Personal Intelligence in Collective Goals

A Bottom-Up Approach from PKM to OKM

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Abstract—This paper investigates the PKM processes of knowledge workers in order to develop an agent-mediated PKM framework and how this mediation could collectively manifest an OKM framework from the bottom-up approach in PKM. We propose a conceptual model for agent-mediated PKM to show the emergence of a collective personal intelligence towards achieving the organisational goal.

Keywords-personal intelligence; personal knowledge management; bottom-up approach of knowledge management; software agent technology; nodal approach.

I. INTRODUCTION

> *"The focus [of knowledge management] has begun to* shift from organisational knowledge management (OKM) towards personal knowledge management (PKM). The vision of PKM is no longer just about extracting knowledge from experts, codifying it, and making it widely available to others via databases, as in a first generation knowledge management system. Instead PKM, using Web 2.0 tools, facilitates the whole life cycle of knowledge processes in a human context. Web 2.0 enables a new model of PKM that contributes to **collective intelligence** through formal and informal communication, collaboration, and social networking tools. This new PKM model facilitates virtual interaction, social processes, collaboration, and knowledge exchanges **on the web and in organisations**. Personal and collective knowledge are two faces of complex knowledge management processes that are not opposed but have the potential of making the management of knowledge *more efficient both at individual and collective levels."* [1]

Most knowledge management strategies implemented in organisations are based on some specific issues of knowledge management (KM) and are dictated by what the management considers best for everyone to follow. This leads to the concept of top-down approach to strategic KM in which technology and infrastructure are deployed based on what management "thinks" and "wants". On the other hand, the models of system hierarchy and knowledge sharing highlight the importance of 'people' factor in ensuring the successful implementation of technology in any organisation. In other words, people's involvement should be taken into account alongside management support.

The area of 'PKM' is derived by user intention to get their jobs done. It shows that KM does not only belong to organisation, but also the end users. If end users have their own means of getting the jobs done to achieve organisational collective goals, then there is a possibility of looking at an organisational knowledge management (OKM) from the bottom-up approach.

In this research, 'people' are defined as the individual knowledge workers. This research tends to prove the possibility of software agents (i.e. artificial intelligence technology) to mediate the individual processes. Using software agents, a model can be developed to show how the PKM processes of knowledge workers are replicated and collectively manifest the organisational goals. Technically, an agent-mediated PKM can be considered as the personal intelligence of a knowledge worker.

A. Methodology

This study starts with a survey and review of the literature on agent-mediated personal knowledge management and PKM-OKM frameworks. This is followed by a study and analysis on collective personal intelligence, deriving from the agent-mediated PKM, from which five hypotheses are conceived to be quantitatively and/or qualitatively proven in this research. A conceptual model for a collective agent-mediated PKM processes is proposed as a result of this study to show how it emerges into a collective personal intelligence towards achieving an organisational goal. This model will form the basis for applying a human-agent collaborative framework, to be further developed in this research.

The conceptual model for a collective agent-mediated PKM processes is formalised by analysing a set of shared knowledge sources that individual knowledge workers or knowledge experts refer to in their daily work. Since it is based on the software agent technology, this model considers only the work processes through computer and Internet technologies, where tacit knowledge is expected to be applied within the processes.

With the conceptual model drawn from the analysis, a set of hypotheses are suggested to be proven as follows:

H1: Software agents can mediate PKM

H2: Agent-mediated PKM can be replicated

H3: The replicated agent-mediated PKM represents a function of an individual knowledge worker's intelligence in an organisation

H4: The replicated agent-mediated PKMs overlap to reveal tasks for a common goal

H5: The overlapping replicated agent-mediated PKMs can be integrated to manifest an agent-mediated OKM.

II. RELATED WORKS

Related works are based on the review and analysis of the literature from two sides of this research: knowledge management, and intelligent software agent technology. In order to relate the PKM and OKM in justifying the bottom-up approach, previous works on both concepts are reviewed. Although the concept of personal intelligence is well-known in psychology research, this research is focus on the technology aspects to enabling the alignment of personal intelligence with software agent technology.

