International Journal of Computer Applications (0975 – 8887)
Volume 43– No.12, April 2012

A Nodal Approach to Modeling Human-Agents Collaboration

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ABSTRACT
In this paper, we present the concept of a node which consists of a human actor, one or more agents, and their combined functions to represent a collective intelligent entity. Basically, the instantiation of nodes with diverse pre-defined functions in a workflow process could represent a domain in which humans interact with other humans via software agents in a collaborative environment to achieve some common goal. Here, the agents' functions supplement the demands of the corresponding human's pre-defined functions. As a part of this research, a survey is conducted to determine generalized functions of humans and agents in a node. The aim is to solicit information pertaining to humans' daily tasks and the kind of assistance they would prefer to have to ease those tasks. The tasks entail communicating with people, using several devices and/or media such as Document, Email, Phone, and SMS. This paper proposes a Nodal Approach (NA) to simplified modeling of humans and software agents with their pre-defined functions for collaboration. An example user application is developed and tested involving several academician functions assisted by their corresponding software agents.

General Terms
Collaboration, Environment, Behaviors, Autonomy, Models.

Keywords
Software agents, multi-agent system, nodal approach, human-agent node, academician functions.

1. INTRODUCTION
An agent is an entity that acts in its environment and judged based on its actions (e.g. humans, worms, insects, etc.). A computational agent is one whose action and decision can be explained in computational terms [1]. In computer science, we are interested in developing such agent that can act intelligently on its own decision [2]. For example, an agent that is equipped with cameras to receive input about its external environment, an agent that is associated with an expert system to receive input information from humans and carrying out tasks or it could act purely in a computational environment, i.e. software agent.

The rapid changes that are occurring in the information world has somewhat reduced our capacity to deal with the information we need. Consequently, a diversity of roles can be delegated to software agents to ease the drudgery of mundane tasks. Such roles include monitoring, filtering, detection, recognition, and information retrieval [3]. Intelligent software agent can be considered as a solution to these problems and it can make the real world less complex.

One of the characteristics of a software agent is autonomy. An autonomous agent can create its own decisions in a wide range of circumstances and provide an alternative approach to its performance. Moreover, it enables systems to be self-managing as it can be provided with knowledge of how to deal with problems in special situations, rather than being explicitly programmed to resolve predictable situations [4].

Numerous agent modeling techniques have been proposed and developed in several areas that possess large and complex relationships between agents (e.g. AOM [5] and GAIA [6]). However, modeling agents pose difficulties in a variety of aspects. One of these difficulties is when there are many agents involved to resolve a particular issue. In this case individual agents are modeled and assigned different functions [7]. Figure 1 illustrates some of the possible actors and interactions of a typical agent model.

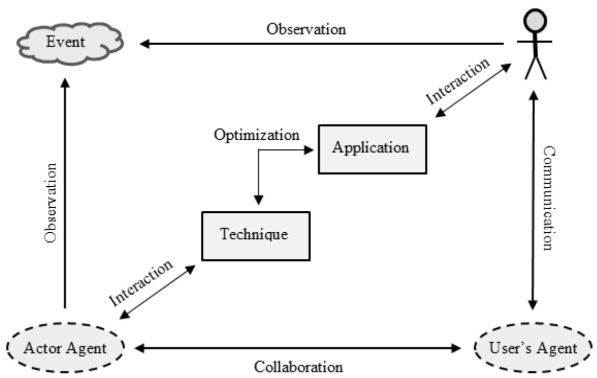

Fig 1: A typical agent model

If the agent is an assistant to a human actor, several other interaction aspects are required to be modeled in such setting. In addition, communication, or in some cases in conjunction with other techniques, applications and events are more likely to be necessary when they are parts of the same environment [8].

In this paper, we develop a modeling technique in which a human actor is assisted by one or more agents. Conceptually, we consider the symbiosis between a human actor, his/her one or more agents, and their combined functions as a node. To ensure the generality of the human's and agents' functions and the applicability of the model to a wide range of domains, we conducted a questionnaire survey to identify the possible functions that could be performed by a human actor in real world environments.

