Towards a Multipurpose Goal Model for Personalised Digital Coaching

Helena Lindgren[1], Jayalakshmi Baskar[1], Esteban Guerrero[1], Rebecka Janols[2], and Juan Carlos Nieves[1]

[1] Department of Computing Science
(helena, jaya, esteban, jcnieves)@cs.umu.se
SE-901 87, Umeå, Sweden
[2] Department of Community Medicine and Rehabilitation
rebecka.janols@umu.se Umeå University
SE-901 87, Umeå, Sweden

Abstract. Supporting human actors in daily living activities for improving health and wellbeing is a fundamental goal for assistive technology. The personalization of the support provided by assistive technology in the form of digital coaching requires user models that handle potentially conflicting goals and motives. The aim of this research is to extend a motivational model implemented in an assistive technology, and outline a team of assistive agents with supplementary goals following the human's different properties, orchestrated by a *companion agent* based on the multipurpose motivational model for the human actor who is to be supported. The multipurpose motivational model and supportive arguments relating to different motives are exemplified based on a use case from an earlier pilot user study of the assistive technology. Future work includes user studies to validate the model.

Keywords: Personalisation, Motivation, Multiagent Systems, Assistive Technology, Argumentation, Persuasive Technology, Behaviour Change

1 Introduction

Research has contributed with methods and technology for digital coaching in several directions. Little research has been done with the aim to explore situations where multiple purposes, or goals may be relevant, and even less when different goals may be conflicting. A number of coaching systems have been developed for different purposes, in particular, for the purpose to increase physical exercise (e.g., [5, 13, 28, 31]). They are typically focussed on one purpose, although the nature of humans' motivation and activity are complex [10, 17, 29].

The purpose of the research presented in this paper is to explore multiple motives and driving forces behind human activity, and develop formal models of goals and motives as part of user modeling in order to enrich coaching for improving health and well-being. Research questions include how multiple potentially conflicting motives can be handled by a team of digital agents with different responsibilities and different knowledge domains, and how person-tailored multipurpose arguments can be composed to promote health in humans.

Based on humans' multiple properties and motives, we define a team of digital agents encompassing a range of goals and responsibilities to meet the needs of a human actor, which is introduced in Section 2. A prototype coaching system that aims to encourage older adults to increase their level of social and physical activity has been developed that includes a user model, which is further developed in this work. This system is briefly introduced in Section 3. The proposed multipurpose motivational model is exemplified in Section 4 with a use case obtained in an earlier user study presented in [16]. Strategies to select supporting arguments, and multipurpose arguments supporting different potentially conflicting motives are exemplified. The multipurpose motivational model is translated into a multipurpose goal model for orchestrating the personalized support by the team of agents with different goals and responsibilities. This is exemplified in Section 5. Related work is discussed in Section 6 and some conclusions and future work are summarized in Section 7.

2 Software Agents' Purposes, Roles and Instruments

The motivation for using multi-agent systems in our work is that this approach allows for modeling the conditions for reasoning and knowledge generation, in spite of ambiguous, uncertain and incomplete domain knowledge and knowledge about the user's situation. The agency of semi-autonomous software agents can be used for mixed-initiative collaborative reasoning and actions, involving also human agents [30]. In addition, we anticipate that agent-based dialogues will facilitate the interaction design of more intuitive and natural dialogues between the user and the system.

The motive for why applying the more holistic method to generate arguments to be posed to the user is to target reasons to conduct activity that are *intrinsically* motivated, in terms of Self-Determination Theory (SDT) [29], and thereby more likely to be achieved. This way, motivation for some activities may reinforce other activities, and lead to a more sustainable behavior change for the purpose to improve health.

Different roles of intelligent software agents have been targeted in research literature. We identified the following roles, which correspond to different purposes: *activity supporter*, *social and emotional supporter*, *learning supporter*, *monitor of physical processes and environment*, *information mediator* and *product promoter*. In this section an analysis of the different roles related to their interaction with humans are presented. We limit our analysis to the roles, which aim at improving humans' health, wellbeing and activity performance.

