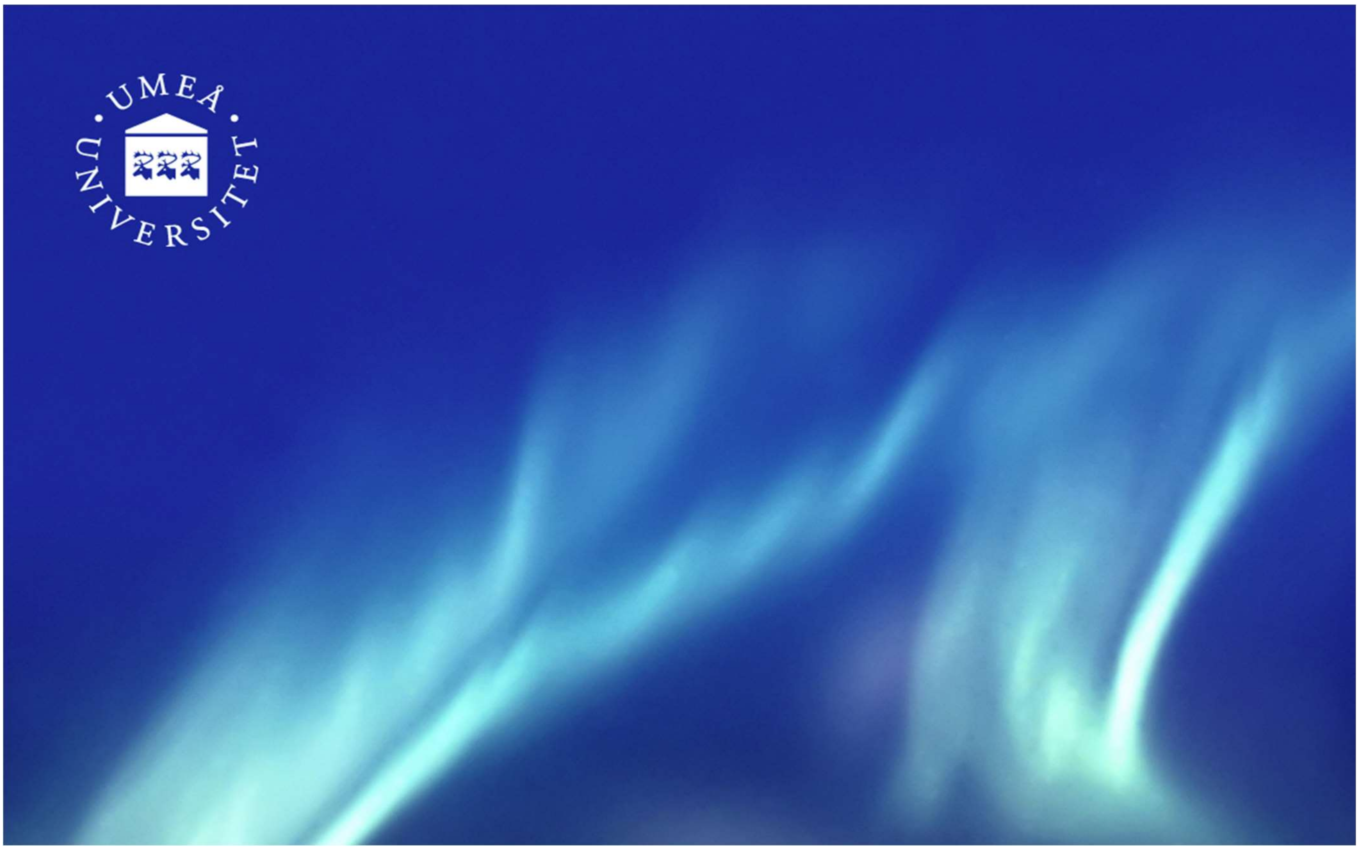

A Semantic Model of Human-Agent Dialogues

by

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ABSTRACT

A common conversation between an older adult and a nurse about health-related issues includes topics such as troubles with sleep, reasons for walking around nighttime, pain conditions, etc. Such a dialogue can be regarded as a "natural" dialogue emerging from the participating agents' lines of thinking, their roles, needs and motives, while switching between topics as the dialogue unfolds. The purpose of this work is to define a generic model of purposeful human-agent dialogue activity including different types of argumentation dialogues, suitable for health-related topics. This is done based on analyses of scenarios, personas and models of human behavior. The model will be shared between the human and the agent, allowing for adaptation to the human's reasoning, needs and motives.

