Deploying the Concept of Agents of Things for Social Intelligence in Knowledge Management

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Abstract—Recent studies have shown that agent-based knowledge management (KM) systems have evolved into a more discrete perspective, known as personal knowledge management (PKM) that are rife within the social networks. The use of intelligent software agents has given way for new conceptual models to appear, utilising the belief-desire-intention (BDI) architecture of having goals and tasks that are aligned with each other. In one PKM model, the concept is illustrated as cognitive enablers, which are the drivers of a PKM’s get, understand, share and connect (GUSC) processes. Furthering this development, this paper conceptualises a 3D framework of Detect-Determine-Direct, in which agents are designed to mediate the tasks of knowledge mapping in manifesting social intelligence within a social network. The conceptual model is developed based on a questionnaire survey conducted among final year students of a Malaysian university. This 3D framework portrays the intelligent nodal entities of Agents of Things (AoT).

Keywords—personal knowledge management; software agent; nodal approach; social network; cognitive enablers; GUSC model; agents of things

I. INTRODUCTION

Knowledge management (KM) theories primarily discuss issues that are related to the organisational perspectives of knowledge, somewhat neglecting those that are related to university students in managing their personal knowledge. Having a lifestyle that is almost fully virtualised, the current generation of university students connect and communicate over the social networks during their learning processes, or in other words while managing their personal knowledge. Since the research domain shifted from KM to a more discrete level of personal knowledge management (PKM), the software agent technology is found to fit the needs in conceptualising models of intelligence behind the interactions and socialisation that occur within a social network during the PKM processes.

This paper discusses a related data survey conducted on a group of final year students from a university, to design a conceptual model based on the needs and understanding of how the students perform the PKM processes (i.e. get, understand, share and connect), interacts and connects with each other. In achieving this, we discuss the concepts of KM, PKM (related models like GUSC [1]) and software agent technology (the nodal approach [2] and agents of things).

We present this paper to meet our objective of deploying the concept of agents of things (AoT) by illustrating the social intelligence in agent environment, with our Detect-Determine-Direct (3D) framework.

The paper is organised as follows. Section II reviews the work related to our research. In Section III, we present the case study on students’ personal knowledge management process in relation to the GUSC model. The data is used in a social network analysis from which agents tasks are defined in Section IV. Section V discusses the conception of a 3D framework arising from the tasks defined for the agents. Section VI comments on the findings of the paper and Section VII concludes the paper.

II. RELATED WORKS

A. Social Intelligence in PKM

In contributing to the knowledge management (KM) domain, the GUSC Model [1] is introduced to depict the personal knowledge management (PKM) processes. The model postulates the processes of Get, Understand, Share and Connect [1, 3] that exist in a virtual network comprises of knowledge workers as its members. The model further manifests the KM application in software agent environment [1]. It also construes the existence of cognitive enablers, known as Identify, Method, Decide and Drive [1, 3], which are needed within the agent environment.

In general, PKM is “an evolving set of understandings, skills and abilities that allows an individual to survive and prosper in complex and changing organisational and social environments” [4]. The personal context of KM in recent studies have produced better insights on individuals and their understanding of knowledge for personal and professional growth [5], which is further exploited in system designs the GUSC Model derives [3, 6].

In highlighting the intelligence aspect of KM, social intelligence enables an agent to ‘understand’ and connect with other agents that utilise their individual intelligence [7], enabling it to achieve its assigned goals, such as identifying knowledge expert, understanding knowledge found as knowledge sought [8]. Social intelligence is also important to collaborate or compete for resources with other agents [7], especially in an integrated intelligence of module-based agents without a central coordinator [8]. This is seen as an opportunity to have agents’ ability to collaborate (instead of compete) for resources within a social network, in the quest for identifying possible knowledge experts beyond network boundaries. The use of agent-based technology for KM
purposes is supported by other research, especially in information processing, connection and end-user’s knowledge or behaviour for knowledge practices over computers [9], which need connections and knowledge processes among the community members over multiple channels including computers and mobile devices.

The latest contribution on multi-agent system’s design with the GUSC concept applied is the assignment of the four main processes as agent roles: get or retrieve knowledge; understand or analyse knowledge; share knowledge; and connect to knowledge sources or other individuals (i.e. knowledge experts) [1, 10].

B. Software Agents and the Nodal Approach

The definitions of software agents revolve around the common understanding of the agents’ capabilities in mediating tasks for human counterparts. The most quoted definition states that software agents are “entities that function continuously and autonomously in a particular environment that is often inhabited by other agents and processes” [11]. This definition supports the idea of agents being as encapsulated computer system situated in environment, and are capable of flexible actions to meet their design objectives [12, 13, 14, 15, 16]. High expectations are on agents’ ability to learn from experiences and environment, cooperate with people and other agents (i.e. socialising), and move around within private networks and Semantic Web [3]. The agents’ characteristics are depicted as intelligent, autonomous, reactive, proactive, able to communicate, adaptive, goal-oriented, capable to cooperate, reason, and flexible [17].