The needs and wishes of a human actor are complex, and are often conflicting. This is mirrored in the agent roles which have been identified throughout different projects targeting different knowledge domains, e.g., [2, 15, 25, 32, 34] (Table 1). Moreover, an agent may be assigned more than one role in the implementation of the different agent-based systems. A consequence of the different roles is that their motives may be in conflict, which requires that the agents have strategies to handle conflicting motives and preferences, while optimizing the value of the support they provide to the human actor.

Table 1. The team of agents, their roles, responsibilities and examples of implementations presented in research literature.

Name	Role	Motives	Responsibilities	Reference
Companion Agent	a friend, coach or discussion partner	Guard and monitor the user's interests, prioritised goals	1. Recognise user's needs, goals, preferences; 2. Respond /act upon user's requests, needs and lack of goal satisfaction	[2, 3]
Activity Agent	Activity supporter	Optimise activity performance	1. Recognise, evaluate activities, 2. Personalise activity support	[15, 23, 1]
Environment Agent	Monitor physical environment	Organise and optimise the tools of activity	1. Monitor the physical space and objects including the user's location 2. Personalise support for tool manipulation	[11, 25, 32]
Domain Agent	Domain Expert	Contribute to reasoning and decision-making	Provide the expert's view on a situation	[34, 35]
Soc Agent	Monitor social environment	Organise the social resources and optimise social experience	1. Recognise, evaluate social activities 2. Maximise positive social activities	[7]
Emo Agent	Monitor emotional health	Optimise positive experience and well-being	1. Recognise, evaluate emotions, experiences 2. Maximise positive emotions, experiences	[6, 27]
Bio Agent	Monitor physical health	Organise and optimise the body/ physiological resources	1. Recognise, evaluate body signals and actions 2. Personalise support for rest vs. active life, day-night routines, food intake	[15, 24]
Exercise Agent	Personal Trainer	Optimise strength and balance	1. Recognise, evaluate strength and balance 2. Personalise physical exercise	[31, 5, 13]

Our categorization of roles of potential agents follows partly the functional domains of a human distinguished in the International Classification of Functioning, Disability and Health (ICF)[3], which provides an instrument for distinguishing each agent's domain of knowledge, responsibilities and prioritized goals. Another advantage is that a human actor is familiar with these domains and can relate to their different purposes, which facilitates cooperation. A human actor possesses resources in the following basic domains: physical, emotional, social and environmental. We

[3] http://www.who.int/classifications/icf/en/

name the agent roles relating to these functional domains *Bio Agent*, *Emo Agent*, *Soc Agent* and *Environment Agent*. The different roles are described in Table 1.

These resources are taken into use by the human actor in the conduction of activity and in the case of limited personal resources, a team of agents may compensate for identified limitations. In addition, activity requires composite resources we typically call knowledge, problem solving and (motor and process) skills, partly for utilizing instruments in an efficient way [18]. A particular type of knowledge is the medical and health-related qualified knowledge, which the health professionals are expected to possess, and not necessarily the human actor who is utilizing the assistive technology, and possibly not yet the novice health professional. This knowledge is typically represented in medical guidelines, evidence-based medical sources, and medical terminologies and classifications. Therefore, the *Domain Agent* plays a crucial role in agent-based medical decision-support systems, aiming at assisting and educating the clinician in the diagnostic procedure. Moreover, a team of domain agents with different expert domain may be useful to define.

We add to this set of agents the *Companion Agent* and the *Activity Agent*, which represent more composite roles, where for instance, the Activity Agent may be dependent on the other agents to provide the optimal support, considering the physical environment and the human actor's mental, physical and social resources. Other agents may be dedicated to focus on a subarea of another agent, such as the *Exercise Agent*, which is primarily focusing muscle strength and balance, as a foundation for reducing the risk for an older adult to fall down. A summary of the roles and their properties is given in Table 1.

In addition to these purposes, the Companion Agent may need to act as an *orchestrator* of the other agents' potential proactive behavior, since the Companion Agent should acknowledge the human actor's current motivational model and optimize the tailored support provided the human actor. The reasons for this will be illustrated in the following sections.