2. OBJECTIVES

Researches on the conceptualization of complex systems, which compose of several agents, are continuing, e.g. [9], [10], [11] and [12]. Consequently, this paper proposes another approach to agent modeling via the concept of a node. We propose to formulate this approach via the following objectives:

- To develop a model for human-agent collaboration using the concept of a node by investigating the collaborative structure of a human actor and an agent.
- To identify common functions for the human actor and his/her agent in implementing collaboration.

3. LITERATURE REVIEW

Collaboration means parties, people, or organizations which see different sides of a problem and try to solve it together. They explore their differences and search for solutions that go beyond their own limited vision of what is possible. It involves relationships between people toward commitment to general mission, thorough communication and planning, pooled resources, and shared risks and products [8].

A collaborative agent is an agent that works together with humans and other agents to carry out a task [7]. Collaboration is useful in several areas; ant colony is a good example. Each ant has some capability, but when many of them work together, they can do an incredible task such as moving heavy objects. Similarly, if we can arrange several agents to perform tasks cooperatively, we can achieve some goal more efficiently.

A common structure for collaboration is defined as an evolving forum for improving and accomplishing goals and for resolving complicated matters [8]. An adequate structure forms to implement created solutions jointly. In fact, such structure holds more explicit integration of members' interests, roles, and resources. Typical forms are collaborative and continued coalitions.

3.1 Agents Behavior

An agent does not just act on any ground but it has to interact with its environment, other systems or some other sources to extract information. It interacts based on its prior knowledge, history of interaction with the environment, goals of what it is trying to accomplish, and abilities which consist of basic actions that it is capable of [13].

Knowledge and reasoning are important to the agent because they enable successful behaviors that would otherwise be hard to achieve. An agent can receive knowledge by accepting input from a human actor and knowledge bases and it can be designed in a way that is capable of perceiving its percepts or autonomy [14].

3.2 Collaborative Agents

Models are normally intended to formalize the meaning of systems. A modeling process initially starts as an abstract of initial ideas. Progressively, these abstract ideas are converted to concrete, detailed, closer to reality model and subsequently implemented.

Usually, humans interact with agents via a set of commands in closed systems [9]. In these systems, an agent is delegated to handle tasks for its human counterpart. Consequently, an agent is tightly coupled to its human counterpart to improve the workflow process [15].

The definition of collaboration by [16] delineates the kind of behavior that we are beholding which is "a coordinated, synchronous activity that is the result of a continued attempt to construct and maintain a shared conception of a problem." As a matter of fact, the tasks of a collaborative technology are difficult to be evaluated and validated. Hence, the technology that corresponds to the tasks could be successfully deployed based on high level of competency and/or cooperation to achieve the required objective.

Collaborative agents (humans or software) should have the capacity to discuss and negotiate the goal towards its achievement [17]. Agents need to have the capacity to choose options and then decide on courses of action including; assigning different parts of a task to different agents, assess the current situation, explore possible future eventualities, determine resource allocation, negotiate initiative in the interactions and report to others to update shared knowledge [18]. Such capacity lends well to the concept of a node.

3.3 Collaborative Systems

A collaborative system possesses multiple users or agents which are engaged in a shared activity, sometime from remote locations. In large distributed applications, we distinguish collaborative systems by the fact that the agents from the system are working together in order to reach a common goal i.e. Multi-agent System (MAS) [11], [19]. Figure 2 elucidates some of the MAS core entities.

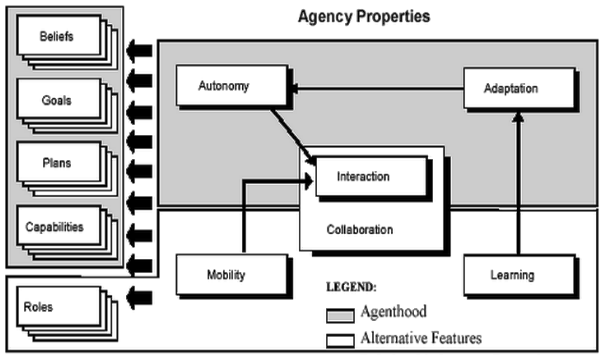

Fig 2: Traditional multi-agent system [20]

Chen et al. [21] present a collaborative system which is an innovative Human Agent Collaboration (HAC) framework aiming at flexible human agent cooperative tasks. The framework employs MAS technologies and human agent interaction concepts. High quality decisions often require the combined intelligence of multiple agents that collaborate in a situation, combining their knowledge, expertise and capabilities to reach a better outcome than each could reach alone. The HAC framework is realized through negotiated processes including computational agents and people. It ensures that human experts are kept attentive and can always influence their task assignment processes through collaboration with software agents for coordinated problem solving.

