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Agent Based Personal Knowledge Management System Supported by Mobile Technology Cross-Platform Solution

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1. Introduction

A historic transition from the industrial age to the information age has happened during several previous decades. The industrial age can be characterized by following: standardized information routines, usage of fixed procedures, and creation of material goods and consumption of them. In opposite the information age is focusing on creation and consumption of information, usage of ad-hoc approaches and non-standardized information for decision making. During this time of transition the Web has developed very rapidly along with information explosion. That has led to a notion of information overload. In organizations workspace environment and equipment is turning to be more sophisticated. Also learning environment is becoming more information and technology dense. As a result work is becoming increasingly complex (Wiig, 2004) requiring additional knowledge and skills to handle it. In turn that leads to recognition that knowledge has become a very important asset both for individuals and for organizations. Thus knowledge more increasingly has been seen as an active area of research. Notions of knowledge work and accordingly of knowledge worker have strengthen their positions out of transition from information to knowledge.

Much of attention is focused towards researching different knowledge related areas. Knowledge management (KM) is one of such areas. It was first defined by Wiig in 1986 (Wiig, 1997). As per (Tiwana, 2002) KM has three basic processes: knowledge acquisition, sharing, and utilization. Knowledge is divided in two broad categories: tacit (i.e. tacit knowing) and explicit (i.e. explicit knowing) (Polanyi, 1966). There are also several other ways of classifying knowledge based on particular perspective of research (Maier, 2004). Majority of research is connected with knowledge that we do know and with knowledge we know that we do not know. However per (Frappaolo, 2004) there still remains knowledge which we do not know that we know and knowledge which we do not know that we do not know. Thus we propose a new concept of knowledge substance to encompass all knowledge elements (KE) as a basis for further research.

New technological solutions such as mobile technology and accordingly different types of mobile devices have appeared in addition of transition to the information age and development of the Web and the Internet. These devices have greatly influenced

individuals' habits and their ways of consuming, sharing and storing information. A large and growing variety of mobile devices and a number of new forms of communication have been developed to accommodate expanding needs of people. Thus, for example, based on (i2SMS, 2008) almost every second person uses a mobile phone in 2008. But two years later as per (mobiThinking, 2011) there are already 77% mobile subscribers of the world population in 2010. However that has its drawback by making it difficult to develop services and applications accommodating a vast array of mobile devices and their platforms. Accordant innovative services are lacking a momentum of development. Frequently they are still mainly based on rather old technologies such as text messaging despite this wide acceptance of mobile phones. Thus there is a necessity for new developments and technologies in the area of mobile device service and application creation. Per (Koch & Rahwan, 2004) agent technology promises to be as such within this domain. In particular Java agent development environment (JADE) besides other possibilities proposes a way to develop mobile device based cross-platform applications.

By taking into account mobile and agent technologies possibilities we focus also on knowledge and especially on personal knowledge. As knowledge is increasingly valuated and used in business and in regular life situations then it points to a necessity for well educated people. Thus there is an implication for need of an effective personal knowledge management system (PKMS). Such system should lay foundation blocks for a new knowledge-based society, economy, and should allow ambient participation in a social and economic life. Per Jefferson currently available PKMS are just a bit more than just productivity tools (Jefferson, 2006). He suggests that there is a necessity for systems with ability to adjust to individual.

This chapter reports on several stages of broader research targeted at perspectives of developing a PKMS. The proposed solution is encompassing three personal knowledge management (PKM) aspects of well-rounded PKMS (Apshvalka, 2004; Apshvalka & Grundspenkis, 2005): social, psychological and technological. Technological aspect is based on agent and mobile technologies (Osis & Grundspenkis, 2009b; Osis & Grundspenkis, 2010; Osis & Grundspenkis, 2011a) utilizing mobile-cross platform solution based on JADE environment. In addition within this paper the technological aspect is elaborated in a detailed way and encompassing the whole PKMS perspective. Social and partially psychological aspect of PKM is based on proposed personal trinity model approach (Osis & Grundspenkis, 2011b) for developing a well-rounded PKMS. Within this aspect of PKMS is included the personal knowledge cone-spiral (PKCS) which makes it possible to avoid knowledge worker "burn-out" by detecting PKCS pattern in knowledge acquisition process. As well this aspect of PKMS includes five knowledge acquisition principles based on knowledge substance and its elements characteristics to support PKM.

The goal of this chapter is the following: using summary of existing PKM tools and systems and overview of approaches of their development taken over from the our previous research (Osis & Grundspenkis, 2011a) to propose a conceptually new approach for developing more well-rounded PKMS, which takes into account also a social and psychological aspect of PKM. As one area of usage of such PKMS is a learning environment support (Osis & Grundspenkis, 2010), which is briefly described in this chapter as well to provide a demonstrative example for potential utilization of proposed system. The main contribution of this chapter is an attempt to incorporate social and psychological aspects of PKM with its technological aspect into the PKMS, and to stimulate the debate in this regard.