3 A Prototype System for Personalised Digital Coaching

A prototype was developed with the aim to support older adults in planning physical and social activities, and evaluate these (Figure 1) [16]. This system consists of a baseline application for collecting information to be fed into the initial user model, and a mobile application that guides in every day activities. The user is reminded to plan activities, encouraged with messages, and is given feedback on their performance. The prototype was evaluated in a formative and qualitative pilot study with four older adults, and different aspects were studied regarding how a supportive application in the form of a personalised persuasive coach could be designed to increase motivation [16].

At baseline the user provides information about how important different kinds of activities are (Figure 1). This information forms a base for a motivational model, as an extension to the user model [20, 21, 16].

The categories of *motives* or *needs* that direct human activity, following the terminology of Activity Theory [17], are based on earlier studies involving a group of older adults [19], and include:

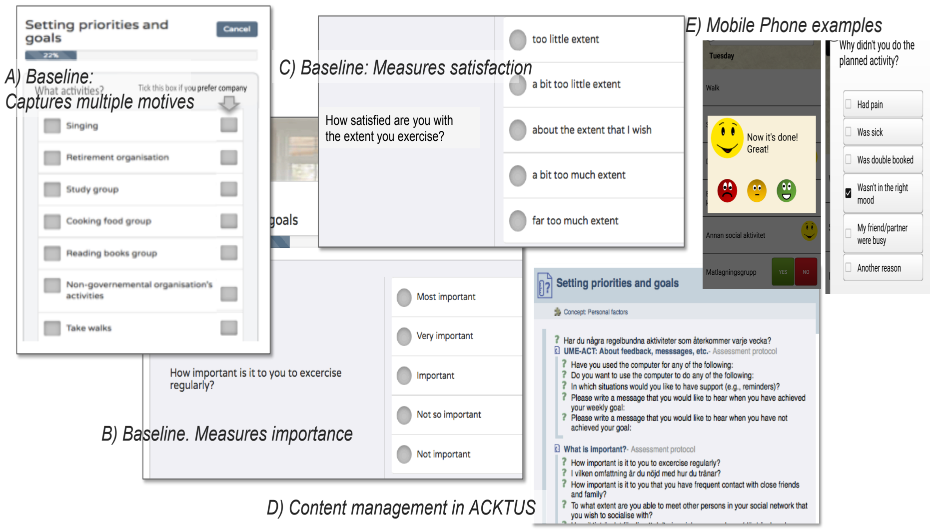

Fig. 1. Screenshots from the baseline application, the mobile application and the content management system ACKTUS.

i) being part of, and maintaining a social network,
ii) being part of society,
iii) maintaining physical strength and physical health,
iv) maintaining mental health,
v) performing activities of one's choice,
vii) having fun and being entertained,
vi) feeling safe and secure.

Notably, Motives i) - vi) correspond to the purposes of the different agents, described in Table 1, while Motive vii) should be a common goal for all agents. Questions about activities relating to these motives are integrated as part of the baseline assessment. The human actor specifies for each category of activity the following:

1. **Importance**: the degree of importance to the client following a five item scale ranging from *not important* to *most important* (Figure 1B),
2. **Satisfaction**: to which extent the activity is currently being performed in a satisfactory way. The categories of degrees relate to satisfactory or not satisfactory, here distinguished between *too extensively*, or *too little* (Figure 1C),
3. **Intervention**: whether or not the client wants to have support from assistive technology to manage the activity, and thereby define a goal relating to this activity.

Based on the user studies, the motivational model was further extended in this work. The purpose is to develop a method for aggregating *multipurpose arguments* for the user to increase physical and social activities that are based on the user's motivation to conduct the different activities. The model is based on theories of human motivation and on activity theory [17, 29]. We build the hierarchical model of generic motives on earlier results from user studies [19]. The formalization of the model and implementation is built on argumentation theory [9, 26]. Content and structure of the prototype application was adapted using ACKTUS, a platform for developing knowledge-based systems [22]. The platform provides a core ontology that is used for organizing information into a semantic model that distinguishes between types of motives, motivation, activities, body functions and human capabilities.

The encouraging messages provided by the system were the result of workshops with older adults.They were designed for being generic and suitable for a range of different physical and social activities. They were also primarily designed for giving feedback as a post reflection on a day's activities. In this work, we supplement these messages with motivational arguments, primarily aimed at encouraging people to conduct an activity as planned. Feedback messages of a more argumentative type were created. A multipurpose motivational model was developed that directs the argumentative behavior of the system, which is presented and exemplified in the following section.