A. PKM and OKM

It is argued that individuals are the essential core of organisation and that OKM initiatives should not only focus on the broad, enterprise-wide level, but should also address the needs of personal knowledge assets [2]. In supporting this, [3] discusses the value of PKM in the workplace by emphasising the importance of KM for individuals. The authors support the idea of bottom-up approach in KM to be applied in organisations, with a focus on PKM in reflecting the needs of the OKM.

Reference [2] pointed out the lack of fundamental analysis in academic research on the strategies of implementing the technologies to reconcile the conflicts between PKM and traditional OKM. This issue has been brought to his attention to address the gap by studying the linkage between the two concepts of KM. Other researchers [4] explore the essential PKM skills. Reference [1] look into the technological point of view by suggesting the tools for managing knowledge at individual and organisational levels. The authors suggest that Web 2.0 tools provide an opportunity for new developments of the PKM concept as an extension to the commonly used technology by individual knowledge workers.

Among the related works on PKM, the important aspect argued by the researchers is the 'people factor', where the PKM processes are defined in terms of networking, finding people who share the same interest, social, sharing knowledge, collaborating, extension and extrapolation, and community of practice. The following lists the definitions of PKM found in the literature:

- "best viewed as based on a set of problem solving skills that have both a logical or conceptual as well as physical or hands-on component." [5];
- "consists in a collection of processes that an individual needs to carry out in order to gather, classify, store, search, and retrieve knowledge in his/her daily activities." [6];
- "activity we perform in order to improve our problem recognition, formulating attempted solutions, and error elimination activities." [7];
- "an individual, disciplined process by which we make sense of information, observations, and ideas." [8].

Different individuals go through different processes of PKM and use different flow of processes at different times. Some literature proposed PKM processes in detailed manner, whereas some proposed the main categories of processes, but both show the flow of the PKM processes according to normal routines that is performed by individual knowledge workers, which are aligned with the concept of PKM over Web 2.0 defined in [1]. Among a few PKM process flows found in previous works are as follows:

- Manage personal knowledge (tool: networks), Organise personal knowledge (tool: library, databases), Share knowledge (tool: community of practice) [9];
- Retrieve – Evaluate – Organise – Collaborate – Analyse – Present – Secure [5];
- Create – Organise – Share [4];
- Gather – Classify – Store – Search – Retrieve [6];
- Seek (find aggregators/filterers), Sense (find an expression medium), Share (find people with same passion) [10];
- Aggregate, Understand, Connect [8].

PKM reflects the goal to support individual knowledge workers rather than establish an organisational approach [1]. PKM environments integrate individual work environments and infrastructures to support joint creation, distribution, sharing, and application of knowledge [11]. This proves that even though PKM is looking at the individual aspect of KM, collectively or in 'joint' PKM can contribute to OKM.

B. Personal Intelligence and Software Agents

There are many aspects and understanding on 'personal intelligence' (PI). From the reviews of related works, most authors agree that PI is electronic based or technologically enhanced facility it represents human counterparts, and this is the context of PI for this research.

In [12], personal intelligence is defined as one of the five layers that constitute collective intelligence, where the layer deals with "enabling users to both upload and access multimedia information submitted to the intelligent services using a range of devices". The authors predict that personal intelligence will contribute to collective intelligence and will reach their peak of usage in year 2015, regardless of the change in technology or user trends. Looking at the similarity of the concept of PI and agent technology, [12] point out the restriction factors, or in agent technology terms the elements in agent environment, to the event, user, content capture, terminal,

and network [12]. These elements will be discussed further to relate to the model that supports the hypotheses.

In another aspect, PI involves the abilities to: (a) recognise personally-relevant information from introspection and from observing oneself and others; (b) form that information into accurate models of personality; (c) guide one's choices by using personality information where relevant; and (d) systematise one's goals, plans, and life stories for good outcomes [13]. It is more on targeting the agent to be rational as part of being an intelligent system. Following these PI abilities, the theoretical analysis in [14] is more on justifying an individual's cumulative life decisions that helps in that person's well-being. For the purpose of this research, the concept of PI is taken into account in terms of how this 'cumulative decisions' can reflect the collective goals of achieving OKM.