Chapter is organized as follows. This brief introduction is followed by an overview of personal knowledge management from knowledge worker's perspective. Within this perspective a short summary of previous findings about existing PKM tools and systems is given. The third section describes personal knowledge management system's conception. This section includes description of social and partially psychological aspect of PKMS. In addition it contains a brief look into technological aspect of PKMS detailing several types of modules the proposed PKMS consists of. These modules include PKMS core or basic module, several supplemental modules, which are further divided into two types: frequently used modules and specific area modules. Description of specific area module "m-learning" focusing on learning environment support is given to illustrate a particular example of this type of module in more details. The fourth section is geared towards the development of proposed PKMS. This section includes a brief description of environment of mobile devices– types, platforms and ways of communication. Next it looks into strength and weaknesses of mobile devices in perspective of PKMS. That is followed by introduction of main elements of mobile Java environment. Then agent technology and mobile devices in perspective of PKMS and particularly also JADE and JADE LEAP environment, which focuses on mobile devices is described. All these pieces are put together and a detailed description of proposed PKMS architecture is given covering all types of modules involved. Specific attention is given to the core or the basic module, which encompasses also individual's knowledge profile, user profile and a special configuration area for adding supplemental modules to PKMS on a need basis. A conceptual specific area module "m-learning" is also described, which involves a case study at Vidzeme University of Applied Sciences to enhance a course grading system at the Faculty of Engineering as a learning environment supportive effort. The chapter ends with conclusions including summary of key results and the future work perspective. References section is included as well.

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 (Pauleen, 2009). Thus PKM has been chosen as one of basic research objects of this work.

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. 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. At the same time these numbers indicate that particular PKM process is included within accordant researcher's given PKM definition.

Authors of this work provide a new view within PKM process context by taking into account summarized PKM processes in Table 1 and Barth's description of information processing skills and tools (Barth, 2005). Authors distinguish 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, analysing, retrieving, collaboration, usage and sharing, and security.

PKM processes	(Apshvalka, 2004)	(Tsui, 2002)	(Jarche, 2009)	(Moghe, 2010)	(Frand & Hixon, 1999)	(Frei, 2006)
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

Table 1. Personal knowledge management sets of processes

Based on nine PKM processes, authors have developed a PKM process model which is shown in Figure 1. This model 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). One can observe that security process is parallel to all other PKM processes.

With Barth words PKM essentially is responsible about what you know, who you know, and what they know (Barth, 2005). 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) (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 a knowledge worker and for an individual towards his / her growth and improvement. Thus it is also important that for a knowledge worker personal knowledge management system's (PKMS) support is available for simple information management tasks as well as for more intellectual activities.

By conducting analysis of PKMS it was determined that research in this area started relatively recently. So far PKM and PKMS is less researched KM area (Pauleen, 2009). As PKMS definition within this paper is considered one by Apshvalka and Grundspenkis (Apshvalka & Grundspenkis, 2005), which states that PKMS is a complex system and it contains social, psychological and technological aspects. Its operation is closely tied with a knowledge worker's perception, emotions, believes, surrounding society, environment, wishes and goals. Technology in PKMS context has an important role as well. A PKMS goal is to support as much as possible its owner in decision making and performing actions.

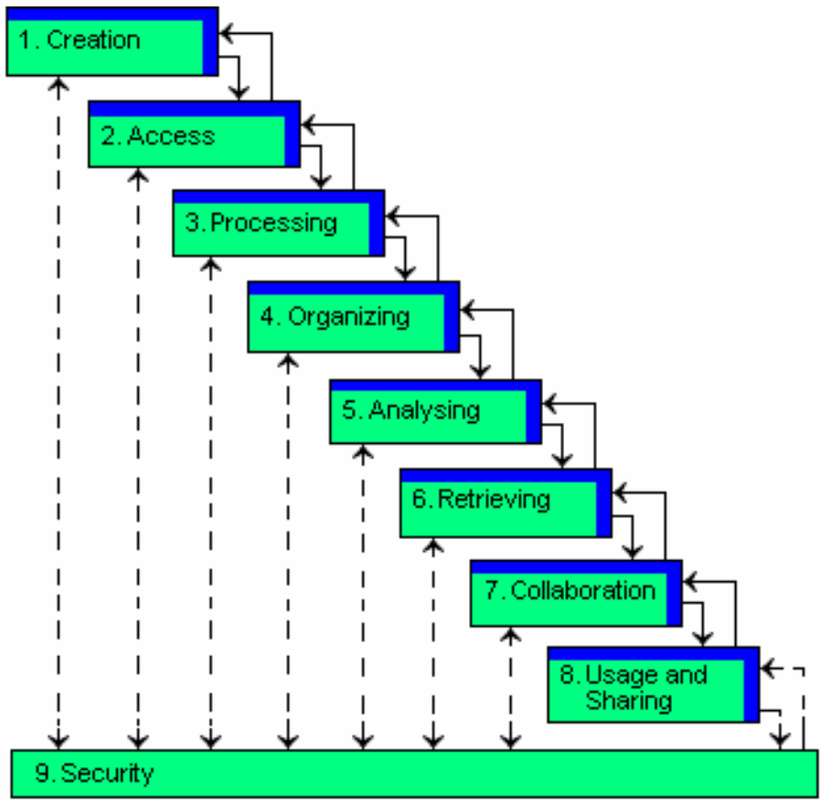

Fig. 1. Personal knowledge management process model

It is determined, that PKMS supports knowledge objects finding, acquisition, creation and sharing. PKMS also supports decision making and environment creation so that individual could share his / her knowledge with other knowledge workers or with CoP acquaintances. Miller considers that PKMS from practical point of view contains that how individual can find personal information sources in a computer or in a mobile device, and how this information can be adopted to particular situation to create intellectual and knowledge values to foster success at work or in personal life (Miller, 2005). In addition PKMS focuses not just to an individual personal information sources, but also to sources outside the set of latter mentioned sources.