4 The Multipurpose Motivational Model

A multipurpose motivational model was developed that includes degrees of importance and different potentially conflicting motives and goals (Figure 2).

The user's motivation for different activities is captured by a set of questions posed at baseline where they rank the importance, and their satisfaction with their performance. In addition, they give information about how they prefer to conduct the different activities (see examples in Figure 1). This information is aggregated into a generic user model, see example in Figure 2A. In a specific situation when focussing a certain activity, a motivational model is aggregated that relates to the situation (Figure 2B). The motivational model is based on the generic user model.

Motivational arguments for conducting a particular activity can be augmented with different weights, based on how the user rated the importance and satisfaction of the underlying motive (Arg1-Arg5 in Figure 2C). In the multipurpose motivational model these different arguments are used for aggregating strength for conducting a particular activity, by using the strength of arguments promoting other motives. Multipurpose arguments are formed that use information about the different activities (Figure 2). This can be done in two ways: 1) combine different arguments that are specifically targeting the different motives that are ranked as most important to the activity in focus (Goal Rank 2 in Figure 2B), or 2) merge motives and generate new arguments (Goal Rank 1 in Figure 2A). The strength of arguments is generated based on the user's rated importance and satisfaction levels. These two strategies is exemplified as follows: Let us assume that *taking a walk* is the activity that is in question, and the following arguments are specific for the different motives: Arg1: "Conducting activity with friends increases joy.", Arg2: "Conducting activity together with others maintain social network.", Arg3: "Taking walks maintain physical capability.", Arg4a: "It is painful to walk.",

A: ***USER MODEL***

Motive	Goal rank 1	Importance: 0-4	Satisfaction	Motivation
Having fun, feeling good	1	4: most important	4: Too little	intrinsic
Maintain social network	1	4: most important	4: Too little	intrinsic
Maintain physical strength and health	3	2: not that important	3: Bit too little	extrinsic
Reduce pain	2	3: important	3: Bit too little	intrinsic
Maintain "musts", e.g., personal economy, etc.	3	2: not that important	3: Bit too little	extrinsic

B: ***SPECIFIC SITUATION: Taking a walk***

Motive	Goal rank 2	Importance: 0-4	Satisfaction	Motivation
Having fun, feeling good	**2**	4	4	intrinsic
Maintain social network	**2**	4	4	intrinsic
Maintain physical strength and health	**1**	2	3	extrinsic
Reduce pain	**1**	3	3	intrinsic
Maintain "musts", e.g., personal economy, etc.	-	2	3	extrinsic

C: ***SPECIFIC SITUATION: Taking a walk***

Motive	Having fun feel good	Maintain social network	Maintain physical strength and health	Reduce pain	Maintain "musts", e.g., personal economy, etc.
Having fun, feeling good	Arg1		Arg7		
Maintain social network		Arg2	Arg2+Arg3		
Maintain physical strength and health		Arg2+Arg3	Arg3	Arg3+Arg4	
Reduce pain			Arg3+Arg4	Arg4 Arg6	
Maintain "musts", e.g., personal economy, etc.	-				Arg5

Fig. 2. Examples of the following: (A) an extract of the user model, (B) the relating multipurpose motivational model, and (C) an illustration of arguments relating to different motives. The examples are based on how a user has rated importance and satisfaction.

Arg4b: "Walking reduces pain after the walk is done." (Figure 2C). Each argument has the weight corresponding to the goal rank in Figure 2A. The average weight is calculated in the following examples of combining arguments into multipurpose arguments. Optimal weight of an argument is 1.

The first strategy uses the motives that are ranked to be most relevant to the situation (here physical activity). This strategy would lead to the multipurpose argument that combines Arg3 and Arg4b into Arg6: "Take walks because it maintains physical capability and pain will be reduced after the walk". The strength would be at the level 2.5, addressing needs of some importance to the individual.

The second strategy takes a more holistic perspective on the situation (Arg7 in Figure 2C). If merging motives and aggregate arguments addressing more motives than the ones that are most relevant for the situation, the following could be a new multipurpose argument: Arg7: "Take a walk with a friend because it is fun to do things with others, you keep contact with the friend, and you will maintain physical capability" (Arg1, Arg2, Arg3). The aggregated strength would be at the level 1.3 and addressing needs of highest importance to the individual.