Recent research on human-centered teamwork highly demands the design of cognitive agents that can model and exploit human partners' cognitive load to enhance team performance. It focuses on teams composed of human-agent pairs called Shared Mental Models for all (SMMall) [22]. SMMall implements a hidden Markov model (HMM)-based cognitive load model for an agent to predict its human partner's instantaneous cognitive load status. It also implements a user interface concept called shared belief map, which offers a synergistic representation of team members' information space and allows them to share beliefs.

3.4 Adaptation Through Collaboration

Several researchers have proposed ideas to bring comparable adaptation and learning to human-computer collaboration. The critiquing paradigm naturally shows a form of learning to users. It shows a well-designed critic that presents an alternative perspective on what a user has done by pointing out potential problems, suggesting additional relevant issues to consider, and making reasonable guesses to fill in low-level details [23].

In another approach, extending argumentation dialogues is proposed to allow users to modify the system's argument base: The IBIS method and derivatives [24] are commonly used to organize argumentation. As users interact with such an argument structure, it is easy to allow them to add new issues to be learned.

4. THE CONCEPT OF HUMAN-AGENT NODE

The Nodal Approach (NA) is conceived based on the concept of a node in which a human actor and his/her one or more agents virtually reside. The human and agent functions are selected, which correspond to the human actor's role in the domain. The agent assist its human counterpart by performing routine and mundane tasks (i.e. the tasks which the human should not worry about) [15], [17].

4.1 Modeling Nodal Structure

The idea of this concept is motivated by the difficulty of using and familiarizing existing agent platforms to implement workflow processes that involve humans and agents [15]. This concept espouses the notion that agents could be deployed to assist humans in many common workflow processes to handle mundane tasks. Consequently, in this concept, an agent is tightly coupled with its human counterpart. The human-agent coupling represents a symbiotic relationship between a human and his/her agent. We model such symbiosis as a node which consists of the human and one or more agents.

In the node, the human is accorded with a set of functions. Correspondingly, the assisting agents are also conferred with a set of functions which extends and supplements those of their human counterpart [18]. The human interacts with the agents via a set of commands reflecting the functions performed by him/her and the agents respond to him/her via messages displayed in some agent interface. Figure 3 and 4 show the concept of a node which constitutes the human and his/her agent(s).

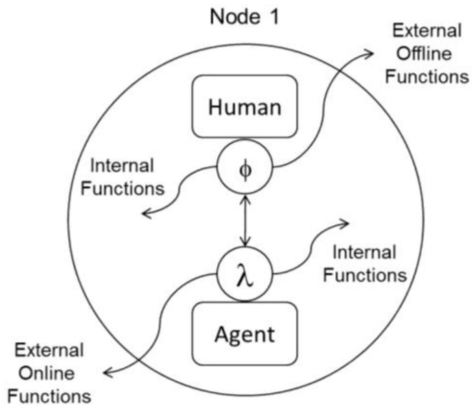

Fig 3: Node 1

Figure 3 shows the structure of Node 1. It shows a human with his/her set of functions, ϕ, and one agent with its set of functions, λ, presumably to handle all the mundane tasks of its human counterpart. In Node 2, as shown in Figure 4, the human is assisted by three agents. Each of them handles one or more specific mundane tasks for its human counterpart. The human's and agents' functions are selected during the create mode, in which relevant human and agent functions are selected to instantiate a node.