Reference [6] propose that "an intelligent OKM system should operate like the human brain and fulfil functions of knowledge acquisition through sensors, knowledge formalisation, representation, and storage in the knowledge space, knowledge inference, sharing, and use". The use of agent-based technology in KM is supported by [15] with further discussion on information processing, connection and end user's knowledge or behaviour for knowledge sharing practices. In another aspect of intelligent system, a framework for collaborative knowledge sharing is suggested with recommendations on taxonomic partial reputation on the personal knowledge directories [16]. Their knowledge sharing and recommendation schemes depend on the autonomous and collaborative relations among users or knowledge workers, which is the focus in this research.

C. Software Agents in mediating PKM Processes

According to [17], software agents are entities that function continuously and autonomously in a particular environment. Agents are expected to have the ability to learn from their experiences, communicate, and cooperate with people and other agents, including moving around within private networks and semantic Web if necessary.

There are many definitions of software agents. Among the most quoted definitions on software agents are:

i) "programs that engage in dialogs and negotiation and coordinate the transfer of information" [18];

ii) "anything that can be viewed as perceiving its environment through sensors and acting upon that environment through effectors" [19];

iii) "software entities that carry out some set of operations on behalf of a user or another program with some degree of independence or autonomy, and in so doing, employ some knowledge or representation of the user's goals or desires" [20];

iv) "autonomous agents are computational systems that inhabit some complex dynamic environment, sense and act autonomously in this environment, and by doing so realize a set of goals or tasks for which they are designed" [21];

v) "an encapsulated computer system that is situated in some environment and that is capable of flexible action in that environment in order to meet its design objectives" [22];

This research focuses on the 'definition' of software agent. They are autonomy, reactive, proactive, able to communicate, adaptive, goal-oriented, capable to cooperate, reason, and flexible. These features are adapted from [23].

Software agents can be divided into weak notions (i.e. autonomous, sociable, reactive, and proactive) and strong notions (i.e. ability to do humanistic emotions like having beliefs, desires, intentions, diligence, knowledge, obligation, commitment, and many others) [24, 25]. The strong notion derived from the humanistic concepts is the intentional notion, which espouses the mentalistic attributes of agents and deemed to be a necessary condition for agenthood. The authors [24, 25] suggest two category of attitudes in representing agents to complement the necessity of intentional notion: information attitudes (i.e. belief, knowledge); and pro-attitudes (i.e. desire, intention, obligation, commitment, etc.).

References [26] outline the relation between KM as an application and software agents as a basic technology for supporting KM. They argued that the basic features of agents (social ability, autonomy, re- and pro-activeness) can alleviate several of drawbacks of KM technology. They established a classification schema for the description of agent-based KM systems and propose issues which an agent-mediated KM should deal with. Reference [27] presented an agent-mediated KM approach for multiple autonomous domains transcending multiple organisations. The approach enables discovery of distributed and heterogeneous knowledge resources through an infrastructure of knowledge repositories by means of software agents. Ontologies and agents play important roles in providing distributed knowledge discovery in multiple autonomous domains, the interoperability of which is achieved through software agent mediation.

On a more practical note, [28] present an analysis and modeling case study for agent mediated KM in educational environments. They developed an agent-based peer-to-peer helpdesk system to support extra-class interactions among students and teachers. They use Agent-Object-Relationship Modeling Language (AORML), an UML extension for agent-oriented modeling to support collaborative learning.

III. Preliminary Findings

In developing an agent-mediated PKM, we conceive a knowledge worker working cooperatively with a software agent in a virtual workspace called a node. A node consists of a knowledge worker and one or more agents, also known as role agents, to perform some roles of the knowledge worker. The knowledge worker has a set of functions, some of which could be delegated to the agents. Our analysis of human-human interactions reveals that there are two types of function of a knowledge worker: (i) common functions, e.g. open

document, create/edit document, take action on document, upload/download document, delegate role, request; and (ii) unique functions based on the knowledge held, e.g. analyse problem, propose solutions, response-to-request.

The knowledge worker in a node needs to perform these functions with his/her knowledge to drive some work process within the organisation. We also identify the mundane housekeeping functions for which a software agent could be deployed based on the analysis of human-agent and agent-agent cooperation – agent functions to assist/complement humans, e.g. forward/receive documents, communicate with other agents, remind deadline, remind action, calculate and award/penalise merit/demerit points, log actions, open file, inform process delays, track process, information search.

