Chapter 2
Argumentation-Based Personal Assistants for Ambient Assisted Living

Stella Heras, Javier Palanca and Carlos Iván Chesñevar

Abstract Personal assistants may help the elderly population to live independently and improve their welfare in ambient assisted living environments. However, although there are current proposals already developed both in academic and commercial domains, these systems are still far from being established on the daily lives of the general population. Argumentation technologies can help to deal with open challenges in this domain. In this chapter, we explore the connection between the related areas of argumentation, recommendation, decision-making and persuasion, and we review related work that can play an important role on the development of the next generation of personal assistants for ambient assisted living.

2.1 Introduction

Nowadays, many studies claim that *Time* is people's most valuable asset [33]. Consequently, Personal Assistants (PAs), which are able to assist people in many tasks and save them time, have recently gained much success. However, the concept that most people have about a PA has deeply changed over time. While in the 20th century PAs were seen as that secretary or administrative staff that all the businessmen or celebrities had, if today we ask someone if they know any PA, it is very likely that they will answer *Siri*,[1] *Cortana*[2] or *Google Now*.[3] The conception of *time* has also

[1]http://www.apple.com/ios/siri.
[2]https://www.microsoft.com/en-us/windows/cortana.
[3]https://www.google.com/search/about.

S. Heras(✉) · J. Palanca
Universitat Politècnica de Valencia, Camino de Vera s/n, 46022 Valencia, Spain
e-mail: sheras@dsic.upv.es

J. Palanca
e-mail: jpalanca@dsic.upv.es

C.I. Chesñevar
Institute for Research in Computer Science and Engineering (ICIC),
UNS - CONICET, San Andrés 800, Bahía Blanca, Argentina
e-mail: cic@cs.uns.edu.ar

A. Costa et al. (eds.), *Personal Assistants: Emerging Computational Technologies*,
Intelligent Systems Reference Library 132, DOI 10.1007/978-3-319-62530-0_2

undergone an arguably slight change. The enormous technological advances of the last decades have gone hand in hand with a progressive aging of the population, and an unprecedented availability of information. Nowadays, people do not have time to learn how to take advantage of the enormous possibilities that technologies and the big volumes of data available on the Internet may offer them. Furthermore, they not only want to have more time, they want more *quality time*, and this means welfare in terms of health and happiness.

So here is where these new and intelligent software PAs can play their crucial role. They could act on people's behalf (taking care of us or our relatives, helping us in our duties, checking our agenda, etc.), and all this in the most efficient way and with the highest quality. Paradoxically, their level of acceptance by the general population is still very low. Although many have PAs in their mobile devices, for instance, they do not feel them as really necessary. As pointed out in [15], PAs *reductionist* architecture may be the cause for their slow establishment in our daily lives. They are still no more than *'an interface to a collection of discrete and effectively independent underlying functionalities'*, but this *'does not add up to intelligence'*. Technologies for personal assistance are still in their infancy and there is a huge room for new approaches and cross-fertilization from other related research areas.

In this chapter, we will focus on the specific domain of PAs for Ambient Assisted Living (AAL). AAL deals with the application of ICT-based solutions for aging well, one of the main pillars of the European Commission roadmap.[4] By 2060, 1 in 3 Europeans will be over 65 and the ratio of working people to the 'inactive' others will be shifting from 4 to 1 today to 2 to 1 [17]. This imminent aging of the population will entail a series of problems that must be addressed from this very moment. Among them, the combination of socialization problems, physical and/or psychological limitations, and the need of specific care raises important challenges for PAs in AAL.

On the one hand, PAs may help the elderly population to live independently and improve their welfare. These technological devices can bring together the elderlies' relatives or friends to make the elderly person feel accompanied. Also, they can manage and track elderlies' activities, show them reminders to take pills, warn caregivers when they are nor feeling well or need help, etc. However, elders did not grown in the current technological age and most have no experience with PAs. Notwithstanding, most show some interest in operating new devices and in learning new things, although they have a general distrust towards computers when they have not been taught to use them [1]. The issue with the current PAs is that they are not truly designed for the elderly, and most will abandon such applications if they are not forced to use them.

To achieve the ultimate goal that the elders actually use PAs in their daily lives, they need to build a relationship of trust between them and the application. Unfortunately, people tend to trust the information that is presented by digital systems even if it is not true or it is incomplete, and when people realize that they were tricked by the system, they stop using it [35]. It is crucial that PAs present truthful infor-

[4] http://www.aal-europe.eu/.

mation, in an understandable and simple way, personalized and appealing for their users. A growing body of work in artificial intelligence has been devoted to deal with research challenges in this domain, and the argumentation research community has also echoed this trend [34]. However, this is still a novel research area with few contributions to date. In this chapter, we review recent advances on computational argumentation in this domain and discuss how these approaches can be successfully applied to overcome research challenges for PAs in AAL settings.