KEYWORDS

Human-agent collaboration, Activity theory, Argumentation dialogues

1 INTRODUCTION

Our work focuses on dialogues between a human actor and an *active* assistive technology [10] in the form of an intelligent software agent. From a cognitive ergonomics perspective, with the development of new interfaces, new ways of interaction are required. Hollnagel et al [6] state that the design of HCI must include a comprehensive task analysis and dialogue design. The concept of Embodied Cognitive Agents (ECA) is generally used for such systems [1]. The ECA uses a virtual representation of a human with the ability to send information through body language in addition to linguistic messages. However, we restrict the focus in this work to structured linguistic dialogues based on semantic models of relevant knowledge similar to Hunter in [7, 8].

The goal is to build a software agent that interacts with the human as their personal coach, friend or a discussion partner, i.e., as a *Coach Agent* as described in [13]. In this work, we focus on the dialogue activity, and restrict the agent's autonomy to the agent's task of selecting topics, dialogue types and moves within a dialogue initiated by the human.

In particular, we are interested in how a dialogue, which includes the types of argumentation dialogues information-seeking, inquiry (generate new knowledge), deliberation (deciding about what actions to do) and persuasion dialogues defined by Walton and Krabbe [15] can be organized following theories of purposeful human activity (Activity Theory [9] and Self-Determination Theory [14]). The main contribution of this paper is a conceptual and formal model of the Coach Agent's knowledge regarding conducting the dialogue activity for assessment purposes.

The paper is organized as follows. A description of the methods applied is provided in the following section. The scenario that was used for defining the model is presented in Section 3 and a generic model of the dialogue activity is provided in Section 4. The article ends with some conclusions and directions for future work.

2 METHODS

The semantic model for adaptive human-agent dialogues is designed based on the persona and scenario of a female older adult named Eva, and the dialogues aimed for supporting a human actor described in [12, 13]. The scenario was analyzed, providing baseline requirements and a conceptual model of goal-directed dialogue activity. The theoretical base for analysis is Activity Theory [9], which also informed the models generated as results of our work.

3 MODEL BASED ON A SCENARIO

Our persona called Eva shares similarity with some of the participants in a study conducted by Lindgren and Nilsson [11], and is therefore considered representative. Eva is 84 years old, suffers from pain in her back and legs and had suffered from few falls before a hip fracture. We envision that Eva begins to walk around nighttime, and that she may discuss the situation and her sleep with a nurse. The nurse asks a few specific questions about Eva's activities and health, and this dialogue will wander from one aspect to another, sometimes coming back to a topic already mentioned.

This example of a natural dialogue is rather different from dialogues described in literature, which aims at reaching one particular goal of a dialogue, e.g., [3]. Following the categorization of dialogue types, described by Walton and

Krabbe [15], the dialogue with the nurse is a simplified example of a combination of different goals: finding information (*information-seeking* type), generating new knowledge, i.e., conclusions (*inquiry dialogue* type) and deciding upon actions to make (*deliberation* type). In case one of the agents has reasons for arguing for one particular action to be made with the purpose to convince the other, e.g. for safety reasons, the dialogue may include a *persuasive* part, e.g., to convince Eva that she needs to go to the hospital for investigation. Based on this, we can define a set of *generic goals* for the agent to use in its organization of dialogues. More concretely, the generic outcome of each type of dialogue is the following: *information*, *new derived knowledge*, *plan of actions* and a *change of priority*. It may be that all of these types of dialogues need to be conducted to fully explore a particular *topic*. These generic goals will correspond to actions and *schemes* defined in Section 4.

Consequently, the agent needs to be able to handle nested multi-purposed dialogues with different topics. To accomplish this, the agent needs to be able to distinguish between *topic*, *generic goal* and have a semantic model of how these inter-relate in a particular situation. For instance, if the agent would have the dialogue with Eva instead of the nurse, the agent needs a semantic model for how walking around nighttime relates to sleep patterns, pain, cognitive ability, medication, worries, etc. (i.e., a *domain model*). Moreover, it needs strategies to plan next moves, based on a knowledge model, which may not provide a pre-defined hierarchically organized plan of actions based on goals and sub-goals to be followed, but rather a collection of prioritized actions, among which the order may become determined and changed by the dialogue evolvement and Eva's line of thinking (enabling *situatedness* of dialogues and the agent to adapt).

The *topics* relate to the human agent's goals and priorities. From the software agent's perspective, goals relate to finding answers to questions, finding and deciding about actions to make to increase levels of satisfaction, evaluate actions made, etc. Consequently, for the human agent, goals are purposeful, topic-driven and context dependent.