In the following section we exemplify the case by applying the different types of agents.

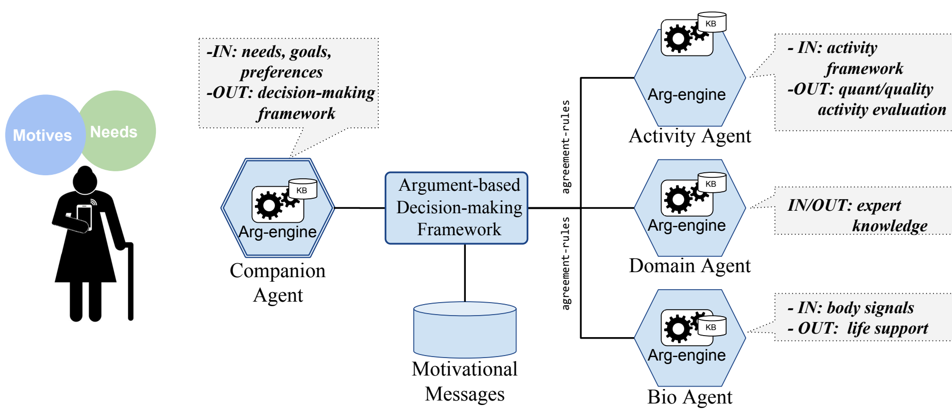

Fig. 3. Multiple agents being orchestrated by a Companion Agent.

5 Orchestrating a Team of Agents with Different Goals

In this paper, agents are characterized as a knowledge structure $Ag = \langle \Sigma, AR, CS, SS \rangle$ in which: Σ is the agent's knowledge base, AR is a set of argument-based protocol messages called *agreement rules* in [25]; CS which is a repository of clauses where the agent stores argued conclusions as a result of a dialogue with other agent, the so called *commitment store*; and SS is a store of *assistive services* this is a store of the "best" services that can be provided by an agent fulfilling a given need. A Companion Agent coordinates information among other agents by defining a decision-making framework (Argument-based decision-making framework module in Figure 3). The agents *vocabulary*, *i.e.,* the communication process to coordinates activities is based on agreement rules. In this paper, we extend the notion of deliberative argumentation dialogs introduced in [25] to centralize the decision-making process into the Companion Agent by updating goal priorities of the commitment store and by adding the service store. In the agent's topology shown in Figure 3, we assume a broadcasting operation of the communications using a publish-subscribe communication pattern. Here we do not discuss the type of communication topology among different agents, *i.e.,* if moves are transmitted to all the agents group using a broadcasting manner or if the Companion Agent has a peer-to-peer communications capabilities. We are certainly interested in exploring different topologies of agent's communications, which is part of our future research.

Roughly, orchestration starts when the Companion Agent identifies an assistive service to provide from prioritized needs and motives of a person. The agent's internal reasoning engine generates a dialogue move *e.g.,* when the Companion Agent identifies a lack of activity exercise, a move:

$$\langle Coach,\ open, (\langle supportInfo, decision, (\alpha lackExercise)\rangle)\rangle$$

is sent to the agent's group. Such move is received by the Exercise Agent which in turn, responds to the Companion Agent with an acknowledge move in order to starts a dialogue. Along the entire argument-based move communication, every agent updates their commitment stores; and depending of the every agent's resources, the service store is also updated.

When different human needs are identified to be supported by the Coach Agent, a prioritization of services has to be done. Each participating agent ag_i ($i \geq 2$) performs an *open*, *assert* or *close* move which are related to open/close/agreeing a dialogue regarding what type of service to provide (*assert* move). These moves have a structure: $\langle ag_i,\ (assert/open/close),\ (\langle S, d, (\alpha, g)\rangle)\rangle$, where α is the preference for the goal g. In this setting, the process for updating services in the SS is performed by the Companion Agent re-ranking goals-services according to user preferences.

Finally, as output of the orchestration process, the Companion Agent has a complete perspective about: 1) the individual's current situation; and 2) a ranked set of assistive services that the multi-agent architecture can provide. A steps list describing the orchestration process is presented in List 1.