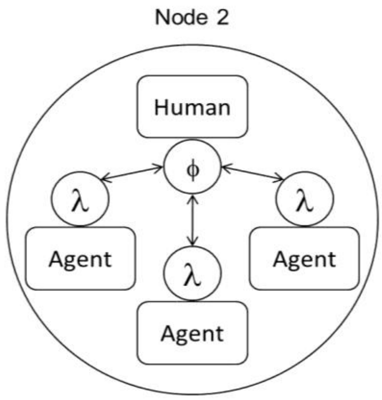

Fig 4: Node 2

Depending on the functions selected, the node represents a unique intelligent entity, which behaves and operates within a collection of other unique nodes to achieve some common goal. Consequently, in the create mode, a user could create the following nodes:

- A human-only node, when no agent's functions are selected,
- An agent-only node, when no human's functions are selected,
- A human-agent node, when a human's and an agent's functions are selected,
- A human-agents node, when a human's and many agents' functions are selected.

Depending on the application domain, nodes could be instantiated by selecting relevant human's and/or agents' functions to animate some workflow process. For example, Figure 5 shows a simple interaction between two nodes to exchange information via the agents. Normal offline interactions between humans proceed as usual.

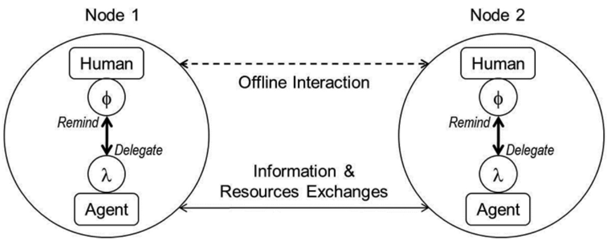

Fig 5: Nodes interaction

4.2 Logical Model of a Node

Firstly, we need to identify the entities which are involved in our model. In the following sub-sections we define these entities.

Definition 1: A node is defined as a virtual entity which implements a set of actions based on the functions performed by a human actor and the agents to achieve some goal.

We model a node to consist of a human actor, one or more agents, and their combined functions. The functions performed by the human actor and his/her agents are consequences of the states of the environment E. The human actor and his/her agents share a common workspace, W, within the node. So, a node N, is a virtual structure, which consists of six entities: Human, H; his/her set of functions, ϕ; a set of agents, A; a set of agents' functions, λ; environment, E; and work space, W, or,

$$N = <H, \phi , A , \lambda, E, W>$$

Definition 2: A human function, $\phi_i \in \phi$, is an action performed by the human actor on a set of artifacts Art, to produce a set of outcomes, O. The action handles the input artifacts such as document; email messages; phone calls; SMS messages; and people. Some of the functions that a human performs upon these artifacts are send, forward, record, save, delete, etc.

If Art is a set of artifacts, and O is a set of outcome of actions performed on those artifacts, then,

$$\phi: Art \rightarrow O$$

Definition 3: An agent, $\alpha \in A$, is defined as an entity which performs a set of functions λ based on the current states of the environment, E, to produce a new set of environment E', i.e.

$$\alpha: \lambda \times E \rightarrow E'$$

Definition 4: An agent function, $\lambda_i \in \lambda$, is an action performed by the agent, which extends the action of its human counterpart for the achievement of some goal.

The functions of the agents performed on the artifacts, Art (document, email, etc.) extend and supplement those that the human does. Such functions include sending message, record, save, remind, etc. If O is the set of outcomes of a human's functions, an agent function extends the function of its human counterpart, which affects the state of the environment E, then

$$\lambda: O \rightarrow E$$

Within a particular node N_n, a human function is to be satisfied by the cooperation of both human's and agent's actions.

Definition 5: An environment, E, is a set of states, e_i, which governs the behavior of agents, i.e.,

$$E = \{ e_i \mid i \geq 1\}$$

Definition 6: A workspace, W, is a shared work area where the human actor and his/her agents perform their actions and in which they store artifacts at a set of locations, L, i.e.,

$$W = \langle \phi, \lambda, L \rangle$$

Definition 7: A location, $l \in L$, in a workspace is an artifact store defined with an atomic name, e.g. an empty location is defined as simply, *s1*, and a location, *s2*, in which an artifact, *doc1*, is (to be created and) stored is written as *s2(doc1)*.

5. HUMAN & AGENT FUNCTIONS

The challenge in this research is to identify the possible functions that could be attributed to humans that cover a wide range of domains. To address this challenge, we conduct a two-part questionnaire survey to solicit information about the kind of operations that are performed by humans in their tasks. We distribute the questionnaire to the academic staff of our College in diverse positions. For the first part of the questionnaire, we gather information on the kind of tasks they normally perform to process the inputs, which they received and the outputs they produce. The outcomes are utilized in configuring the human functions in a node.