So far observed PKM research areas can be divided in two directions. One direction mainly focuses on PKMS as a part of company's KMS (Völkel & Abecker, 2008) and it's interaction with KMS. Another direction focuses on usage of PKMS or PKM tools in individual's context thus paying less attention to company's KMS factor (Jarche, 2006; Li & Li, 2009).

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 (Doong & Wang, 2009), for example, Google Desktop, Windows Search, Apple Spotlight and Copernic Desktop Search. Other PKMS are based on Web technologies such as wiki, for example, WikiPad (WikiPad, 2010), or Web blogging (Li & Li, 2009). There have been attempts to combine latter mentioned approaches (Kim et al., 2007), 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 (Maier, 2004) with focus on individual level, Apshvalka's developed one based on brain functionality PKMS conceptual model (Apshvalka, 2004), Smedley's conceptual PKMS (Smedley, 2009) based on theoretical models in KM (Nonaka & Konno, 1999) and in learning (Kolb, 1984), Wright conceptual PKMS (Wright, 2005, 2008) based on four mutually connected scopes (analytical, information, social, learning). In the case of Smedley conceptual PKMS very important is that a knowledge sharing process is the trust factor (Smedley, 2009), but in Wright's approach very important is tight collaboration and networking (Wright, 2005, 2008).
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 requirements 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 the 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 (Jefferson, 2006) 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

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 the KW it is important to have a PKMS support. A PKMS only from technological aspect will not make a successful system's integration and usage for backing the KW's task supporting process. It is important that individual himself / herself is willing to use a 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 (Maslow, 1954). 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 (Chapman, 1995). In 1970-s hierarchy of needs was extended with levels of cognitive and aesthetic needs, but in 1990-s there was added level of transcendence needs (Maslow, 1954; Chapman, 1995).
The theory of hierarchy of needs has been also criticized being subjective and the order of needs levels being not appropriate (Boeree, 2006). However from a 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 the 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 (Chapman, 1995). There are also some other problems KW-s have to deal with (Etzel & Thomas, 1996). 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 (Herzberg et. al., 1959) 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 (McClelland, 1967). 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 (Haslam, 2004).

3.1 Personal trinity model – Social and psychological aspect

Authors have proposed a PKMS development approach taking into account several influencing factors of individuals (Osis & Grundspenkis, 2011b). This approach is named the 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" (Day, 2007). 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. The head part relates to a human cognitive and exploring aspect. The hart part relates to a human social, emotional and cultural aspect, while the body part relates to a human physiologic aspect.

From the whole-human simulation point of view authors will look more closely at the head part. Johnson talks about innovation and new ideas. He states that at the beginning there is a hunch (Johnson, 2010) 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 (Johnson, 2010). A thoughts exchange can take place within an 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.

Authors have defined the knowledge substance concept (Osis & Grundspenkis, 2011b). Based on the square of known-unknown (Frappaolo, 2004) the knowledge substance concept encompasses a breadth of all knowledge all around individuals and around the environment they 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 knowledge elements (KE). In addition knowledge an individual is striving to acquire in the context of knowledge substance can not be seen only as a dichotomous item (or items) as it is in the case of knowledge domain stated in the

knowledge space theory (DeRose, 2005; Cognitive Science Section, 2007). Meaning that there exist such KE-s which can not be fully cognizable or can not be identifiable at all. However they are also part of knowledge substance. Based on this concept authors have proposed five knowledge acquisition principles (Osis & Grundspenkis, 2011b) to support a PKM and knowledge elements acquisition.

The first 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 (Fortnow, 2009), or which can not be known at all thus leaving them in a semi-find-out state (i.e. even they are found out in a hunch level though they stay as tacit knowledge, which further can not be explicated).

The second 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.

Nowadays regarding KE 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 2 based on the proposed personal knowledge cone-spiral (PKCS).

For nowadays individual such additional knowledge and skills acquisition stages or spiral twines are more comparing with people centuries before. In order to be competitive in job

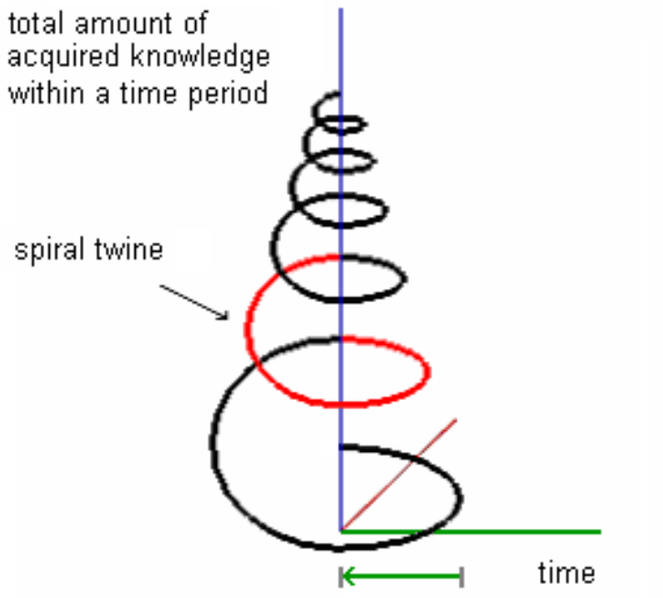

Fig. 2. Personal knowledge cone-spiral (Osis & Grundspenkis, 2011b)

market a 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 (Intel, 2011). This pattern of even shorter spiral twines bears a potential side effect. Such pattern can indicate the potential of KW burn-out. Thus the PKCS not only describes nowadays the common pattern of even shorter periods of knowledge acquisition, but also may serve as warning signal built in the PKMS for a KW to adjust his / her learning intensity in order to avoid potential burn-out symptoms. This serves as an example that by using a PTM in development process and in execution of PKMS a KW has a support to voluntary leverage his / her life areas.