Concretely, the usual operation of a PA in AAL can be seen as a reasoning process with several steps, as depicted in Fig. 2.1. First, the system receives input from different sources of information, like environmental context registered by the PA's sensors (e.g. weather conditions, localization), the user model (e.g. objectives, preferences,

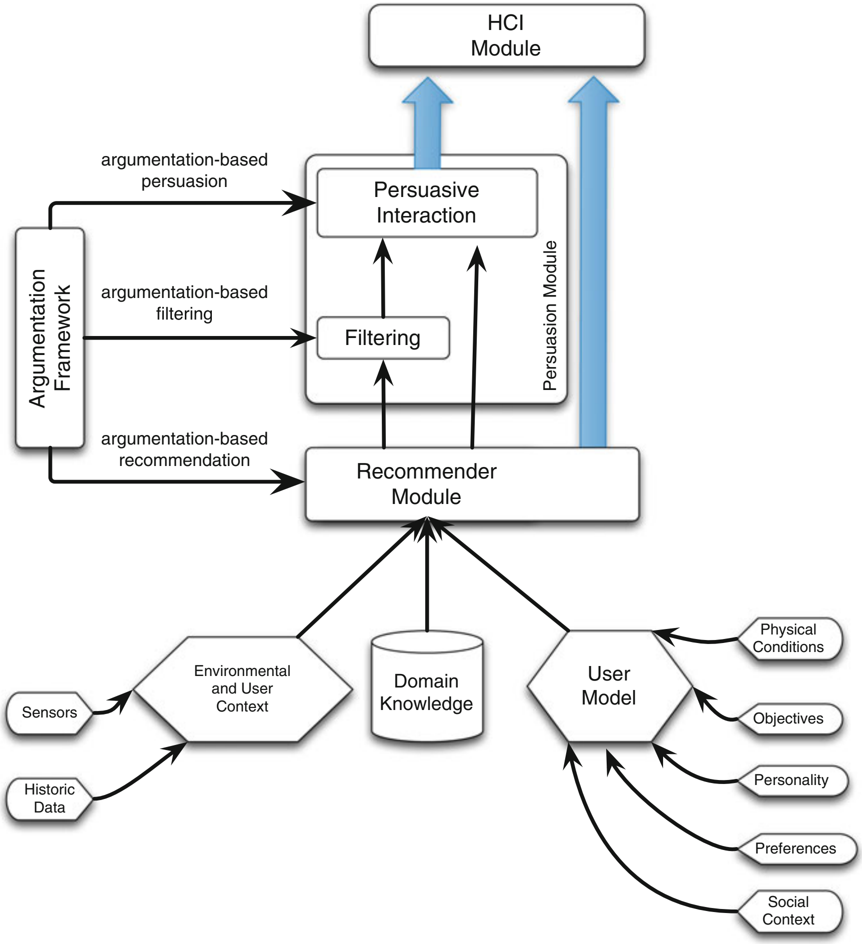

Fig. 2.1 AAL reasoning process

personality, physical conditions, social context), and other possible general knowledge about the domain (e.g. clinical guidelines). Then, it processes these data and generates an advice or recommendation depending on the PA's purpose. Finally, the recommendation is provided to the user. Different styles of human-computer interaction can be followed. For instance, the system may automatically make a decision for the user and directly perform an action on her behalf (e.g. schedule an activity). Other less intrusive approach may be to generate an alert (e.g. a reminder, a warning) that tries to persuade the user to do something, but leaving the final decision of performing it or not at her will. Also, an alternative may also be to allow the user to interact with the system throughout the reasoning process, just to provide more information or to allow her to correct the PA's reasoning (make the PA scrutable).

In this process, argumentation can be applied at different steps and with different purposes. On the one hand, argumentation can be used at the very first steps of the process to make decisions and generate recommendations. Therefore, in Sect. 2.2 we will focus on how argumentation can be used by PAs to promote users' health by helping in decision-making and recommending the best practices or activities in view of the users' goals, preferences, context (environmental, physical, social), etc. Once a list of candidate activities or potential decisions are selected, in Sect. 2.3 we will discuss the role of argumentation to generate persuasive arguments to support them. Here argumentation can pursue different goals. It can be used to filter the list of recommendations and argue in favor or against the provision of a particular advise (i.e. use argumentation as an internal reasoning process for the PA to select the potentially more persuasive recommendation). Alternatively, argumentation can be also used to interact with the user with the aim of persuading her to accept the recommendation once it has been proposed (i.e. use argumentation to promote user's understanding of the systems decisions, or user's behavior change). Finally, in Sect. 2.4 we provide a summary on the work reviewed and identify open issues in this domain.