The nodal approach is a multi-agent model in which humans and their corresponding agents reside in a virtual node and communicate with other nodes [10]. According to this model, a node consists of a knowledge worker and one or more software agents, defined as role agents that perform some roles of the knowledge worker [2]. A node, N, can thus be specified as follows: a knowledge worker, KW; all functions of the knowledge worker, fi; one or more agents, Aj; all functions of agents, fjk; i.e. a node is a four-tuple structure, N = <KW, fi, Aj, fjk>, where fi ∈ KW, fjk ∈ Aj, and i, j, k ≥ 1.

Roles assignment to agents is similar to the concept of roles assignment to humans, in which the roles consists of tasks to perform depending on the goals – both ‘individual’ goals (own or personal goal) and collective goals (when the agents work together to achieve a common goal). A recent study proposes the application of the GUSC model as agent roles, with the software agents assigned with the get, understand, share and connect roles to mediate the tasks for their human counterparts [10]. This produces a multi-agent organisation in multiple nodes, which can be replicated within a virtual environment.

C. The Internet of Things (IoT)

The concept of the IoT is based on sensors (e.g. Radio Frequency Identification, RFID), which generates signal to identify the object it is attached to so that the object could be accounted for [18]. Without information, it is difficult to know and understand the implications of things that are related to human’s daily activities. However, if these things are connected, computations could be done on those things to benefit humans.

In her compilation on experts’ opinions on the possibilities of the IoT, Pretz [19] highlighted the integration of sensors and actuators with the cloud that defines the development of IoT industries. By stating the use of sensors and actuators, she suggested an extension in the research domain to include intelligent agents that are known to work based on sensors and actuators.

Chui et al. [20] highlighted the IoT concept in relation to data management scenario in which information travels along familiar paths. Proprietary information in databases is analyzed for reporting to the management and externally gathered information is acquired from public sources, such as the Internet, or bought from information producers. They claimed that these predictable information pathways are changing attributed by the change in the physical world that is becoming a special type of information system. In this new system, sensors and actuators are embedded in physical objects and are linked through wired and wireless networks using the Internet Protocol (IP). These networks generate huge volumes of data that are analysed by computers.

When objects are able to sense the environment and communicate, they become useful tools to understand the complexity and provide the ability to respond accordingly. The revolutionary innovation in all these situations is that these physical information systems are now beginning to be deployed, and some of them even work autonomously without human intervention. For example, billboards in Japan have been designed to peer at passersby, assessing how they fit consumer profiles and instantly change displayed messages based on those assessments [20].

Another concept presented on the evolution of the IoT is the Internet of People, where computers are connected to the Internet communicate with each other [21]. Such connection has moved beyond the physical computers to connect mobile devices with which people interact and exchange messages and information.

Beyond such connection, devices and gadgets (or things) are also connected to make it possible for objects to get information about their position in the world, to interact with other objects and to have access to comparative information for data gathered in their vicinity. Seeing the tight coupling between devices in IoT with the ‘people’ or humans who have these devices on them at all times and using them in certain behaviour or usage patterns, it paves the way for the emergence of the concept of Agents of Things (AoT) in which software agents are programmed to work closely with their human counterparts.

D. Agent of Things (AoT)

Mzham [23] introduces the concept of Agents of Things (AoT), which is an extension of the concept of Internet of Things (IoT) [19]. The IoT concept entails that if all objects are equipped with some kind of electronic tags, they could be identified and their situations could be monitored for immediate actions of some sort. He extends this concept further, which he called the Agents of Things (AoT), by embedding these tags with software agents that perform
tasks in mediating the processes required for the monitoring and reporting actions. The reason for embedding agents in devices (or things) is because these devices are generally considered as passive unintelligent devices, reacting only to queries or requests and do not proactively exploit their environment for other value-added services to humans. The concept of agents of things attempts to connect all objects (or things) in agent-like environment so that information about the objects can be accessed. While the Internet of Things (IoT) attempts to assist humans in deciding better data management solutions for their domain-specific problems by sending relevant information, the Agent of Things attempts to augment the IoT by embedding intelligent software agents in things to enhance the services that could be derived from the interactions of agents in those things [23].

The challenges perceived in implementing and manifesting AoT include fulfilling the need for agents to reason on its environment, identify specific actions to take and whether those actions are within its autonomy [22]. Based on the initial theory by a group of researchers in Malaysia [23], the concept of AoT involves the thing itself. For example, a simple RFID sensor provides a unique identifier for the object it is attached to and stores information about the object. A simple agent-like function for an RFID is to respond to a query command, relaying its information back to the requester. We consider all Things as belong to a set, \( T \), in the like of Classes and Objects. Each thing is represented as a node, \( N \), which consists of an agent, \( \alpha \), and its optimised set of functions, \( \Phi \), i.e. \( N = \langle \alpha, \Phi \rangle \).