Therefore, the agent in our approach combines a generic goal with a specific topic, to identify the *specific goal* with an action. In the following we give an example of a dialogue, where the topic selected by the human agent is "Sleep pattern may be disturbed", which is a claim representing a belief, which has not been verified. This is an example of the initiation of an *inquiry* dialogue, aimed at finding and verifying new knowledge. The agent can choose to conduct a dialogue with the purpose to find information about sleep (specific goal) and initiate an information-seeking dialogue. Topics related to sleep are e.g., pain and medication, and consequently, in this situation, the sub-goals are to *find information about pain* and *medication*, respectively. This is an example of how different types of dialogues can be nested, for the purpose to feed information and knowledge into the cooperative reasoning process of solving the overall topic, here chosen by the human actor.

To summarize, the scenario emphasizes the need for the following three semantic models for enabling human-agent dialogues: 1) a *domain model*, which contains generic knowledge about a particular domain, 2) a *user model*, which contains the collected knowledge about the human agent, and 3) a *dialogue activity model*, which provides the relations between topics, generic and specific goals and actions to be made by the participating agents in a dialogue. Moreover, the third model can be seen as the generic behavior knowledge model of the Coach Agent in dialogues. However, enriched with specific knowledge, which relates only to the Coach Agent that forms the fourth model: 4) an *agent model*. The emphatic components of a dialogue we regard as generic behavior (social) knowledge need to be present for the dialogue to become pleasant to the Human Actor. This is an example of knowledge, which the agent model needs to encompass. The dialogue activity model has been developed as a part of this work, and is presented in the following section.

4 A MODEL OF THE DIALOGUE ACTIVITY

As described in Section 3, the software agent needs to share a common semantic model with the human agent, to be able to reason and decide upon which actions are valuable to the human agent. In this section the dialogue activity model will be defined.

The activity-theoretical model of human activity was used for organizing actions and their goals at different levels [9]. Activity Theory captures the complexity in human activity, including human *needs and motives* as driving force, *goal-directed actions*, and *operations*, which constitute basic actions conditioned by the agents and the environment.

Figure 1 provides an overview of the shared model of a dialogue activity in which both a human and software agent participate. As can be seen, in the dialogues a common *topic* is the representation of the overall *motive for an activity*. Each dialogue is initiated by one of the agents, by posing a selected topic to the other agent.

The identified operations relate to passing information to and receive information from the other agent(s) (*send* and *receive* in Figure 1), and wait for responses.

In addition to these basic and top levels of activity, a set of potential generic sub-actions have been defined, which may take place in the conduction of a dialogue. These are also organized in a hierarchical representation, since an action may serve as a sub-action to more than one action at different

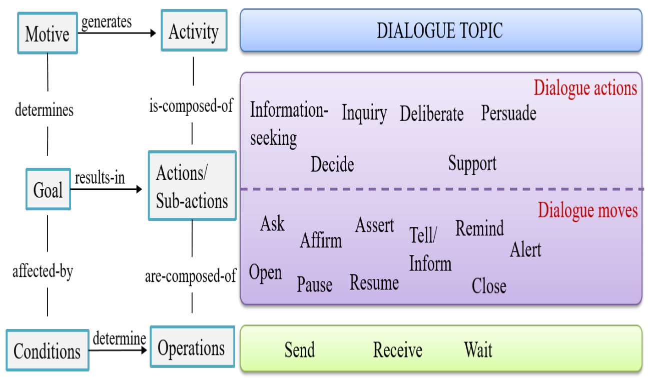

Figure 1: A model of the dialogue activity, which both a human and a software agent are expected to comply with.

levels. However, we identify the following generic set of actions at the highest level: *information-seeking, inquiry, deliberative,* and *persuasive*, related to the common goals of different types of dialogues described in Section 3: seek information, find new knowledge, decide upon actions to be made and lead the other agent to change opinion. To these actions, we add the action *organize dialogue*, which contains the sub-actions typical for multi agent dialogues, e.g., *open* and *close*. These sub-actions are called *moves* in multiagent literature [3]. We extend the set of moves (i.e., sub-actions) and include the following moves as valid actions for the agent to take as part of the different actions: *open, close, pause, resume, ask, assert, affirm, inform, remind* and *alert*.

The model of dialogue activity presented in this section defines the actions, which need to be common between the participating agents as a part of a common semantic model. To distinguish the lower level actions, which represent different types of moves in a dialogue, we hereafter call these *moves*, explored in the following sub-section, and denote the different dialogue types at a higher level as *actions*, specified in Sub-section 4.