Regarding the PTM heads part there are proposed three more principles (Osis & Grundspenkis, 2011b) related with knowledge sharing and acquisition:

The third principle: in order to successfully acquire new KE-s an individual has to work out a desire to acquire them and to strive for this knowledge.

The fourth 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.

The fifth principle: sharing tacit knowledge is best accomplished by using analogies and similarities. In this way it is possible to transfer not only the direct meaning of knowledge but also the spirit of knowledge.

The PTM - individual needs point of view. The PTM is projected on the 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 (Maslow, 1954). 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 (Boeree, 2006). By taking into account these arguments authors propose that a knowledge workers should strive for other super-set of individual improving values (Osis & Grundspenkis, 2011b; Concordia, 1986) 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 easily angered;
- forgiveness and not to remember/remind mischief;
- joy about truth and not delight about evil.

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 constantly trying to achieve them. Then that will be the real gain for a KW from the individual perspective and even more valuable from collaboration with others perspective. Especially that applies to the 5th principle stated above.

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

The PKMS social aspect and psychological aspect based on PTM focuses directly on a KW himself / herself. Partially they are connected with the technological aspect (note: this partial connection is true in opposite direction as well) by using previously defined 9 PKMS processes as a transition link. As a solution basis for these two aspects is previously described LFO-FT set of characteristics and 5 KE-s acquisition supporting principles. The PKMS technological aspect has a modular approach. Agent and mobile technologies are a solution basis for the technological aspect. In more details it is described in the fourth section of this chapter. PKMS general development approaches are depicted in Figure 3.

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

3.2 Modular personal knowledge management system – The technological aspect

Modular PKMS architecture consists of basic module and several additional modules. The basic module contains 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. The PKMS basic module from the architecture point of view is described in more details in fourth section.

3.2.1 Frequently used modules

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 KW-s with particular specifics of activities. For example, for ice cream development support (i.e. for developing a new ice recipe, solving with quality assurance 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 a PKMS size possibly small as frequently used modules are set the following ones: "goals and tasks management module" and "collaboration management module". Goals and tasks management module from a goal perspective allows a KW to set up personal goals in a simplified way, by using specific goals setting templates depending from chosen goal's type and specifics. From a tasks perspective this additional module supports a