Hence, the concept of AoT is a clear extension of the nodal approach. The issue in AoT is to determine what architecture (knowledge, reasoning, action, communication) are necessary in agentising a wide spectrum of Things. A formal rule is required to determine a cost-effective architecture for each thing that performs its function.

### III. A CASE OF A UNIVERSITY COMMUNITY

#### A. Research Settings and Methods

A group of final year degree students who are undertaking their final year projects is approached to answer a questionnaire. The questionnaire is designed to help us in tabulating the weight of each PKM process that links the students to other individuals. Out of 30 students approached, only the results retrieved from six respondents are presented here, since this research is still in progress. Respondents are given a code from R001 to R006 during the data collection and tabulation.

Four out of six respondents are the members of the two prominent social network groups formed and managed by lecturers who monitor the progress of students under a degree programme called BCNM: BCNM FYP Group and BCNM Club Group. Two out of six respondents are the members of a social network group formed and managed by a lecturer who conducts workshops for BCNM final year project students, called “MSI’s Research Cluster Group”.

In terms of being notified with updates related to final year project (FYP), the respondents agreed that they are connected via mobile phones at most times (i.e. all respondents agreed), followed by the announcements made on the social network group (i.e. five out of six respondents agreed). This result also shows that respondents do not rely heavily on their FYP supervisors, which also indicates the lack of communication with the supervisors due to less number of meetings with them.

Respondents are asked to rate their agreement on statements related to Get, Understand, Share and Connect processes, based on their online interactions with a list of individuals: FYP Trainer, FYP Coordinator, FYP Supervisor, FYP peers, and external party. They are required to provide general names to the respective individuals, to help us in plotting the social network diagram during the analysis stage.

Respondents are also requested to answer five questions related to the cognitive enablers, to help verify in the GUSC network tabulation. Fig. 1 shows the significant findings on the cognitive enablers.

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**Fig. 1.** Survey findings on cognitive enablers.
Regardless of the significant relationship links presented between respondent R003 and the FYP Trainer for the Get, Understand and Share processes (not shown here), Fig. 2 shows that there is no connection between them (i.e. $w_{U,R003-FYPTrainer} = 0.00$). The reason behind this could be that the respondent R003 does not feel connected to the FYP Trainer via the social network, based on the activities described in the Connect statements in the questionnaire survey.

The following are the significant findings derived from the network diagrams presented for the GUSC processes:

- The existence of isolation case: the node labelled Supervisor MRT, who is the respondent R002’s FYP supervisor.
- The high reliance on FYP Senior, with all GUSC links carrying strong weight values (i.e. $0.50 \leq w \leq 1.00$); the results from the respondents connected to this senior show less understanding from the lecturers (i.e. $0.00 \leq w_{U} \leq 0.49$), compared to understanding the senior’s explanation (i.e. $0.50 \leq w_{U} \leq 1.00$).
- Only one respondent declared having connection with an external party (i.e. External AbdHafiz), probably because the other respondents are not yet at development stage of their final year projects, hence the less need for connections outside of the university boundaries.
- There is a difference in relationship link weights when the same lecturer plays a role of a FYP Trainer/Coordinator and FYP Supervisor (refer to the cases of respondent R003’s connections to FYP Trainer and Supervisor MSI, and respondent R006’s connections to FYP Coordinator and Supervisor MWN).

IV. DEFINING THE AGENTS’ TASKS

Even though the agent-mediated PKM emphasises on the processes more than the cognitive enablers, the latter is seen as a better potential in making full use of the software agents’ strong notions, especially to demonstrate the agent-agent PKM processes. With this opportunity of manipulating the capability of the agents, the following tasks and subtasks are assigned to four agents that are defined based on the activities over the social network. The agents’ names are based on the cognitive enablers, whereas the subtasks are defined based on the PKM processes found necessary to be performed by the agents.

Identify Agent’s tasks:
- Task 1. Agent \textbf{detects} who knows what.
- Subtask: Get network members’ profiles.
- Task 2. Agent \textbf{detects} the members’ roles.
- Subtask: Get and understand the roles from the profiles.
- Task 3. Agent \textbf{detects} who the knowledge is for.
- Subtask: Understand the knowledge value by getting the tags, likes, votes, and comments on the knowledge share within the network.

Decide Agent’s task:
- Task 4. Agent \textbf{determines} who the knowledge is for.
- Subtask: Understand who needs what knowledge and match with new knowledge retrieved from the network.
- Task 5. Agent \textbf{determines} the best way to share the knowledge to the identified recipient.
- Subtask: Understand the members’ preference and availability from activity pattern and behaviour over the network.