5.1 Human Functions

We conceive a scenario in which a human (academic staff) handles the inputs (tasks) and outputs (responses) of five categories of artifacts (people, devices, and/or media). The artifacts are People; Documents, including books, magazines, etc.; Email messages; Phone calls; and SMS messages. For each category of questions, we set a threshold based on the percentage of respondents' responses. Table 1 and 2 summarize the results for the input tasks and the corresponding output responses respectively.

Table 1: Input tasks

Actions / Responses	Documents	Phone	Email	People
Response1	Read and understand the contents	Note down the information	Read and understand the contents	Discuss, Consult, Instruct
Score	90%	70%	100%	60%
Response2	Foreword to another location	Take action on information immediately	Take action on information immediately	Take action on information when the time comes
Score	60%	60%	50%	80%
Response3	Take action on information immediately	Take action on information when the time comes	Take action on information when the time comes	Take action on information immediately
Score	70%	50%	70%	30%
Response4	Keep in view (KIV) until a set time before taking action	Foreword the massage	Foreword to another location	Note down the information
Score	60%	40%	50%	50%
Response5	Keep for reference	Ignore	Archive/Store	Redirect person to other person/device
Score	50%	0%	70%	50%
Response6	Discard/ Through away		Print	Ignore/Not relevant
Score	20%		0%	0%
Response7			Move to another folder for Keep in view (KIV)	
Score			30%	
Response8			Delete	
Score			50%	

Table 2: Corresponding output responses

Outcomes / Scores	Documents	Phone	Email	People
Outcome1	Document is unchanged and forwarded	Contents, massages are unchanged and forwarded	Contents, massages are unchanged and forwarded	Decision on information
Score	70%	70%	60%	90%
Outcome2	Document is changed and forwarded	Contents, massages are changed and forwarded	Contents, massages are changed and forwarded	Instruct (verbal) someone to take action
Score	60%	20%	60%	90%
Outcome3	New document is created an send to another location.	Create new document from the content	Create new document from the content	Create new document from the information
Score	40%	30%	30%	30%
Outcome4	Email the content/New information to other location			Email information to someone
Score	70%			50%

From these input tasks and the output responses, we identify those that have similar semantics to be defined as functions for the human actor. Sixteen such functions are determined from the semantic analysis of the input tasks and the output responses: Display, Upload, Move To, Redirect, Forward, Discard, New Document, Decide, Postpone, Take Note, New Email, Instruct, Respond, Print, Inquiry, Save & Exit.

5.2 Agents' Functions

In identifying the agents' functions, we firstly gathered information for the second part of the questionnaire, which is about the kind of tasks that human would assign to an assistant. The results are then summarized in Figure 6 which shows the tasks that supplement the corresponding human's tasks of Table 2. We postulate that the agent's tasks are common to all agents.

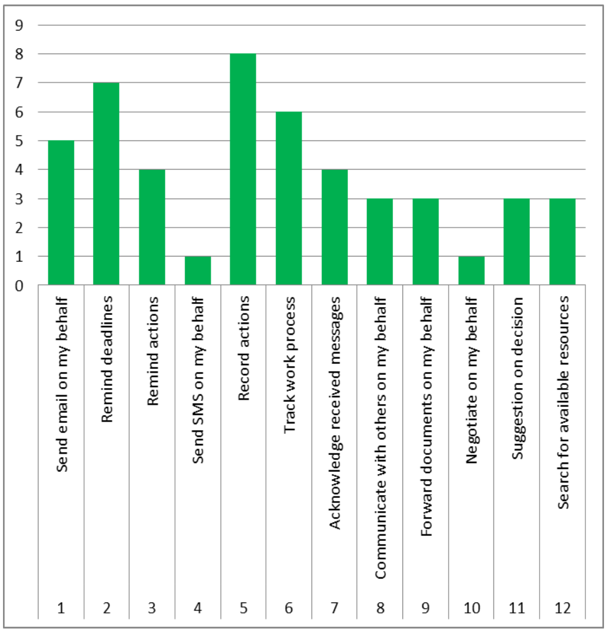

Fig 6: Agents' tasks

Figure 6 shows twelve possible tasks that an assistant could do for a human. We select a threshold value of 1 indicating that items (4) and (10) are omitted from the selection. All others are retained for potential agent's functions. Upon analysis of Figure 6, we conceive the agent's functions, λm, where m is the function number. The proposed agent functions are listed in Table 3.