Dialogue Moves

Formally, a dialogue move for the human agent or software agent in this work, is a tuple (t, a, m) where t is timepoint of the dailogue move, a is the agent and m is the dialogue move. The set of dialogue types (d) includes the following: information-seeking (is), inquiry (wi or ai), deliberate (dd), persuasive (pd) and support dialogue (sd). Based on this (t, a, m) tuple, we define the actions as follows (Table 1).

The *Open* move is the first action carried out to initiate a dialogue, and the *Close* move is used for closing, or stating the end of a dialogue. In our implementation, the human initiates the first dialogue, while the agent initiates all sub-dialogues. Moreover, we limit the type of dialogues to *asymmetric* dialogues, where the human is not providing own claims, only responding to questions.

When the agent needs to obtain information from the human actor, it uses the *Ask* move. It fetches the relevant questions to be asked from the ACKTUS knowledge repository and stores them in its knowledge base. The human's answer is a *Tell* move. The agent uses the Tell move for mediating advices or other information, which are not reminders or alerts.

The *Remind* move is used by the agent to remind the human to act. The *Alert* move is also similar to the remind move but with a timeout. It recommends the human to take immediate action in a critical situation, for example, if Eva has forgotten to take medication after breakfast, then the agent sends the alert about taking medicine. The organization of the agent's supportive actions and pro-active behavior is part of the implementation of interventions and is subjected to future work.

The *Assert* move is used for making a claim about some topic, and it is supported by the set of grounds G on which the claim is being based. The claim is a defeasible fact.

The *Affirm* move is used to acknowledge the other agent and its expressions in a more generic way. The typical purpose is to make the other agent comfortable, providing a "fill" in the dialogue.

The *Believe* move is a particular question posed together with an assert move for investigating if the other agent agrees upon the claim, stated in the assert move. The response is given by a tell move and can be either *I agree* or *I disagree* in our implementation.

Rules for Dialogue Moves. There are rules related to how the moves can be applied. In dialogue games, the restriction that agents take turn in the dialogues, and are allowed to perform only one move at the time does not apply in our dialogues. The reason is that the agents are not competing for "winning" the dialogue, and natural dialogues do not follow this restriction.

Other restrictions apply, such as the open move for a particular dialogue needs to take place before a close move. Similarly, in case a pause move is done, then no move can be done within this dialogue until the dialogue is resumed by a resume move.

Only one dialogue can be active at a particular time point. This means that when a new dialogue is opened by an open move, and if there is an ongoing dialogue, then this ongoing dialogue is paused. This follows the notion of "focus shifts", which occur when humans conduct activity, a phenomenon used for evaluating interactive systems [4].

Since it is the Coach Agent, which is directing the ongoing dialogue, the agent is also closing the dialogue. However, the

Table 1: Valid actions, i.e., moves and their formats. All moves contain the time identifier t_n and a_i, the identification of the agent, which performs the move.

Move	Form	Comment
Open	$(t_n, a_i, open(d_o, \alpha_m))$	α_m is the topic of a dialogue
Close	$(t_n, a_i, close(d_o, \alpha_m))$	α_m is the topic of a dialogue
Ask	$(t_n, a_i, ask(CQ))$	CQ is a structured question
Affirm	$(t_n, a_i, affirm(\alpha_m))$	α_m is a confirmative expression
Tell	$(t_n, a_i, tell(\alpha_m))$	α_m is the message, typically an advice or information
Remind	$(t_n, a_i, remind((\alpha_m, G), a_j))$	α_m is the reminder, G is the set of reasons for the reminder, and a_j is the agent targeted for the reminder
Alert	$(t_n, a_i, alert((\alpha_m, G), a_j, t_l))$	t_l is the timeout for the action
Assert	$(t_n, a_i, assert(\alpha_m, G))$	α_m is the claim and G is the set of grounds for the claim
Believe	$(t_n, a_i, believe(\alpha_m, CQ))$	α_m is the claim or message and CQ is a structured question

human agent can close the main dialogue, and consequently all sub-dialogues, by switching the topic of the main dialogue.

Some moves have the purpose to defer the responsibility for acting to the other agent. Such moves are *ask*, where the asking agent expects a response, and *alert*, when the alerting agent expects the other agent to take action since the situation requires action. Similarly, whenever the human agent respond to an ask move by a tell move, the responsibility to act is passed to the Coach Agent. Consequently, the agent needs strategies to handle the situation when the other agent does not respond as expected.