Orchestration steps (List 1): Selected steps for an agents orchestration using a centralized Companion Agent

1. Companion Agent identifies a specific situation.
2. Companion Agent checks SS to evaluate possible service agent sources
3. Companion Agent starts a dialogue with agent using an opening move
4. Companion Agent makes a move: $\langle CompanionAgent, assert,\ (\langle S, d, (\alpha, g)\rangle)\rangle$ asking for a service fulfilling goal g
5. Dialogue continues till reach a close move.
6. SS is updated using goal preferences.

6 Related Work

The coordination of teams of agents with different roles has been explored in decision making in medical contexts, e.g. regarding organ viability [34], and in ambient assisted living (AAL) (e.g. [11]). In the example of organ transplantation, the task follows treatment protocols defined for the domain to reach an optimal medical decision, and is as such constrained by the relevant medical knowledge. A moderator agent has the role of making the final decision, in case of conflicting opinions among the agents. It is not clear whether this agent is a physician, in order to assign the responsibility of the medical decision to a human. In the AAL project, the task to be conducted has also been primarily defined from the care provider organizations perspective, that is, to deliver certain care services, without taking a holistic perspective on the human actor's motives and goals into consideration. When addressing person-adaptive systems that aim to promote changes in behavior towards more healthy living, the holistic and situated perspective on human activity similar to what therapists aim for, is instrumental [28, 29]. Along the theme to support professionals in the health domain, a multi-agent system for primarily supporting occupational therapists is presented, which includes a method to also involve the patient [8]. However, to our knowledge, there is no system that handles the complexity and uncertainty of human reasoning using agents with multiple and potentially conflicting roles, all with the purpose to adhere to the human's intentions.

Several generic platforms and methodologies for creating multi-agent systems have been studied [4, 14, 33]. Some of these approaches simply support the creation and interaction of agents such as JADE [4]. However, for our requirements, to develop a multi-agent system with the human as one of the actors, in the healthcare domain, key concepts such as norms, knowledge base and agent roles, are significant. The initial version of the Tropos methodology [14] was focused on supporting the agent development life cycle; however, it does not support the concept of norms. In an enhanced version of Tropos by Telang [33], commitments represent contracts between actors however, they do not establish limits on their behaviours. In addition, it is to be noted that social relationship contracts are only partially supported. Similarly, JADE allows the execution of agents in mobile devices but requires using specific libraries that are only available for certain platforms such as Android or J2ME (Java 2 Micro Edition). In addition, it lacks the support for the development of virtual organization with norms etc. Other approaches to MAS such as PANGEA [36, 8] can be used for our purposes since they permit the creation of virtual organizations with key concepts such as norms and roles. However, for the purpose of prototyping, we focus on the agents modeling and development based on Java with communication based on the exchange of JSON messages between the human and software agent. Their utilization of the ACKTUS knowledge bases are also instrumental in our approach.

7 Conclusions and Future Work

A multipurpose motivational model that captures potentially conflicting motives for social and physical activity is presented. This model is used by a Companion Agent that transforms the information into a multipurpose goal model for orchestrating a team of agents with different goals and responsibilities. The agent team provides personalized support in the form of encouraging arguments tailored to the human actor's situation and motivation.

The results include also further development of the prototype application for personalized coaching. Questions were added that are posed to the user at baseline for capturing the aspects illuminated in the user studies, and feedback messages were added suitable for multipurpose arguments, following what the participants in the studies expressed.

Ongoing work includes the formalization of the multipurpose motivational model and the agent team's goals, implementation based on methods for formal argumentation such as answer set programming for handling the uncertainty and strengths in multipurpose arguments.

The results will be evaluated in studies with a group of older adults using the coaching application during a longer period of time.