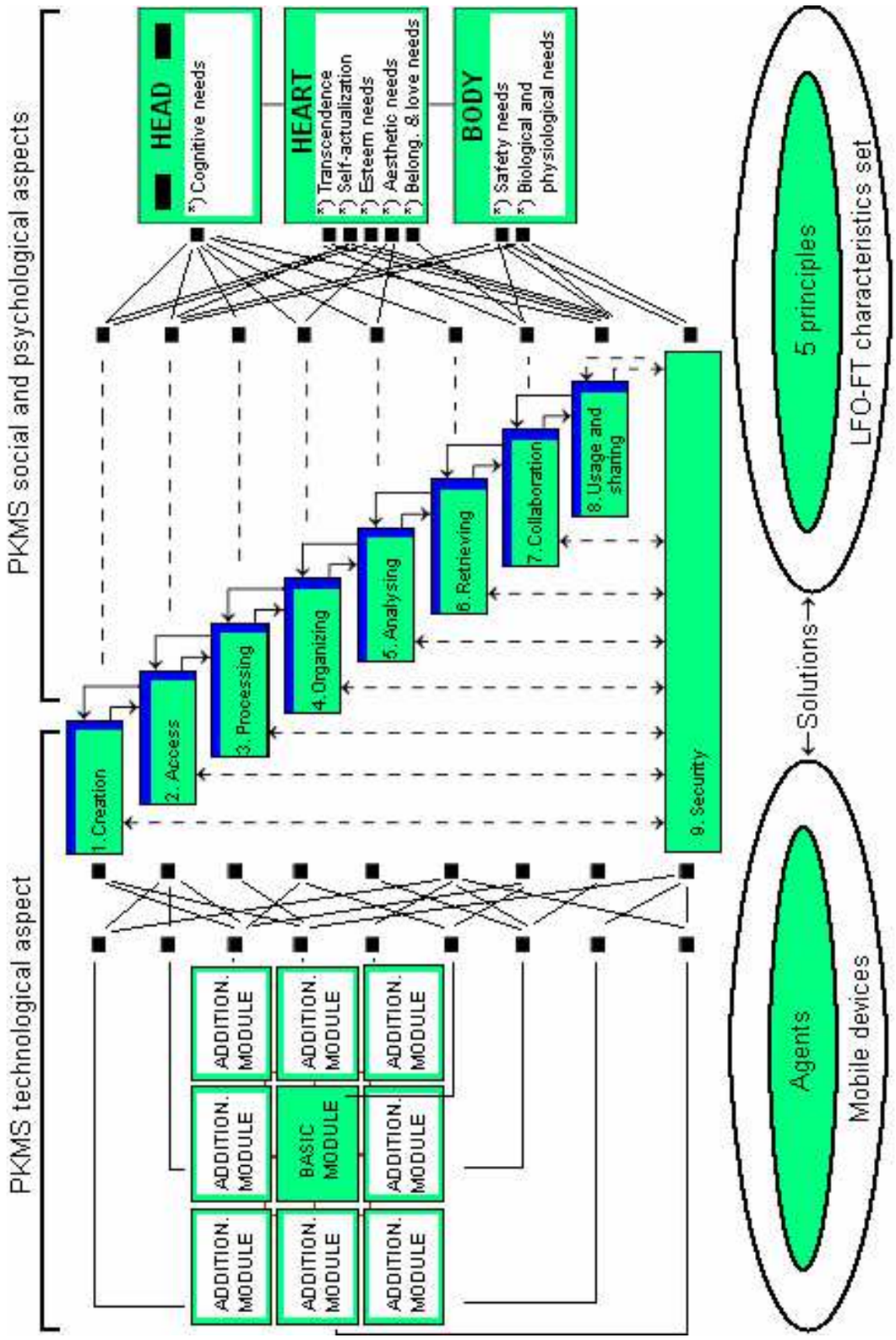

Fig. 3. PKMS aspects general development approaches

KW to set up to do tasks for himself / herself as well as for a PKMS. The collaboration management module provides support of several communication types (see user card – social aspect part) for knowledge worker's collaboration with other individual or for a PKMS collaboration agent with particular individual's PKMS representing agent. More detailed description about agent usage and frequently used modules from architecture and the technical solution perspective is given in fourth section of this chapter.

3.2.2 Specific area module "m-learning"

Each specific area module is intended for concrete group of KW-s with specific or partially specific tasks to do. As everyday work of one of the authors is connected with academic environment as a lecturer for professional bachelor study program in Vidzeme University of applied sciences, then m-learning module is chosen as a specific area 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 a PKMS. So it is not considered as a universal m-learning module. However if for a particular company it is necessary to carry out additional m-learning support then by supplementing modules repository with new modules it is possible to add other m-learning modules to a PKMS. Thereby previous m-learning PKMS functionality is supplemented by additional one. In more details the particular specific area module is described also in fourth section of this chapter. As part of a work on particular specific area module authors have conducted research on mobile learning in PKM context (Osis & Grundspenkis, 2009a).

4. Development of personal knowledge management system

This section contains more detailed description of PKMS technological aspects in context of PKMS development. Within this section 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 technology

By analysis of 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 the PKM is only at its beginnings (Agnihotri & Troutt, 2009). For this reason within this work mobile device overview and evaluation in context of PKM is conducted.

One of the most important KW-s task is developing collaboration with other individuals, for example, as it is in case of Wright conceptual PKMS (Wright, 2005). Developing collaboration contains: ability to communicate, to share explicit and tacit knowledge elements, to do collaboration in any time and in any place.

It is important for KW 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 available work environment within it 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 another important characteristic can be named mobile device security functionality from unauthorized access to device point of view. An additional important point of view to look at is a PKMS ability to function on different mobile devices, i.e. reducing PKMS dependence from one particular mobile device model or even platform.
Within this work have been conducted mobile device summary and analysis, and have been 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 (Gartner, 2011). Mobile device platforms and application development environments are also analysed. 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 the PKMS development based on mobile devices. Later on we describe main Java mobile environment elements.
One of actual features of mobile devices 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. Within our work we have determined and systematized mobile device communication and data transfer types in different parts of the World. In Table 2 these communication and data transfer types are depicted by focussing on European region.

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 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 num. of clients, then some 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.

Table 2. Wireless communication and data transfer types in European region context

Usually knowledge worker conducts its work in company premises or in open air territory of company. 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 territory of company.

An important aspect in KW'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 the 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 is not a wide range of mobile devices supporting WiMAX. Even there are a number of commercial Wi-Fi hot spots though there are 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 KW and the PKMS support the most appropriate is Wi-Fi communication and data transfer type.

4.1.1 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 the following (Osis & Grundspenkis, 2009a): 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). At the same time several mobile devices strengths have been determined in the context of KW and the PKM which are actual both for m-learning and for mobile device based PKMS. They are (Mellow, 2005; Squire et al., 2006): 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 KW (i.e. from PKMS social and psychological aspects) and convenient.

By evaluating mobile devices strengths and weaknesses it is concluded that modern ones have several considerable strengths, which makes them especially attractive for use as a development basis for the PKMS. They are ubiquity, personalization, localisation functionality and interaction characteristic. In addition it is worth to point out 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 (AT&T, 2009) 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).
The 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 (Martin, 2006). 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 (Hill, 2010) is acquired a base for confidence about mobile platform validity and conformity for the PKMS development.