In the case when the human agent cease to respond, the Coach Agent puts the dialogue on hold, and defines and stores, if present, partial results of opened dialogues. At a later occasion, the agent can offer the human to resume a dialogue put on hold.

Goal-Oriented Dialogue Actions

The higher-level actions in Figure 1, which relate to different types of dialogues, can be nested to meet sub-goals in the process of achieving the overall motive for the dialogue activity defined by the topic. In addition, each nested dialogue is initiated by posing a topic, in the same way as the main dialogue is initiated. As a consequence, the execution of the dialogue body needs to handle the different types of dialogues, motives, their outcomes, the organization of these in the dynamic way, which is needed for the agent to be adaptive and flexible. In this process, some constructs are useful for formalizing the dialogues and their outcomes, and for organizing the process of reaching decisions about e.g, actions to make, and their reasons (arguments). The different types of dialogues, their goals, topics and allowed moves are summarized in Table 2.

The purpose of *argumentation dialogues* is to collaboratively compare different views and generate conclusions about which one is best in a situation. This can be what conclusion to draw, what new knowledge do derive, what action to make, and what changes of priority, or beliefs can be achieved. This is a decision-making approach, which provides strategies for handling conflicting information and views. Information, inference rules and conclusions are typically considered *defeasible*, which means that they can be challenged (*attacked*) and defeated. In our work, we assume that all information is defeasible, and no rules are strict rules, valid in all circumstances. Arguments can be attacked in three ways: on their *premises*, on their *inference* (example in Table 3, row 23) and on their *conclusion* (example in Table 3, row 19). In argumentation literature the notion of *argument scheme* is applied for providing semi-formal or formal templates and defeasible inference rules for different kinds of dialogues [16]. A common example is the scheme "Argument from a position to know", which is the starting point for both the human and software agents in our work. Consequently, the agents are considered equally knowledgeable when evaluating their arguments.

In the following, the common features of argumentation are described, which will be followed by a number of subsections in which each type of dialogue is defined. However, we leave the full definitions of the formal argumentation framework applied in our dialogue system for future work.

Argumentation. The topic of dialogues is retrieved from a domain ontology, which incorporates both the Argument Interchange Format (AIF) [5] and the domain knowledge. The domain ontology contains a concept-node system with concepts and their relations. The information-seeking dialogues have a concept as topic, which makes this type of dialogue very generic. Moreover, the domain ontology contains a kind of information node, which has a concept but no values, and functions as the topic for the supportive dialogues (Table 2). We treat these as *statements* in the dialogue, and *literals* in the logic implemented in the dialogue system.

AIF distinguishes between *i-node*, a kind of information node, which in this approach is associated to both a concept and a value, and which form statements; and *s-node* (scheme-node), from which rules are generated. These AIF concepts are used as topic in inquiry, deliberation and persuasion dialogues, with some differences. The formal distinction made in this approach between the inquiry and deliberation dialogues is that the *claim*, i.e., i-node, is in deliberation dialogues associated to a concept related to the node *activity*

Table 2: Dialogue types and their characteristics. The topic is drawn from the ACKTUS repositories, using the semantic characteristics of the knowledge nodes.

Type	Goal	Topic	Valid moves
information-seeking	collect information	*concept*	open, ask, tell, affirm, close
inquiry	create new knowledge in the form of defeasible facts or defeasible rules	*i-node* (defeasible fact) or *s-node* (defeasible rule)	open, assert, believe, affirm, close
deliberation	decide about actions to be taken	*i-node* (defeasible fact) or *s-node* (defeasible rule)	open, assert, believe, affirm, close
persuasion	change a priority or belief	*i-node* (defeasible fact) or *s-node* (defeasible rule), in particular their *value* as a part of a *scale*	open, assert, believe, affirm, remind, close
support	enhance human agent's ability	*information-node* or *conclusion*	open, affirm, tell, alert, remind, close

and participation in the domain ontology, while in the inquiry dialogues the concept is anything else than a node within the activity and participation ontology. Persuasive dialogues can have both kinds, since the focus is the *evaluation of* the phenomenon represented by the concept. This evaluation is represented by its *value* (a measurement of preference or confidence), which is targeted to be changed.

Formally, we treat the i-nodes associated to a value as predicates of the form x that could be an atom or a negated atom. Rules extracted from the s-nodes are formally defined as follows: $x_1 \wedge \cdots \wedge x_n \longrightarrow x_0$ where x_i is a literal.