A node, N, can thus be specified as follows:

- A knowledge worker, KW,
- All functions of the knowledge worker, f_i,
- One or more agents, A_j,
- All functions of agents, f_{jk}.

i.e. a node is a four-tuple structure, $N = < KW, f_i, A_j, f_{jk} >$, where $f_i \in KW$, $f_{jk} \in A_j$, and $i, j, k \geqslant 1$.

With such specification, a node can be easily replicated to instantiate another virtual workspace consisting of a knowledge worker, agents and their functions. Consequently, a significant parameter that is necessary to complete information and knowledge flows between two nodes is the exchange of information and resources between them. Such function can be tasked to a software agent and implemented by manipulating the link between the nodes, as exemplified by Figure 1.

While agents perform most of the communication, information searches, and resources exchanges, normal interactions between knowledge workers are also necessary to resolve offline issues with respect to the task at hand. Figure 1 displays a model in which an agent is delegated to assist the knowledge worker in performing diverse mundane tasks for all roles of the knowledge worker.

An alternative structure shown in Figure 2 depicts a number of agents 1. . . k, in Node 1, where each performs mundane tasks for each role of the knowledge worker. In the figure, only agent SA-2 performs the mundane task for one role of the knowledge worker – in this case, exchanging information and resources with Node 2. Presumably SA-1 and SA-k are delegated to perform other mundane tasks for other roles of the knowledge worker.

Extending this concept further to an organisational setting, there exist an ecosystem of multiple nodes involving human experts, non-experts, internal knowledge resources (databases, knowledge bases and repositories) and external knowledge resources (WWW). A knowledge worker, while performing his job, is likely to communicate and exchange information and knowledge between these nodes. Consequently, multi-structured (structured, semi-structured, and unstructured) patterns of work processes contribute to the achievement of some objectives and the subsequent fulfillment of some goals.

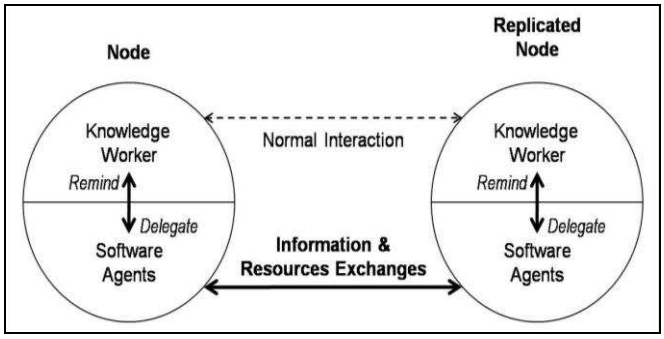

Figure 1. A Node and Interaction between Nodes

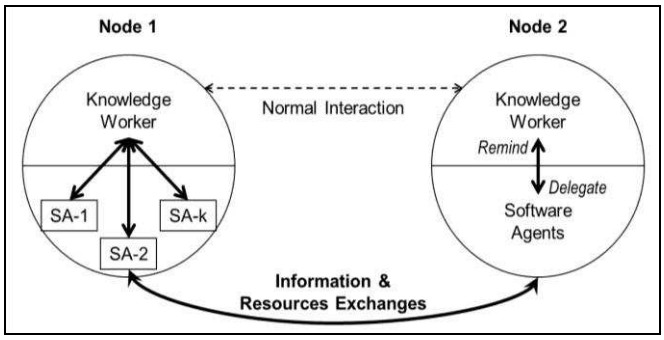

Figure 2. A Node with k Agents

It can be construed that such patterns of work processes represent PKM processes of the knowledge worker. Figure 3 shows such ecosystem involving multiple nodes.

Figure 3 also shows how a knowledge worker connects to three nodes with the help of a software agent (SA) for each of these different nodes. As an example, SA-1 refers to 'Software Agent 1' that connects the knowledge worker to another knowledge worker who is either an unprofiled non-expert or a profiled expert, who may or may not be assisted by a software agent. Similarly, SA-2 is another software agent that mediates the searching, connecting to the knowledge sources, and retrieving the required knowledge.