References

1. F. Abel, Q. Gao, G.-J. Houben, and K. Tao. Analyzing user modeling on twitter for personalized news recommendations. In *UMAP*, pages 1–12, 2011.
2. J. Baskar and H. Lindgren. Cognitive architecture of an agent for human-agent dialogues. In *PAAMS (Workshops)*, volume 430 of *Communications in Computer and Information Science*, pages 89–100. Springer, 2014.
3. J. Baskar and H. Lindgren. Human-agent dialogues on health topics - an evaluation study. In J. Bajo, K. Hallenborg, P. Pawlewski, V. Botti, N. Sánchez-Pi, D. N. Duque Méndez, F. Lopes, and V. Julian, editors, *Highlights of Practical Applications of Agents, Multi-Agent Systems, and Sustainability - The PAAMS Collection: International Workshops of PAAMS 2015, Salamanca, Spain, June 3-4, 2015. Proceedings*, volume 430 of *Communications in Computer and Information Science*, pages 28–39. Springer International Publishing, 2015.
4. F. L. Bellifemine, G. Caire, and D. Greenwood. *Developing multi-agent systems with JADE*, volume 7. John Wiley & Sons, 2007.
5. T. Bickmore, D. Mauer, and T. Brown. Context awareness in a handheld exercise agent. *Pervasive and Mobile Computing*, 5(3):226–235, 2009.
6. T. Bickmore, S. Mitchell, B. Jack, and M. Paasche-Orlow. Response to a relational agent by hospital patients with depressive symptoms. *Interacting with Computers*, pages 289–298, 2010.
7. J. P. Cámara, S. Heras, V. J. Botti, and V. Julián. receteame.com: A persuasive social recommendation system. In Demazeau et al. [12], pages 367–370.
8. A. Casado, A. Jiménez, J. Bajo, and S. Omatu. Multi-agent system for occupational therapy. In J. B. Pérez, J. M. C. Rodríguez, P. Mathieu, A. T. Campbell, A. Ortega, E. Adam, E. Navarro, S. Ahrndt, M. N. Moreno, and V. Julián, editors, *Trends in Practical Applications of Heterogeneous Multi-Agent Systems. The PAAMS Collection, 12th International Conference on Practical Applications of Agents and*

Multi-Agent Systems (PAAMS 2014) Special Sessions, Salamanca, Spain, June 4-6, 2014., volume 293 of *Advances in Intelligent Systems and Computing*, pages 53–60. Springer, 2014.

9. C. I. Chesñevar, J. McGinnis, S. Modgil, I. Rahwan, C. Reed, G. R. Simari, M. South, G. Vreeswijk, and S. Willmott. Towards an argument interchange format. *Knowledge Eng. Review*, 21(4):293–316, 2006.
10. J. M. Corchado, J. Bajo, Y. de Paz, and D. I. Tapia. Intelligent environment for monitoring alzheimer patients, agent technology for health care. *Decision Support Systems*, 44:382–396, 2008.
11. U. Cortés, C. Barrué, A. B. Martínez, C. Urdiales, F. Campana, R. Annicchiarico, and C. Caltagirone. Assistive technologies for the new generation of senior citizens: the share-it approach. *IJCIH*, 1(1):35–65, 2010.
12. Y. Demazeau, F. Zambonelli, J. M. Corchado, and J. Bajo, editors. *Advances in Practical Applications of Heterogeneous Multi-Agent Systems. The PAAMS Collection - 12th International Conference, PAAMS 2014, Salamanca, Spain, June 4-6, 2014. Proceedings*, volume 8473 of *Lecture Notes in Computer Science*. Springer, 2014.
13. J. Fasola and M. J. Matarić. A socially assistive robot exercise coach for the elderly. *Journal of Human-Robot Interaction*, pages 3–32, 2013.
14. P. Giorgini, M. Kolp, J. Mylopoulos, and M. Pistore. The tropos methodology. In *Methodologies and software engineering for agent systems*, pages 89–106. Springer, 2004.
15. E. Guerrero, J. C. Nieves, and H. Lindgren. ALI: An assisted living system for persons with mild cognitive impairment. In *Computer-Based Medical Systems (CBMS), 2013 IEEE 26th International Symposium on*, pages 526–527, 2013.
16. R. Janols, E. Guerrero, and H. Lindgren. A Pilot Study on Personalised Coaching to Increase Older Adults' Physical and Social Activities. 2017. To appear.
17. V. Kaptelinin and B. A. Nardi. *Acting with Technology: Activity Theory and Interaction Design*. The MIT Press, 2006.
18. G. Kielhofner. *A model of human occupation*. Lippincott, Williams & Wilkins, 2008.
19. H. Lindgren. Personalisation of internet-mediated activity support systems in the rehabilitation of older adults - a pilot study. In *AIME workshop on Personalisation for E-Health, 2009*, pages 22–27, 2009.
20. H. Lindgren, J. Baskar, E. Guerrero, J. C. Nieves, I. Nilsson, and C. Yan. Computer-supported assessment for tailoring assistive technology. In *Proceedings of the 6th International Conference on Digital Health Conference*, DH '16, pages 1–10, 2016.
21. H. Lindgren, E. Guerrero, and R. Janols. Personalised Persuasive Coaching to Increase Older Adults Physical and Social Activities: A Motivational Model. 2017. To appear.
22. H. Lindgren and C. Yan. ACKTUS: A platform for developing personalized support systems in the health domain. In *Proceedings of the 5th International Conference on Digital Health 2015*, DH '15, pages 135–142, 2015.
23. J. Liu, P. Dolan, and E. R. Pedersen. Personalized news recommendation based on click behavior. In *IUI*, pages 31–40, 2010.
24. H. Monkaresi, R. Calvo, A. Pardo, K. Chow, B. Mullan, M. Lam, S. Twigg, and D. Cook. Intelligent diabetes lifestyle coach. *OzCHI workshops programme*, 2013.
25. J. Nieves and H. Lindgren. Deliberative argumentation for service provision in smart environments. In *Multi-Agent Systems - 12th European Conference, EUMAS 2014*, volume 8953 of *Lecture Notes in Computer Science*, pages 388–397. Springer International Publishing, 2015.
26. J. C. Nieves and R. Confalonieri. A possibilistic argumentation decision making framework with default reasoning. *Fundamenta Informaticae*, 113(1):41–61, 2011.