The rules together with defeasible facts (statements) fulfilling premises of the rules are used for building arguments of the form (x, a), where a is the claim and x is the support for the claim, consisting of rules and facts. An argument is posed in the dialogue with an assert move.

In our dialogue system attacks by the human agent on arguments are identified by a disagreeing response given by the human to the question posed by the agent using the believe move (example in Table 3, row 22-23). This disagreement is respected, and the argument is considered defeated. If the human supports the argument, the argument is considered accepted and validated (example in Table 3, row 24-25). The two arguments in the examples both address actions to address a problem, and as such they are not in conflict with each other. In the health domain we describe in this paper arguments are often not in direct conflict with each other. They may however support decisions or actions, which are beneficial, or important to different degrees. Moreover, as in the example, a defeated argument may be interesting in the particular situation where it was defeated, since it may provide information, which needs to be used for resolving a problem. Consequently, the state-of-the-art approaches to formal argumentation in research literature where one single winning argument is to be identified are insufficient for complex healthcare situations.

A *dialogue line* is the sequence of moves conducted by the agents and their time points (e.g., [3]). Such sequence is visible in the example of a dialogue, presented in Table 3. In the following sections each type of dialogue is further described, and exemplified.

Inquiry Dialogues (wi and ai). The inquiry dialogue is distinguished from other dialogues in that it is divided into two types following the approach in [3]: *warrant inquiry* (wi) dialogue and *argument inquiry* (ai) dialogue. The topic of a warrant inquiry dialogue is a defeasible fact, while the topic of an argument inquiry dialogue is a defeasible rule. The purpose of the first kind is to create new knowledge, and for the second kind is to create arguments. Consequently, the outcome can be either a conclusion, or an argument. In the case more than one conclusion is generated, a conflict occurs.

The example dialogue shown in Table 3, starts out as a warrant inquiry (wi) dialogue, since the main purpose is to find out whether there is a sleep disorder. The inquiry dialogue evolves when different hypotheses are evaluated and can be assumed to take place after Row 15 in Table 3.

There is a large number of argumentation schemes defined for reaching new knowledge, representing different reasoning strategies and the confidence in the actor, e.g., argument from expert opinion, argument from a position to know, etc [16]. Some reasoning strategy definitions mirror the range of logical inference strategies, e.g., deductive and inductive reasoning, causal reasoning etc. Consequently, the agents can apply different strategies, depending on the purpose and quality of the available information. For our purposes, we assume at this point that the agents apply an abductive reasoning method, which includes possibilistic values. The following is the scheme defined for abductive argumentation:

Example 4.1. Abductive argumentation scheme: F is a finding or given set of facts, E is a satisfactory explanation of F, and no alternative explanation E2 given so far is as satisfactory as E. Then E is plausible, as a hypothesis.

This Abductive argumentation scheme example can be applied to our human agent example as follows:

Example 4.2. The human agent is walking around nighttime (F), the human agent's severe pain (E) is a satisfactory explanation of F, and no alternative explanation given so far is as satisfactory as E, therefore, E is plausible as a hypothesis.

Table 3: Example of different types of dialogues unfolding in a dialogue line.