4.1.2 Main elements of mobile Java environment

As a uniting element and cross platform unification solution for many mobile devices can serve Java programming language despite that these devices might operate on different operating systems (OS). Within mobile Java execution environment there are several differences based on mobile device technical specifications as well. That is why a short overview of main elements of Java execution environment is included.
This environment includes such elements as configurations and profiles. Configurations define the minimal requirements for the hardware of the device and what kind of Java virtual machine is included in the system. In turn profiles define the programming infrastructure available for applications intended to be run on top of particular configuration (Mikkonen, 2007). Two important configurations are distinguished: Connected Limited Device Configuration (CLDC) and Connected Device Configuration (CDC). Each of them sets requirements for underlying virtual machines which in turn are hosted on each particular mobile device operating system. CLDC is the simplest mobile Java configuration and it is available on low-end and middle-class mobile phones and smart phones. This configuration is based on simplified Java virtual machine. CDC configuration lays on standard-featured Java virtual machine even though it does not require all the libraries as in the case of desktop environment (Mikkonen, 2007). Therefore such configuration usually is available on most powerful mobile devices like tablet PC-s, communicators and PDA-s. Each of these configurations has profiles. They can be seen as a connecting element between Java environment creators and mobile application developers. CLDC has two closely related profiles: Mobile Information Device Profile (MIDP) and Information Module Profile (IMP). The first one is meant for mobile devices with small screens, as a minimum limited connectivity and a simple keyboard. Thus the MIDP profile actually is the most widespread one available. The IMP profile is geared for similar devices but lacking screen features like operate-able sensors. The CDC configuration has three profiles: Foundation Profile (FP) being a simplest profile among the three, Personal Basis Profile (PBP) extends the FP and Personal Profile (PP) basically mimicking standard Java running on desktop environment.
Currently in market the dominating configuration is the CLDC both among mobile phones and also among smart phones. Only few smart phones with the CDC configuration were in the market at the beginning of this century such as Nokia 9500 (Forum.Nokia, 2010). These devices were upper level smart phones with a very expensive price tag. As a result it turned out that there is no real business for the CDC configuration environment within a smart phone market. Also PDA-s (which are dominantly based on the CDC configuration) tend to disappear from market as smart phones are taking over their niche and offering even a

wider variety of functionality. However the future of CDC is not necessarily dim. Thus, for example, Amazon Kindle e-Reader is taking over the run for the CDC configuration support. The Kindle software development kit (SDK) (Amazon, 2010) has been made available since spring 2010. Though for time being it is available for Amazon chosen or approved developers only.

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 searching for explicit knowledge elements localy within the PKMS, fostering collaboration among KWs and their representing PKMS, information searching in Web resources, supporting actions of KW in communities of practice and the PKMS hardware operation monitoring and supporting.

Regarding software agents, their characteristics and communication it is determined that first of all agent is a computer system existing in its environment, which can carry out autonomous operations within this environment in order to reach set goals (Jennings & Wooldridge, 1998). 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 (Wooldridge, 1999). Agents' autonomy is compared as equivalent characteristic to humans' free will (Vidal et al., 2011).

Agents possess abilities or characteristics (Jennings & Wooldridge, 1998). They are (Wooldridge & Jennings, 1995; Tveit, 2001; Padgham et al., 2008): autonomy, social abilities, ability to react, pro-activity, mobility, truth, benevolence, rationality. Based on Bradshaw (Bradshaw, 1997) 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 (Bradshaw, 1997): 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 (Zack, 1999).

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 (Nwana, 1996). 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 (Nwana, 1996; Lander, 1997; Lange & Oshima, 1999; Kelash et al., 2005; Kotz et al., 2002). Mobile agents use three types of messages (Kelash et al., 2005): proposal, knowledge based, and mobility

message. There are several reasons to use mobile agents (Lange & Oshima, 1999): they decrease network load (by travelling themselves to data), they overcome 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 a user (i.e. agent owner) (de Carvalho & Tavares Ferreira, 2006).

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 KWs 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 (Koch & Rahwan, 2004) point out that this is the area where usage of agent technology is a promising solution to develop modern software based on mobile devices.

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 (FIPA, 2009). Thus FIPA focuses not only on communication, but also on general meaning services such as standard approach to agent life cycle management (Bergenti et al., 2001).

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 the 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 using wireless and land line networks. Main goal of the LEAP project is to develop a 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 (Bergenti et al., 2001).

There are several development platforms for software agent development on mobile devices. One example of such platform is MicroFIPA-OS (Tarkoma & Laukkanen, 2002), while the most popular one is Java Agent DEvelopment Framework (JADE) (JADE, 2009; Wang et al., 2003; Weng & Tran, 2007). 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. An 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 (JADE, 2009). There is developed the 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 the frequently used agent

platform, which is well documented and has active developers' community. It is determined that the 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 PKMS general architecture, it is scalable and consists from modules combining the basic module and several supplemental modules. The basic module contains KW's knowledge profile and a user profile. The *knowledge profile* contains information about system's user: his / her knowledge level, knowledge specifics, information about desirable knowledge and also knowledge sharing frequency. In addition it contains a knowledge development plan and a knowledge element repository list. The *user profile* contains particular KW personal information, social aspect information, and psychological aspect information. Both these cards are used by the PKMS when there is collaboration with other KWs and accordingly with their PKMS. The *supplemental modules* contain two frequently used modules (i.e. the goal and task management module, and the collaboration module) and specific area modules. Within this work as a *specific area module* is chosen m-learning module, which provides functionality of learning environment support.

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 the PKMS basic module along with installation of a new upgrade package. Based on this list the PKMS recognizes additional supplemental modules. In order to add frequently used module or specific area module to the PKMS there has to be used special PKMS settings and module configuration area called PUMKA. A KW uses PUMKA area only for PKMS configuration purposes and this area is not used during his / her everyday task processing. PUMKA combines the following functionality: adding frequently used modules or specific area modules to the PKMS, and PKMS (i.e. basic module) default settings configuration.

There is needed an intellectual support for a KW everyday to-do tasks in context of PKMS. Solution for this is an intelligent agents' community (see middle part of Figure 4) which creates a base for KW's 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 (Grundspenkis, 2003) in companies' context. In this work it is used in context of PKMS. Secondly, there are agents supporting communication. And finally there are personal agents, which are tightly connected with KW.