Figure 3 emphasises the possibilities of having different software agents (referred to SA-1, SA-2 and SA-N) to mediate the PKM process with other nodes. All the N agents communicate and collaborate with each other so that their human counterpart is served cooperatively to manifest an efficient PKM process. In order to achieve such efficiency, each agent should be able to match its human counterpart's profile with the relevant knowledge resources and knowledge experts.

Another possible alternative method shown here is SA-1*, where a software agent could be assigned to all roles, where it manages its human counterpart's personal knowledge by connecting to all the locations and mediating the KM processes.

Figure 3 supports hypothesis (H1) that **software agents can mediate the PKM of a human knowledge worker** and hypothesis (H2) that **agent-mediated PKM can be replicated**. This model shows some similarities with the restriction factors

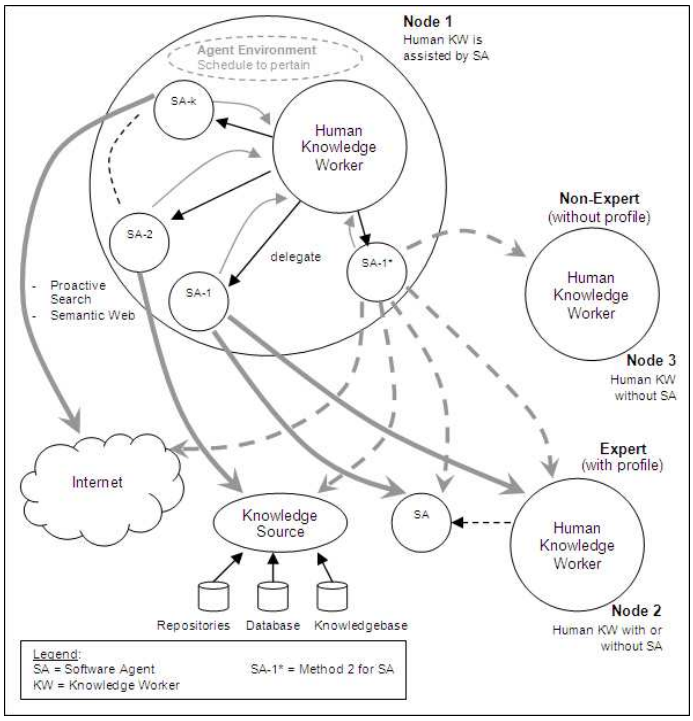

Figure 3. An Ecosystem of Multiple Nodes

of PI in [12]. For example, a software agent acts based on the **event** triggered by the human knowledge worker or the environment, where human knowledge worker is the **user** whom the agent is working for. Depending on the **content capture** required, the assigned software agent will check, try and choose the node to search.

These factors of PI prove that each node can represent a function in fulfilling an individual's PKM processes, and act as the individual's intelligence in handling tasks in an organisation. Thus, it supports hypothesis (H3) that **the replicated agent-mediated PKM represents a function of an *individual knowledge worker's intelligence in an* organisation**.

On a micro level, diverse tasks performed by individual knowledge workers overlap in an organisational setting and can be represented by a Venn diagram in Figure 4, which shows the common tasks and the individual or personal tasks. The overlapping tasks can be considered as the common tasks which all knowledge workers need to perform to achieve a common goal. Such tasks need to be performed concurrently or sequentially depending on the dependencies between tasks. Figure 4 supports hypothesis (H4) that **the replicated agent-mediated PKMs overlap each other to reveal tasks for a common goal**. It also proves that the symmetric difference areas of the nodes are the personal tasks of both knowledge workers.

The common tasks of individual knowledge workers can be assumed to support their corresponding key performance indicators (KPI), which they have to achieve to fulfill a common goal of the organisation. The common tasks may be independent of each other (i.e. each knowledge worker needs to perform task A) or dependent on each other (i.e. task B must