Table 3: Agents' functions

No.	Functions	Description
1	Display λ1	Displays the message window on the screen. This message helps human to know what he/she should do (e.g. submit the documents).
2	Send λ2	Send letters, SMS, emails, etc. from someone to other human with different addresses.
3	Reminder Action λ3	This function helps humans via urging them to answer received emails, documents etc.
4	Record action λ4	This function keeps received document, SMS, etc. which the human can exploit later. It records the action in a file since an agent is performing action.
5	Track documents λ5	This function is used to know the current location of received documents, emails etc.
6	Ack λ6	Acknowledge the sender about receiving the documents, messages, etc.
7	Forward a document λ7	Send letters, SMS, emails, etc. received from someone to other human with different addresses.
8	Suggest λ8	This function is to give a suggestion and it might be decision for a current issue.
9	Search λ9	The role of this function is to search for available resources.

6. IMPLEMENTATION & TESTING

An application to demonstrate the collaborative process between two nodes is implemented. In the prototype, a user selects particular functions for the human and his/her agent relevant to his/her role in the domain. Each node interacts with one or more nodes based on the domain's work process. A multi-agent system is manifested when multiple nodes are instantiated. The interactions within the node as well as between the nodes animate the work process that leads to the achievement of some common goal.

We use Win-Prolog to develop the prototype. It is a logic programming language associated with artificial intelligence and computational linguistics [25]. Win-Prolog has an extended module Chimera, which provides the codes to implement peer-to-peer communication via the use of TCP/IP. Prolog treats data as programs and its expressions can be read from a program (text) for subsequent execution.

6.1 Node Functions Implementation

In this section, we describe a small part of the implementation of the NA to human-agent and agent-agent collaboration. The approach facilitates such collaboration by employing the human and agent functions identified in Section 5.1.

6.1.1 Postpone and Reminder system

In this system, the agent alerts its human counterpart which currently holds the artifact (e.g. documents) by sending a remind message. The following codes show a segment of the Postpone and Reminder function's implementation.

```
% Reminder procedure
node_handler( (node_dialog,24), msg_button, _, _ ):-
node_handler( (node_dialog,26), msg_button, _, _ ),
wclose( node_dialog),
init_node,
load_files(message_file),
agent_message(Message),
wtext( (node_dialog,10), Message),
wenable( (node_dialog,23), 0 ),
timer_create( clock2, clock_hook2 ),
  timer_set( clock2,3000).
  clock_hook2( clock2, Interval) :-
  time( _, _, _, _, _, Second, _ ),
  (
    fwrite( r, 2, 10, Second )
  ) ~> New,
  timer_set( clock2, 3000  ),
  timer_close( clock2 ),
node_handler( (node_dialog,10), msg_button, _, _ ),
reminder_message.
```

Upon receiving the artifact, the agent shows a message about the artifact to its human counterpart, whether he/she wants to display or postpone it. If the human is busy doing other work, he/she can click the 'Postpone' button. In this case, the human does not need to memorize what they have received, thus help him/her in reducing his/her cognitive load.

6.1.2 Status for Sending Message

An agent sends a message to its human counterpart based on the selected function. Then it performs some actions to respond to what its human counterpart needs to do in the message-sending action. An agent may comply with the following states: Display Message, Reminding and Save.

6.1.3 Steps for Sending Messages

A human actor receives a message from another human actor who requests to act upon the contents of the message. In order to send a message, there are some steps that need to be done, such as setting the agent's IP address and port number (the agent is addressed via an Internet Protocol). When the human needs to send a message he/she:

- Open a port to get connected,
- Set the address of agent,
- Initiate the message-sending function.

The port is disconnected when the message has been successfully sent.