2.2 Decision-Making and Recommendation

In a general setting, decision-making is a process of identifying and choosing alternatives based on the values and preferences of the decision-maker. When many possible choices are available, the decision making space can become extremely complex to explore under limited resources (time, money, etc.). That is when *recommendations* (or *suggestions*) provide an alternative to reduce such a search space and analyze possible decisions.

Recommender systems [8, 32, 45] are aimed at helping users to deal with the problem of information overload by facilitating access to relevant items. They attempt to generate a model of the user's tasks and apply diverse heuristics to anticipate what information may be of interest to the user. In fact, PAs for AAL can be seen as a particular instance of such systems, expanding the user's natural capabilities by acting as intelligence or memory augmentation mechanisms, tending to minimize the user's cognitive effort (something valuable for human beings in general, and in particular for elderly people).

Recommender systems technologies usually operate by creating a model of the users' preferences or tasks with the purpose of facilitating access to items that the user might find useful. In this respect, many of such systems attempt to anticipate the user's need, providing assistance proactively. In order to come up with recommendations or suggestions, conventional recommender systems rely on similarity measures between users or contents, computed on the basis of methods coming either from the information retrieval or from the machine learning community.

Two main techniques have been used to compute recommendations: *content based* and *collaborative filtering*. Content-based recommenders rely on the premise that user's preferences tend to persist through time, using machine-learning techniques to generate a profile of the user based on ratings she provided in the past. Collaborative filtering recommenders, on the other hand, are based on the assumption that users' preferences are correlated, keeping a pool of users' profiles, so that when decisions are to be made in the context of the active user, she can be presented with items which strongly correlate with other items from similar users in the past.

An important deficiency of recommendation technologies in general is their limited ability to *qualitatively* exploit data, giving rise to a number of issues:

- *Exposing underlying assumptions and providing rationally compelling arguments*: while recommendations may be simple pointers or hints in many situations, it is easy to come up with scenarios in which the user may need further evidence before taking a course of action (e.g. "take a nap after lunch" is a recommendation which is might not be very helpful if not complemented with "since you're over 60 years old and you have high blood presure.").
- *Dealing with the defeasible nature of users' preferences*: modeling the dynamics of user preferences can help to keep a PA for AAL properly up-to-date, without disregarding decisions made by the user in the past.
- *Approaching trust and trustworthiness*: Recommendation technologies are increasingly gaining importance in commercial applications, including PAs. However, most existing systems simply focus on tracking a customers interests and make suggestions for the future without a contextualized justification. As a result the user is unable to evaluate the reasons that led the system to present certain recommendations.

Argumentation [47] provides a natural approach to model the problems discussed before. The research community in this steadily growing discipline in Artificial Intelligence has consolidated itself in the last twenty years, providing interesting contributions in different areas such as multiagent systems [3], social networks [23, 25], machine learning [9], and intelligent decision making [18], among many others.

Given a potentially inconsistent knowledge base, an *argument* is a collection of facts and rules that provide a rational support to reach some conclusion or claim. An argument can be attacked by other *counterarguments*, which can be attacked on their turn. This results in a graph-like structure from which different arguments

Table 2.1 Running example

(1) If you need to take pill A, then call pharmacy X
(2) If a pharmacy is closed, you cannot get pills there
(3) If you need to take pill B, then call pharmacy Y
(4) If it is Saturday, pharmacy X is closed
(5) Today is Saturday
(6) You need to take pill A
(7) You need to take pill B

may be considered to prevail (so-called *warranted* arguments), according to different argumentation semantics. Argumentation frameworks may include different additional features such as knowledge capabilities for representing uncertainty, preference orderings among arguments, as well as other notions such as provenance and audience [47].

For the sake of example, for the case of a PA for AAL we could have the oversimplified knowledge base associated with medicines to be taken by some elderly person shown in Table 2.1:

This toy example shows that this PA can obtain an argument for calling pharmacy Y (from items 3 and 7), whereas the argument for calling pharmacy X (based on items 6 and 1) is defeated by another argument obtained from items 4 and 5. Hence, contacting pharmacy X should be aborted.