"Engine room" agents idea is that nowadays a number of to-do tasks are connected with technical solutions, which should be done by KWs in order to streamline their 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 KW 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 a KW, support interaction with particular hardware device as well as provide support in knowledge work.

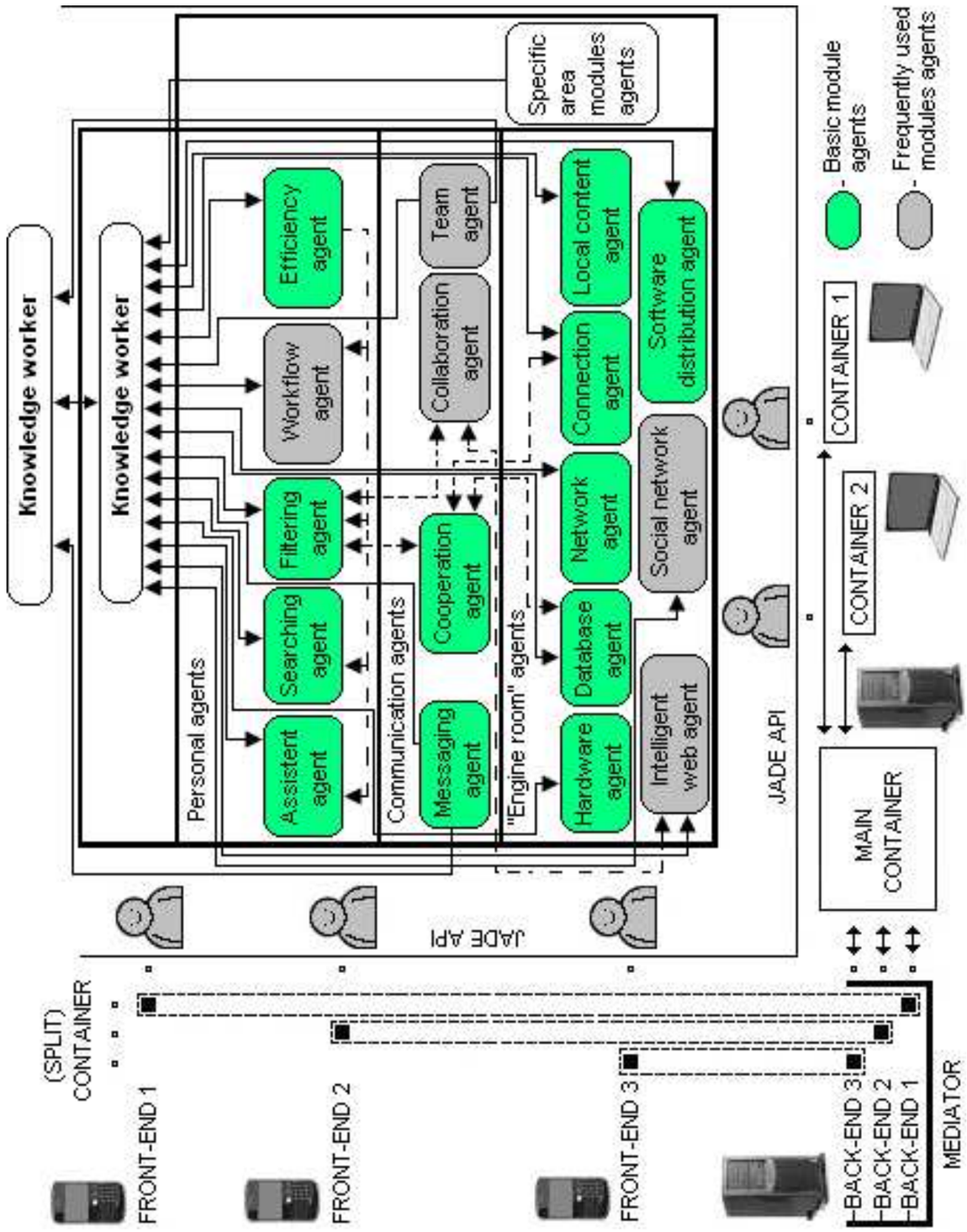

Fig. 4. PKMS three group agent environment in context of mobile devices and agent development environment JADE-LEAP

A KW and the PKMS three group agents environment in context of PKMS modules is depicted in middle part of Figure 4. In green are agents connected with PKMS basic module.

In grey are agents connected with PKMS frequently used modules. Meaning that workflow agent intelligent Web agent is connected with PKMS goal and task management module, but remaining grey-coloured agents are connected with collaboration module. Specific area modules agents should not be showed in details before accordant specific area module is not created and added to modules repository.

Solid lines in the middle part of Figure 4 (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 entirely. It depicts the PKMS architecture by combining agent technology view, mobile device technology view, agent development environment JADE-LEAP view and five KWs using notebook computers and smart phones accordingly as a basis for PKMS.

Specific area module "m-learning" architecture. PKMS specific area module m-learning architecture from agent technology perspective is depicted in the middle part of Figure 5. Solid lines denote communication within specific area module m-learning, but interrupted lines denote communication with the PKMS. This module has four main agents types (Osis & Grundspenkis, 2010): instructor agent, operator agent, student agent and audit agent. The JADE-LEAP agent environment is used. There are included some more FIPA standard management agents. Architecture of PKMS specific area module m-learning in context of mobile devices and agent development environment JADE-LEAP is depicted in Figure 5. 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 5.