6.2 Results Testing and Analysis

We show and illustrate our NA model interfaces and demonstrate the simulation of the prototype. The simulation attempts to cover some functions of the prototype represented by screen messages for humans and the agents, such as reminder from agent to its human counterpart.

6.2.1 Node Creation Interface

Figure 7 shows the node creation interface. The figure shows a few parameters that identify a node, such as Node Name, No. of agents, and System Mode. A user then selects the functions which he/she requires his/her node to have by clicking the relevant check boxes. In the figure, seven functions have been selected for the user and six function for all the five agents.

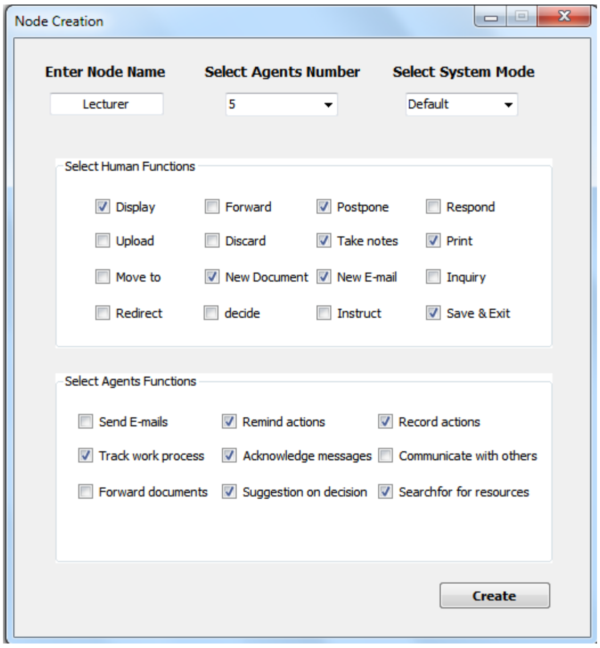

Fig 7: Node creation

6.2.2 Node Interface

As described in Figure 4, the human is tightly coupled with one or more agents that perform tasks on behalf of the human. Here, we show and demonstrate a node's interface. Since it is undeniably impossible to show all the functions performed by the human and his/her agent working in a node, we only explain some selected functions of the agent and its human counterpart (see Figure 8).

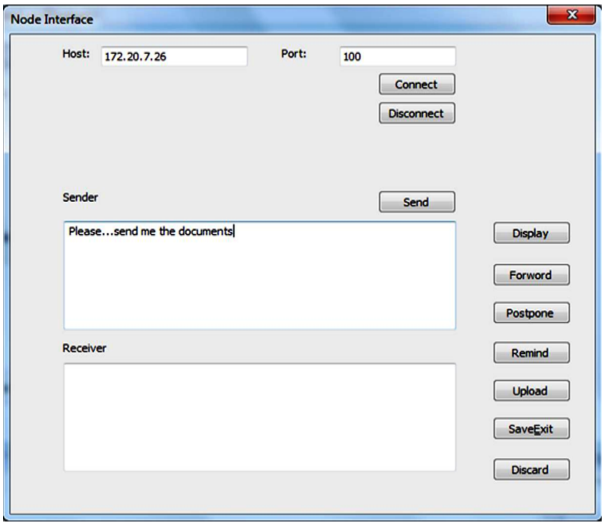

Fig 8: Node interface

6.2.2.1 Display

The human use this function to show the message received from a remote agent. Once a message is received the agent immediately shows a message to its human counterpart (receiver) as shown in Figure 9.

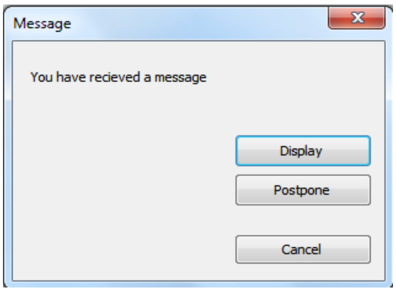

Fig 9: Message dialog box

6.2.2.2 Postpone

This function is quite similar to the Respond function with delay to react to the received message. This represents a function that would require an agent to alert its human counterpart when postponement expires (see Figure 10).