Traditional expert systems [20] rely on if-then rules in order to draw conclusions, but lack of the ability to perform commonsense reasoning in the presence of contradictory or potentially inconsistent information (as in the case of the knowledge base given in Table 2.1). As pointed out in a seminal work by McCarthy [38], this lack makes them *brittle*. By this is meant that they are difficult to expand beyond the scope originally contemplated by their designers, and they usually do not recognize their own limitations. Argumentation is intended to overcome such limitations, as it is based on *defeasible* rules, which provide tentative reasons to arrive to conclusions (thus, the rule *'If you need to take pill A, then call pharmacy X.'* should be understood as a tentative rule, which may be subject to the presence of exceptions). Argumentation deals with contradictory information by allowing the emergence of different conflicting arguments (as it usually happens in human reasoning processes), and deciding which arguments are ultimately to be accepted based on a particular semantics.

Figure 2.2 summarizes the different aspects of argument-based reasoning [4]. Starting with a knowledge base containing potentially inconsistent information, we are able to infer different, potentially inconsistent arguments $A_1, A_2, \ldots, A_n$ (depicted traditionally as triangles) which account as tentative proofs to reach conclusions q_1, $q_2, \ldots, q_n$, respectively (Fig. 2.2b). Conflicts among arguments may arise; some arguments will defeat other arguments (Fig. 2.2c), based on some preference criterion on arguments. In order to determine which arguments ultimately prevail, there are

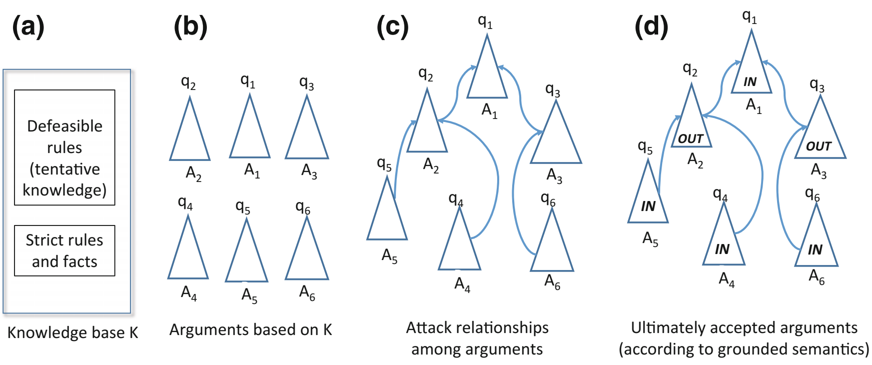

Fig. 2.2 Conceptual view of the different stages involved in the argumentation process

different argumentation semantics which allow to determine which arguments are considered to be *warranted*. For example, according to*grounded skeptical semantics* (Fig. 2.2d) an argument is ultimately accepted (labeled as IN) if it has no arguments defeating it (e.g. arguments A_4, A_5 and A_6), or if all the arguments that attack it are defeated by other arguments which are IN (e.g. as the case for argument A_1). Otherwise, the argument is labeled as OUT (not accepted).

PAs for AAL can benefit from argument-based decision making in many respects. Argumentation theory provides a sound framework for decision making under uncertainty and potentially incomplete information. For the case of PAs, arguments can provide support for different pieces of information, which can be categorized according to their epistimic status (this approach was first introduced in ARGUENET [7], an argument-based web search engine). Argumentation can be also integrated with different formalisms for handling uncertainty (e.g. using possibilistic logic or probabilities), which may also contribute to a richer model for decision making. Furthermore, as explained before, argumentation provides a natural way of tracing the underlying reasoning process carried out to make a decision (instead of adopting a black-box approach, as in many current PAs systems).

Research in argumentation has provided interesting advances which might be helpful for enhancing qualitative reasoning capabilities in PAs for AAL. In [29] an argumentation-based approach to aggregate clinical evidence is proposed. These evidence come from multiple sources, such as randomized clinical trials, systematic reviews, meta-analyses, network analyses, etc., and arguments are used to combine them and decide which treatment outperforms the others or which are equal (can be applied indistinctly). In [46], the authors show how an argumentation-based reasoning service can be used in in a PA for travel services, based on a BDI agent implemented with a Jadex platform. The travel assistant agent illustrates how BDI and argumentation approaches can be effectively integrated in a working system developed with freely available technologies. In [34], the authors discuss engineering aspects for an agent-based AAL system for the home environment using argumentation for decision making. The special requirements of the proposed system are to provide a platform with cost-effective specialized assisted living services for the elderly people having cognitive problems, aiming at improving the quality of their home life, extending its duration and at the same time reinforcing social networking. The proposed architecture is based on an agent platform with PA agents that can service users with more than one type of health problems. In a similar direction, the approach presented in [39] focuses on AAL systems employed to monitor the ongoing situations of elderly people living independently. Such situations are represented here as contexts inferred by multiple software agents out of the data gathered from sensors within a home. These sensors provide an incomplete and potentially inconsistent picture of the world. The solution provided in the paper is based on a multi-agent system where each agent is able to support its understanding of the context through arguments. These arguments can then be compared against each other to determine which agent provides the most reliable interpretation of the reality under observation.