t_i	Agent	Statement	Formal representation of a move
1	Eva	Hi Coach, I wonder if not my *Sleep pattern may be disturbed.*	$(t_1, a_1, open(wi_1, i\text{-}node_1))$
2	CA	Hi, Eva. Okay,	$(t_2, a_2, affirm(info\text{-}node_1))$
3	CA	Then I would like to talk about *sleep.*	$(t_3, a_2, open(is_1, concept_1))$ $(t_3, a_2, pause(wi_1, i\text{-}node_1))$
3	CA	Did the sleeping pills work for you tonight?	$(t_3, a_2, ask(CQ_1))$
4	Eva	No.	$(t_4, a_1, tell(i\text{-}node_2))$
5	CA	Why did you not sleep well last night?	$(t_5, a_2, ask(CQ_2))$
6	Eva	Needed to pee and pain.	$(t_6, a_1, tell(i\text{-}node_3))$, $(t_6, a_1, tell(i\text{-}node_4))$
7	CA	Okay, I see.	$(t_7, a_2, affirm(info\text{-}node_2))$
8	CA	Now I would like to ask about *pain.*	$(t_8, a_2, open(is_2, concept_2))$ $(t_8, a_2, pause(is_1, concept_1))$
9	CA	Where do you have pain?	$(t_9, a_2, ask(CQ_3))$
10	Eva	In my back.	$(t_{10}, a_1, tell(i\text{-}node_5))$
11	CA	How severe is your pain?	$(t_{11}, a_2, ask(CQ_4))$
12	Eva	Severe.	$(t_{12}, a_1, tell(i\text{-}node_6))$
13	CA	Okay, does not sound good.	$(t_{13}, a_2, affirm(info\text{-}node_3))$
14	CA	Let us go back to the topic *sleep* and *priority.*	$(t_{14}, a_2, close(is_2, concept_1))$ $(t_{14}, a_2, open(pd_1, i\text{-}node_7))$
15	CA	You said that maintaining good sleep is of highest priority.	$(t_{15}, a_2, remind(i\text{-}node_8, \{\}), a_1)$
16	Eva	Yes.	$(t_{16}, a_1, affirm(info\text{-}node_4))$
17	CA	You also told earlier that maintaining pain at endurable levels is not important.	$(t_{17}, a_2, remind(i\text{-}node_7, \{\}), a_1)$
18	Eva	Yes.	$(t_{18}, a_1, affirm(info\text{-}node_4))$
19	CA	Since it is likely that severe pain causes disturbed sleep, and you have severe pain, and you think maintaining good sleep is of highest priority, then it should be important to maintain pain condition at an acceptable level. What do you think?	$(t_{19}, a_2, assert(i\text{-}node_9, \{s\text{-}node_1, i\text{-}node_6, i\text{-}node_8\}))$ $(t_{19}, a_2, ask(CQ_6))$
20	Eva	Okay, important I guess.	$(t_{20}, a_1, affirm(info\text{-}node_1))$ $(t_{20}, a_1, assert(i\text{-}node_9, \{s\text{-}node_1, i\text{-}node_6, i\text{-}node_8\}))$
21	CA	Okay, let us talk about what to do about the *pain.*	$(t_{21}, a_2, affirm(info\text{-}node_1))$ $(t_{21}, a_2, close(pd_1, i\text{-}node_7))$ $(t_{21}, a_2, open(dd_1, i\text{-}node_{10}))$
22	CA	Since taking painkiller typically reduces pain, then you can take painkiller. What do you think?	$(t_{22}, a_2, assert(i\text{-}node_{10}, \{s\text{-}node_2\}))$ $(t_{22}, a_2, ask(CQ_6))$
23	Eva	No, painkiller does not work.	$(t_{23}, a_1, tell(i\text{-}node_5))$ $(t_{23}, a_1, assert(i\text{-}node_{11}, \{s\text{-}node_3\}))$
24	CA	Okay, I see. Do you want to talk to your nurse about medication?	$(t_{24}, a_2, affirm(info\text{-}node_2))$ $(t_{24}, a_2, ask(CQ_7))$
25	Eva	Yes.	$(t_{25}, a_1, tell(i\text{-}node_{11}))$
26	CA	Okay then I wonder if I could *inform nurse about summary* for you.	$(t_{26}, a_2, affirm(info\text{-}node_1))$ $(t_{26}, a_2, close(dd_1, i\text{-}node_{10}))$ $(t_{26}, a_2, open(sd_1, concl_1))$ $(t_{26}, a_2, tell(info\text{-}node_5))$
27	Eva	Yes.	$(t_{27}, a_1, tell(i\text{-}node_{11}))$
28	CA	Okay, don't forget to talk to the nurse about your medication!	$(t_{28}, a_2, affirm(info\text{-}node_1))$ $(t_{28}, a_2, remind(i\text{-}node_{11}, \{s\text{-}node_3, s\text{-}node_1, i\text{-}node_6, i\text{-}node_8\}), a_1)$

To execute this type of dialogue, the agent first creates a domain model of how different conditions such as pain or incontinence affect the quality of sleep in general. The following is an example, where → is used for representing a defeasible causal relationship: ((pain, severe) → (disturbed sleep, probable)). The agent combines this knowledge with the knowledge about the human agent represented in the user model, which relates to manifested conditions or observations and the user's priorities: (pain, severe), (walking nighttime), (maintaining pain at endurable levels, highest priority), (maintaining good sleep, highest priority).