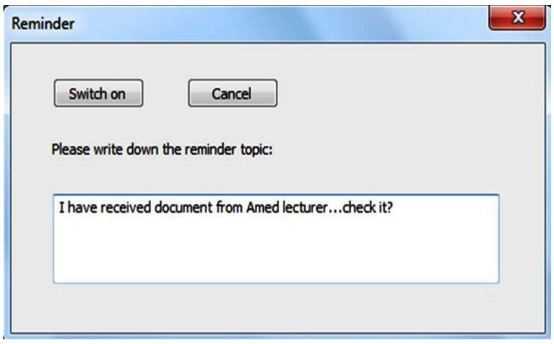

Fig 10: Reminding message

When the human actor receives a document or a message, he/she have a choice to click either display or postpone. If he/she clicks on the postpone button, the agent shows a window containing remind message to him/her during his/her work. The human actor can use this window (i.e. Figure 10) to enter a reminder topic for a received document or message. This function belongs to the assisting agent to remember what it has received. The agent shows the reminder message frequently to remind its human counterpart (see Figure 11).

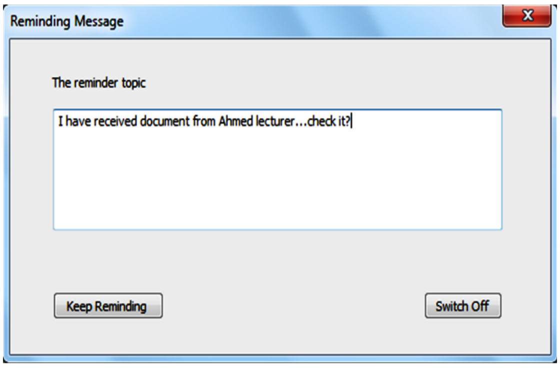

Fig 11: Alert message

The message appears repeatedly if the human clicks the 'Keep Reminding' button to inform the human about the received message. If the human clicks 'Switch Off' the remind message stops appearing. Other human's functions are as follows:

- Respond: This function performs an action immediately as a reaction to a received document, phone calls/SMS, email, and people.
- Forward: The human use this function to send received letters, SMS, emails, etc. to other human with different addresses.
- Save: The function keeps received document, SMS, etc. which the human can exploit later.
- Discard: This function delete files or email message.

The results of our simulation show improvements on the functions which humans usually perform with his/her assistant. Without minding about what messages or documents he/she has received, the human actor is alerted and reminded by his/her agents. We have demonstrated that the nodal approach for modeling agent-based systems is plausible by identifying and providing generalized human's and agent's functions. These functions are executed to manifest a collaborative workflow process that reduces humans' dependent on work schedules.

7. CONCLUSION & FURTHER WORK

We present the Nodal Approach (NA) as a novel solution to agent modeling. The approach is a model for human-agent collaboration using the concept of nodes. It is a generic system, in which a user can create his/her own agents by selecting the functions delegated to the agents. These characteristics make it different and unique from other approaches. In this model, a node consists abstractly of two separate and distinct functions: (i) human functions, and (ii) agent functions.

Consequently, within the node, they work cooperatively in a symbiotic relationship to achieve a common goal. The human actor collaboratively interacts with his/her agent using a set of functions. Agents respond to him/her via messages displayed in some agent interface. Our model provides the overall improvement to workflow processes by providing software agents to perform some tasks and urging humans to fulfill their jobs. The benefits of applying our model are to facilitate and support humans to act upon receiving documents, emails etc.; provide numerous human functions so that the human can select the immediate tasks; and provide numerous agent functions so that the human is reminded for the relevant tasks to improve the workflow process.

Our research contribution is apparent in three perspectives. Firstly, we have presented a NA to be used appropriately in modeling collaborative agents. This model can be adopted and applied in many domains. Secondly, to support some of the human-human collaboration issues in their cooperative and collaborative work, we have developed a method in which agents take over the mundane tasks of document submissions, workflow process tracking, offline messaging, and reminding and alerting the humans. Lastly, it is exploited to reduce human cognitive load without minding the schedule of tasks and their deadlines. Agents, for example, are tasked to send messages and remind their human counterparts.

In the current model, we programmatically connect two nodes to implement the communication between the nodes. In our future work we shall automate this connection based on the procedural rules so that agents intelligently make connections by looking up a database of addresses of the other nodes.

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