises. It informs student agent accordingly based on deadline proximity property value. This value can be set by student agent. (2) *Appealing scenario* is started by a student. Then it is taken over by student agent. It sends an appeal directly to instructor agent. If it is too late and the appeal deadline is passed then instructor agent on its own rejects this appeal. If that is not the case, then instructor is informed. (3) *Extending deadline scenario* begins when instructor

decides to extend a deadline for a given exercise. Then that information is transferred to operator agent. There it is saved and communicated further with audit agent and then student agents are informed. (4) *Scheduling an appointment scenario* provides possibility for a student agent to send a request directly to an instructor agent to schedule an appointment. If such request is received by instructor agent then it consults with its PKMS time management module agent (i.e. if it is available). The latter one on its own decides if to accept or reject particular appointment request.

4.5. Conclusions

Main conclusions are:

- already now are available mobile devices that can serve as a part of PKM tools or PKMS;
- smart phones are most suited mobile devices as a platform for PKMS support;
- there are available a number of different wireless communication and data transfer types;
- at the current moment Wi-Fi wireless connection offers free of charge usage in many places and in the same time also a high data transfer rate;
- mobile devices have number of weaknesses in context of PKMS, for example, small and different screen sizes, and small keyboard keys which does not provide an easy data input;
- mobile devices have a number of strengths, besides mobile devices strengths are additional factor which makes these devices suitable for PKMS support;
- smart phones are suitable mobile devices as a platform for PKMS;
- smart phone characteristics are suitable for PKMS development based on these mobile devices, besides these characteristics tend to improve and it is not foreseeable that this tendency may change;
- software agents are important PKMS functionality support element which performs knowledge worker supportive actions within PKMS. It is important especially because knowledge worker work intensity is increasing;
- as smart phones have limited characteristics in comparison with personal computer then there is needed a light weight agent development platform in order to use them in development of smart phone based PKMS;

- JADE-LEAP Lightweight Extensive Agent Platform is developed based on FIPA standards, it is frequently used for mobile device software development, it has communities of practice, also it has a well done documentation; JADE-LEAP is suited light weight agent platform for development of agent and mobile device based PKMS.

Main results are:

- there is developed PKMS basic module un frequently used modules architecture in context of agent and mobile technology;
- there is developed PKMS specific area module architecture in context of agent and mobile technology.

Mobile devices and particular smart phones provide suitable accordant platform for PKMS development and further usage. In this context especially significant are mobile devices characteristics such as ubiquity, personalization, localization, interaction and potential of universal technical applicability. Besides it is also notable that smart phone platform provides support for agent based PKMS development.

MAIN RESULTS AND CONCLUSIONS

The goal of the thesis was set to develop a PKMS conceptual development approach, which would combine technological, social, psychological aspects, and such system's an architecture solution, which uses mobile and agent technologies for support of learning environment. The set goal is achieved and set tasks are completed.

There is acquired following scientific new gain:

- based on determined six types of PKM processes there are defined nine PKM processes which combine a broad set of doable actions and functions in context of PKM, and there is developed PKM process model;
- based on defined nine PKM processes there is developed PKM skills, types of tools, and tools real representatives summary and overview;
- by taking into account such individual influencing factors as everyday life related problems, several needs, satisfaction with work done, motivation and employee self categorization as one in individual level or as one in social level, as well as mobile and agent technologies, there is developed a conception for PKMS development based on PTM which combines social, psychological and technological aspects;

- there is developed adaptable personal knowledge management system architecture based modular PKMS development approach and on this system's additional configuration capability, as well as on usage of mobile and agent technologies; this system combines technological, social and psychological personal knowledge management aspects.

In thesis there are acquired following main new theoretical and practical results:

- there is defined new notion of knowledge substance, which encompasses a breadth of all knowledge all around humans and around the environment individuals live in as a community by communicating and interacting with each other. This notion of knowledge substance is integrity of all knowledge, and it is not further dividable in knowledge sub-substances but only in knowledge elements. Knowledge substance is made of all known knowledge elements and of all unknown knowledge elements;
- there is defined a new notion of knowledge utility quotient which depicts in particular context useful or accessible knowledge proportion against the all in this particular context knowledge necessary to solve particular task;
- there is developed personal knowledge cone spiral (PKCS) which describes individuals extra knowledge vertical growth thus creating a new view on individuals knowledge and skills acquisition progress. PKCS provides opportunity to warn individual to decrease the knowledge acquisition intensity in order to avoid experiencing a "burn-out" situation;
- in regards to defined knowledge substance related notion of knowledge element there are developed five principles for knowledge worker to foster acquisition of knowledge elements in three PKM contexts;
- following the view that existing PKMS should be considered rather as tools, and that there are needed systems with ability to adapt to individual, there is developed robust framework for a scalable, modular PKMS creation and development, and is adjustable in several levels to particular knowledge worker;
- there is developed PKMS aspects general development approach and PKMS three aspects (i.e. social, psychological and technological) combining solution and is depicted visually based on mobile and agent technology usage as well as on knowledge element acquisition five principles and on knowledge worker set of values to strive for (i.e. love for others and for themselves (LFO-FT));

- based developed adaptable PKMS architecture there is developed concrete system's specific area module's prototype for learning environment support in Vidzeme University of Applied Sciences which accordingly to developed architecture is based on mobile and agent technologies.

There are acquired following main conclusions:

- according to performed research personal knowledge management is less researched area of knowledge management and it has a potential to provide support to knowledge worker in order that he / she could follow the dynamic changes in surrounding environment in relation with individual's different areas of life which include professional, academic as well as personal one;
- during performed research there were identified following PKMS shortcomings: so far developed PKMS only partially support PKM requirements and conditions, and do not contain all three PKM aspects: social, psychological and technological as well as such systems should be rather considered as tools. There are needed PKMS with ability to adjust them to individual. Mentioned PKMS shortcomings are being solved within this thesis accordingly to set goals and tasks of the work to be done;
- Defined nine PKM processes, developed PKM process model, developed personal trinity model, knowledge element acquisition five principles, LFO-FT set of values, mobile and agent technologies are enablers for development of adjustable PKMS architecture;
- developed adjustable personal knowledge management system architecture allows to create modular and configurable PKMS that includes all three PKMS aspects: social, psychological and technological. Based on this architecture developed PKMS is adjustable to particular knowledge worker and his / her accordant area of work or life. As an example of this serves prototype of specific area module for learning environment support in Vidzeme University of Applied Sciences.

Possible directions for future research:

- based on created PKMS development conception to research organization's KMS potential influence on conceptual PKMS and knowledge worker using this system;

- to perform in-depth research how knowledge workers can be motivated to use PKMS both from social and psychological aspects and from technological aspect.

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