However, since there are other potential hypotheses, which may be generated, the Coach Agent needs to continue the reasoning and dialogue to reach a sufficiently complete view of the human agent's situation, following an *exhaustive* method for investigation. The situation is common when there may be more than one hypothesis with same level of satisfaction as the explanation of a finding. Consequently, we will adapt the scheme for allowing the agent work with more than one hypothesis in parallel, and generate an outcome of the inquiry dialogue, which can be utilized as base for further actions. For instance, in the situation when two or more explanatory hypotheses are present with same level of satisfaction, this may lead to the initiation of an information-seeking dialogue, or a deliberation dialogue about what actions to take to resolve the situation with conflicting hypotheses, e.g., involving a healthcare professional (e.g., Table 3). One strategy to resolve the conflict is to accept more than one argument as explanation, and pursue deliberation dialogues for addressing all in a treatment plan.

Deliberation Dialogues (dd). Argumentative reasoning with the goal to decide about what actions to make is often denoted *practical reasoning* in literature (e.g., [2]). The following scheme for practical reasoning is defined by Walton [16]:

Example 4.3. In the current circumstances R, we should perform action A, which will result in new circumstances S, which will achieve goal G, which will promote value V.

In our scenario, this may correspond to the following:

Example 4.4. We know that the pain is severe (R), and if the pain is reduced (A), this will result in the new circumstance where the pain is mild (S), which will achieve the goal to keep the level of pain at a manageable level (G), which promotes good sleep (V).

The execution of this type of dialogue follows the same procedure as in previous example. The topic of the dialogue is *reduce pain*, which is an action (Table 1). The agent creates a domain model of how pain and other conditions and medication may affect the quality of sleep in general: ((pain, severe) → (disturbed sleep, probable)), (painkiller → reduced pain). The agent combines this knowledge with the knowledge about the human agent represented in the user model: (pain, severe), (walking nighttime), (maintaining pain at endurable levels, highest priority), (maintaining good sleep, highest priority).

The dialogue in this situation will deal with what to do to reduce the pain level, in order to affect the sleep disturbance in a positive way. In our example, using painkiller to reduce pain would be the suggestion (rows 21-25 in Table 3).

The outcome of a deliberation dialogue is a plan of action, which may be empty.

Persuasive Dialogues (pd). Persuasive dialogues aims at resolving a conflict of opinion.The agent creates a user model of the human's prioritized activities, for example: (taking medication, important), (wellbeing, very important) and (maintaining good sleep, highest priority). For illustrating a persuasive dialogue, the user's preference regarding managing pain is set to the the following: (maintaining pain at endurable levels, not important). Then the agent combines this knowledge with the knowledge obtained from the human actor during the dialogue. Suppose the human has disturbed sleep and initiates a dialogue with the Coach Agent about the topic "sleep patterns may be disturbed". During the information seeking dialogue, the agent asks the human about pain and if the human responds that a pain condition is present, and the pain is "severe", then the agent updates its user model with (pain condition, yes) and (pain, severe), and initiates a persuasive dialogue (rows 14-20 in Table 3) based on its knowledge about the relationship between sleep and pain condition.

The agent makes new statements, reminds the human about the relationship between pain and sleep, and the human changes the evaluation of the importance of managing the pain condition (the value *important* is stronger than the value *not important*). Next step for the agent is to propose actions to do something about the situation.

Information-Seeking Dialogues (is). The topic of an information -seeking dialogue is a *concept*, which is a broader topic than the defeasible facts or rules, used as topics for an inquiry, deliberation or persuasion dialogue. An information-seeking dialogue typically unfolds as an interview, where the Coach Agent in our examples asks relevant questions to the human agent, and receives answers. To some extent the agent evaluates the new information, however, primarily for deciding upon next step, typically what question to ask next. Therefore, we use the move *tell* in the information seeking dialogues instead of *assert*, to distinguish between answering questions for reasoning purposes such as in inquiry dialogues, and answering primarily for collecting information.

Support Dialogues (sd). The topic of a supportive dialogue is an *information-node*, which is not associated to a value. The content of a support dialogue is typically the outcome of an earlier conducted deliberation dialogue, where the human agent and the Coach Agent have agreed upon a plan of actions to be conducted. The actions performed as support dialogues are one of the following: provide the human agent with information or advice, remind the person of actions to make, and alert the person when important things need to be done. A remind and alert move are arguments, which contain the information about what is to be done, i.e., a claim, together with the motivations, i.e., the grounds, which support the claim.

5 CONCLUSIONS

The purpose of this work was to define a generic model of purposeful human-agent dialogues about health-related topics. This was done based on analyses of scenarios, personas and models of human behavior. The major contribution of this work is the dialogue activity model to be shared between the human and software agents. Future work includes the implementation of the dialogue model together with a purposeful user interface, and conducting user studies with both experts in the knowledge domain and older adults. Main focus will be on the adaptability of the dialogues to the human's line of reasoning.

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