Drive Agent’s task:
- Task 6. Agent \textbf{determines} the urgency of the knowledge to the identified recipient.
- Subtask: Get to understand the sharing needs, urgency and priority from the network and profile.

Method Agent’s tasks:
- Task 7. Agent \textbf{directs} the knowledge in a form suitable to the recipient (learnability defined).
- Subtask: Share the knowledge in the preferred format (i.e. that the members who need it prefer as a connection form).
- Task 8. Agent \textbf{directs} the knowledge through the channel suitable to the recipient.
- Subtask: Connect to the members through the preferred ‘connect’ channel, device or tool.
- Task 9. Agent \textbf{directs} the knowledge through multiple paths if it is urgent to reach the recipient (including through social network members’ paths).
- Subtask: Based on the sharing needs, urgency and priority, connect to the members through multiple ways to ensure that the members receive the knowledge.

V. DETECT-DETERMINE-DIRECT (3D) FRAMEWORK

A conceptual model is designed according to the tasks defined for the agents. From the tasks assignment discussed in Section IV, a pattern emerges in terms of defining goals for the agents: “Detect” as Identify Agent’s goal; “Determine” as Decide and Drive Agents’ collective goal; and “Direct” as Method Agent’s goal.
Since the goals are the basis of this conceptual model, the overview of the multi-agent system in Fig. 3 shows the 3D partition or territory that the goals covered.

![Diagram of 3D Framework]

**Fig. 3.** Detect-Determine-Direct (3D) Framework.

In the Detect-Determine-Direct (3D) Framework, we assign the Identify Agent to reside in the social network with certain boundaries, to avoid the agent from being ‘lost in space’. The main goal for this agent is to “detect”. The agent should be able to roam within the network to perform tasks 1, 2 and 3, as described in Section IV. This agent will then report to the central knowledge repository on the findings of those tasks.

The agent residing in the central knowledge repository is the Decide Agent that mainly ‘understands’ or analyses the report retrieved from the Identify Agent. In doing so, this agent performs tasks 4 and 5, as stated in Section IV. The main goal for Decide Agent is the same as the Drive Agent, which is to “determine”.

The Drive Agent concentrates on performing task 6, which is heavily on determining the urgency of the knowledge needed by the members in the social network. With this task in hand, there is a need for the Drive Agent to monitor the social network, to ‘pick up’ any form of date and time stamps (that is later than the current system date and time stamps) mentioned in the network by its members. This finding is further analysed to determine if it is a potential source of urgency, need and priority of the identified members. If urgency is determined, then a report is submitted to the Method Agent for further action.

Method Agent falls under the goal to “direct” (i.e. define the action, distribute). It performs the actual tasks of connecting to the members of the social network, via various channels or mediums, because the members may not always be online in time to get the urgent knowledge that they need. In doing so, it also reports to the knowledge repository on its chosen method and success rate in directing the knowledge to the rightful recipients. As defined in Section IV, the Method Agent performs and reports on tasks 7, 8 and 9.

**VI. AoT in Social Intelligence Environment**

The 3D framework is a form of proactive multi-agent system that manifests social intelligence within a virtual environment without humans’ intervention. The framework’s implementation exploits the concept of AoT by locating agents in ‘things’, such as the social network environment (i.e. network system) and the knowledge repository (i.e. database). Other possible locations for agents to be assigned at include the devices that the humans prefer to use for urgent matters (e.g. mobile devices), to which the Method Agent would have chosen to direct the knowledge.

The organisation of the 3D framework utilises the BDI architecture with which the AoT concept that incorporates the nodal approach operates. Such organisation manifests the intelligence in knowledge management that emerges as a consequence of the social interactions between the agents.

**VII. Conclusion and Future Work**

This paper exploits the concept of Agent of Things (AoT) to implement the emergence of social intelligence manifested by the interactions of software agents embedded in things. The AoT is an expanded concept of the IoT in which software agents are embedded in things to perform reasoning and communication actions. Such actions are necessary precursors of intelligent behaviours.

A survey solicits information that reveals network-like interactions from which a set of agent-based tasks are conceived. Consequently, a formal rule is created in the form of the Detect-Determine-Direct (3D) framework, which is a cost-effective architecture for each thing to perform its functions. Most of the things or devices are currently used in the humans’ environments, which are exploited by the AoT concept.

In the KM scene, the concept of knowledge management is not merely confined to organisational scale issues, but also implementable at a discrete level of KM as depicted by the social interactions of software agents in performing the tasks for their human counterparts.

In our future work, we shall enhance the concept of agents of things further and implement a new application based on this concept.

**REFERENCES**