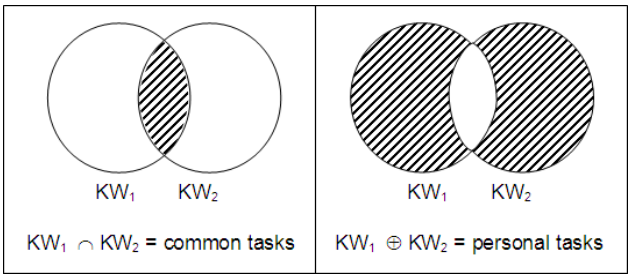

Figure 4. Common and Personal Tasks

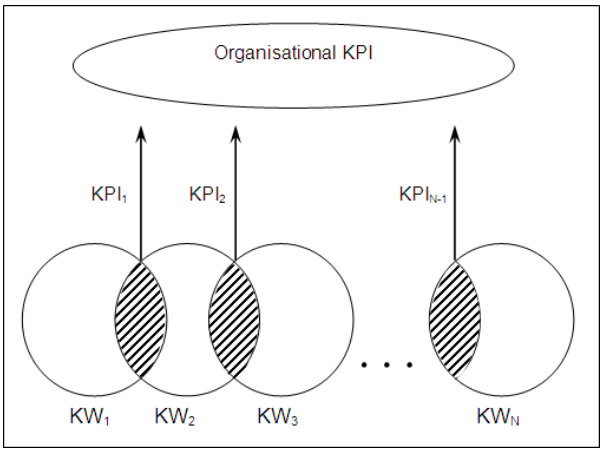

Figure 5. KPIs manifest OKM

be completed before task C can be performed). The integration of all tasks leading to the achievement of each KPI can be manifested as an OKM process, as demonstrated in Figure 5.

Figure 5 supports the hypothesis (H5) that **the overlapping replicated agent-mediated PKMs can be integrated to manifest an agent-mediated OKM** with KPI as the measurement metric.

If the intersection of common organisational tasks of knowledge workers:

$$KW_1 \cap KW_2 \cap KW_3 \cap \ldots \cap KW_{N-1} \cap KW_N \quad (1)$$

can be measured by their individual KPIs:

$$KPI_1 + KPI_2 + KPI_3 + \ldots + KPI_{N-1} \quad (2)$$

then the collective processes of achieving the organisational KPI can be construed as the OKM process.

$$\begin{aligned} KPI_o &= KPI_1 + KPI_2 + KPI_3 + \ldots + KPI_{N-1} \\ &= KW_1 \cap KW_2 \cap KW_3 \cap \ldots \cap KW_{N-1} \cap KW_N \end{aligned} \quad (3)$$

IV. Discussions and Conclusion

The conceptual model of agent-mediated PKM is conceived based on the people-oriented KM strategy, in which individual knowledge workers and their software agents drive the cycle of task performances while using and exchanging information and knowledge resources to complete the tasks. Knowledge workers are the central core of organisational processes, who create, use, exchange, and share knowledge with other knowledge workers to achieve some common goal. Each

individual knowledge worker, while interacting with other knowledge workers, performs structured, semi structured and unstructured tasks. The variety of ways in performing these tasks constitutes their personal approaches in managing their knowledge.

A knowledge worker and his/her agents can be abstracted as a node, which consists of the knowledge worker, his/her functions, the agents, and their functions. The agents perform their functions to assist the knowledge worker in performing his/her main functions, the completion of which supports the achievement of some organisational goal. Such symbiosis between human and agents can be construed as the intelligence in PKM. This concept can be extended to an ecosystem of multiple nodes, which interacts to manifest multi-structured processes of collective intelligence in OKM.

An abstraction of such multi-structured work processes consists of intersection of tasks, performance and completion of which lead to the achievement of a common goal. Further abstraction of this concept reveals a somewhat structured OKM process in which each knowledge worker performs tasks individually to support the achievement of a common key performance indicator. On the other hand, the symmetric difference of tasks represents an individual knowledge worker's personal tasks, the performance and completion of which lead to the achievement of individual goals.

The above discussion supports all our five hypotheses proposed in this paper. Software agents can indeed be deployed to mediate the PKM processes of knowledge workers. The nodal approach to agent-mediated PKM enables the replication of nodes where each represents a function of an individual knowledge worker's intelligence in PKM. Such intelligence overlaps to reveal tasks for a common goal, the integration of which manifests an agent-mediated OKM.

We shall establish the reliability of this conceptual model to support the bottom-up approach of PKM-OKM using quantitative and qualitative data to be collected and analysed in our future work.

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