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. The 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 the operator agent. Then the operator agent saves that information. It uses help of DF agent (i.e. it is a JADE framework internal agent) and broadcasts this information to each student agent accordingly. 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 the student agent accordingly based on deadline proximity property value. This value can be set by the student agent. (2) *Appealing scenario* is started by the student. Then it is taken over by the student agent. It sends an appeal directly to the instructor agent. If it is too late and the appeal deadline is passed then the instructor agent on its own rejects this appeal. If that is not the case, then the instructor is informed. (3) *Extending deadline scenario* begins when the instructor decides to extend a deadline for a given exercise.

Then that information is transferred to the operator agent. There it is saved and communicated further with the audit agent and then student agents are informed. (4) *Scheduling an appointment scenario* provides possibility for the student agent to send a request directly to an instructor agent to schedule an appointment. If such request is received by the 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.

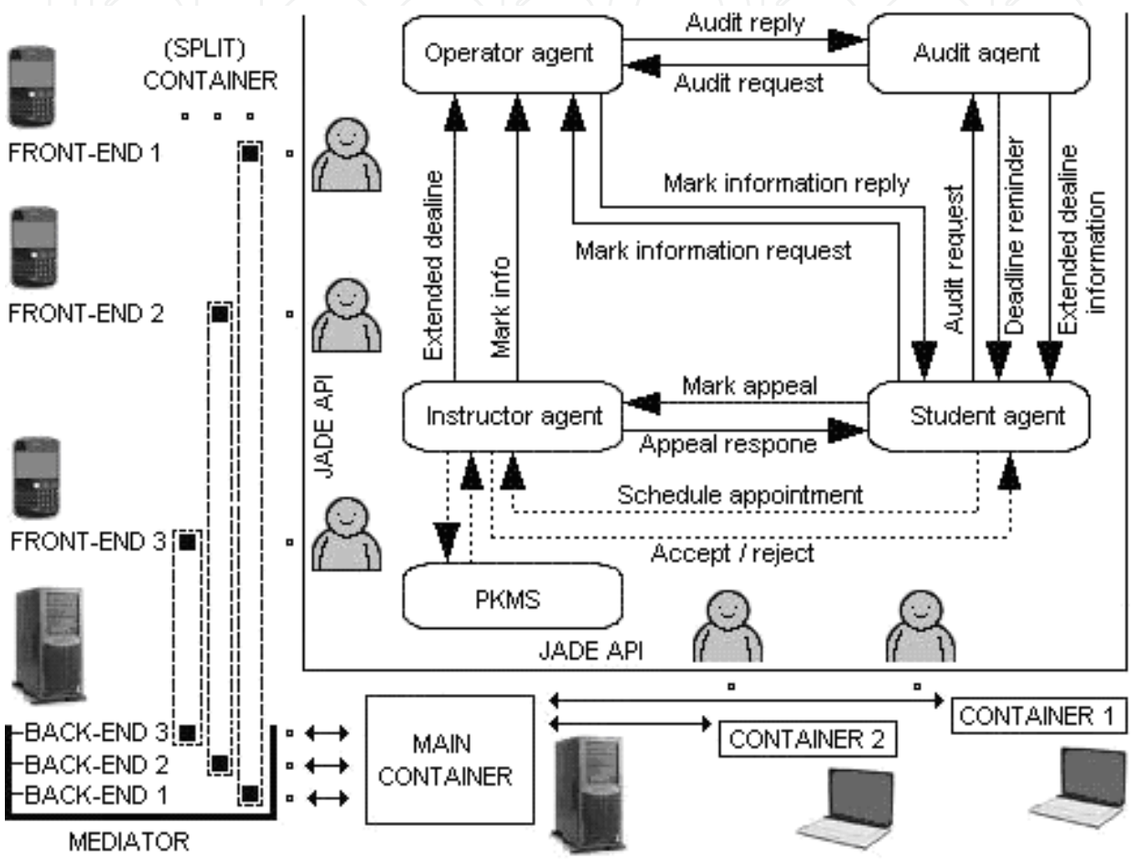

Fig. 5. PKMS specific area module m-learning architecture in context of mobile devices and agent development environment JADE-LEAP

5. Conclusion

The goal of broader research and to create within this work the personal knowledge management system conceptual development approach of combining technological aspect, social aspect and psychological aspect and such system's architecture solution based on mobile and agent technologies has been reached. Within this work is gained the following scientific novelty: (*) defined PKM nine processes and created PKM process model; (*) developed conception for united PKMS development based on suggested personal trinity model which combines technological, social and psychological aspects; (*) developed adaptable PKMS's architecture based on application of mobile and agent technology, and which contains all three latter mentioned PKMS aspects.

Possible directions of future work are: (*) based on created PKMS development conception to research company knowledge management system potential influence on conceptual PKMS and on KW using this system; (*) to conduct in-depth research how KWs can be motivated to use the PKMS from this system's social aspect and psychological aspect, as well as from its technological aspect.

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Due to the development of mobile and Web 2.0 technology, knowledge transfer, storage and retrieval have become much more rapid. In recent years, there have been more and more new and interesting findings in the research field of knowledge management. This book aims to introduce readers to the recent research topics, it is titled "New Research on Knowledge Management Technology" and includes 13 chapters. In this book, new KM technologies and systems are proposed, the applications and potential of all KM technologies are explored and discussed. It is expected that this book provides relevant information about new research trends in comprehensive and novel knowledge management studies, and that it serves as an important resource for researchers, teachers and students, and for the development of practices in the knowledge management field.

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