27. M. Ochs, , C. Pelachaud, and D. Sadek. An empathic virtual dialog agent to improve human-machine interaction. *AAMAS 2008 Proceedings of the 7th international joint conference on Autonomous agents and multiagent systems*, pages Vol. 1, pp. 89–96, 2008.
28. H. op den Akker, V. M. Jones, and H. J. Hermens. Tailoring real-time physical activity coaching systems: A literature survey and model. *User Modeling and User-Adapted Interaction*, 24(5):351–392, Dec. 2014.
29. R. M. Ryan and E. L. Deci. Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist*, 55(1):68–78, 2000.
30. A. Sanchis, V. Julián, J. M. Corchado, H. Billhardt, and C. Carrascosa. Improving human-agent immersion using natural interfaces and CBR. *International Journal of Artificial Intelligence*, 13(1):81–93, 2015.
31. M. Sandlund, H. Lindgren, P. Pohl, A. Melander-Wikman, B. Bergvall-Kåreborn, and L. Lundin-Olsson. Towards a mobile exercise application to prevent falls: a Participatory Design Process. . *Int J Child Health Hum Dev*, 9(3):389–398, 2016.
32. D. Surie, B. Berker, and H. Lindgren. Proxemics Awareness in Kitchen AS-A-PAL: Tracking Objects and Human in Perspective. In *9th International Conference on Intelligent Environments, Athens, Greece (IE 2013)*, pages 157–164. IEEE Computer Society Press, 2013.
33. P. R. Telang and M. P. Singh. Enhancing tropos with commitments. In *Conceptual Modeling: Foundations and Applications*, pages 417–435. Springer, 2009.
34. P. Tolchinsky, U. Cortes, S. Modgil, F. Caballero, and A. Lopez-Navidad. Increasing human-organ transplant availability: Argumentation-based agent deliberation. *IEEE Intelligent Systems*, 21(6):30–37, 2006.
35. C. Yan, J. C. Nieves, and H. Lindgren. A multi-agent system for nested inquiry dialogues. In Demazeau et al. [12], pages 303–314.
36. C. Zato, G. Villarrubia, A. Sánchez, I. Barri, E. Rubión, A. Fernández, C. Rebate, J. A. Cabo, T. Álamos, J. Sanz, et al. Pangea–platform for automatic construction of organizations of intelligent agents. In *Distributed Computing and Artificial Intelligence*, pages 229–239. Springer, 2012.