Clearly, an appropriate integration of *context-adaptable criteria* is very important in order to get a PA for AAL working properly. Following the previous example, the recommendations to be provided associated with pills and medicines are subject to different context issues: if the pills are to be taken in the night, some kind of backlight might be needed in the PA device in order to facilitate an easier reading of messages for an elderly person, whereas in daylight the backlight is not required. Similarly, if the person is moving to a different city, the PA's GPS system should provide new context information in order not to look for pharmacies *X* and *Y*, and search for alternatives instead. Recent research has led to integrating context-adaptable selection criteria with argument-based reasoning mechanisms. In [51], the authors present an approach that expands the capabilities of existing argumentation-based recommender systems.The proposal is based on specifying how to select and use the most appropriate argument comparison criterion based on the selection on the users preferences, giving the possibility of programming by the use of conditional expressions, which argument preference criterion has to be used in each particular situation.

Combining argumentation with trust has received particular attention from the research community in the last years, particularly in connection with reasoning under uncertainty. In [48] the auhors present the design and analysis of a user study which was intended to evaluate the effectiveness of ArgTrust –a decision making tool based in formal argumentation, where the user can assign trust values to evidence– in a collaborative human-agent decision-making task. Empirical results show that users interactions with ArgTrust helped them consider their decisions more carefully than without using the software tool. In [2] an argument-based system is presented that allows an agent to reason about its own beliefs and information received from other sources. An agent's beliefs are of two kinds: beliefs about the environment (e.g. "the window is closed") and beliefs about trusting sources (e,g, agent *i* trusts agent *j*). Six basic forms of trust are discussed in the paper, including as well the notion of graded trust (agent *i* trusts agent *j* to a certain extent). When attempting to persuade an agent to believe (or disbelieve) an argument, it can be advantageous for the persuader to have a model of the persuadee. In [28] the author introduces a two-dimensional model that accounts for the uncertainty of belief by a persuadee and for the confidence in that uncertainty evaluation. This gives a better modeling for what the user believes/disbelieves as outcomes, and the confidence value is the degree to which the user does indeed hold those outcomes. The framework is also extended with a modelling of the risk of disengagement by the persuadee.

2.3 Computational Persuasion

Persuasion is a human activity that involves a party attempting to influence a person's beliefs, attitudes, intentions, motivations, or behaviors. From its origins on the ancient Greek philosophy persuasion and argumentation theories are intertwined. Aristotle's *Rhetoric* [19] describes the modes of persuasion furnished by the spoken word as of three types: *ethos* –when persuasion is achieved by the speaker's personal authority or credibility; *pathos* –when persuasion comes through the hearers, when the speech appeals to to the audience's emotions; and *logos* –when persuasion comes through the speech itself when the truth (or apparent truth) is proven by means of persuasive *arguments*. Therefore, argumentation can be used as a persuasion device. On the other way round, persuasion is considered as one of the arts included in the interdisciplinary field of argumentation theory, where it has been one of the most studied types of argumentation dialogues [52].

Nowadays, with the advent of artificial intelligence and the exponential growth of the digital data available on the Internet, many theories of human behavior and thinking have been applied to develop advanced information and telecommunication technologies that represent, interact with and advise humans. Among them, persuasion technologies are an interdisciplinary field of research that focuses on the design and development of interactive technologies that can create, maintain or change the thinking and human behavior using persuasion techniques.

Interestingly, although argumentation has a long history of successful applications that provide computational models of persuasion in many domains [41, 42, 49], it does not play a remarkable role in the current persuasion technologies. As pointed out in [26], most current persuasion technologies designed to produce behavioral changes in humans are based on the following approaches:

- Combining questionnaires to find out information about users;
- Providing information to motivate behavior change in users;
- Using computer games that allow users to explore different scenarios with respect to their behavior;
- Providing applications that allow users to record their behavior;
- Providing applications that display messages to encourage users to continue with the improvement of their behavior.

In these systems, the arguments favoring behavior change are just assumed or implicitly provided. The generation and explicit representation of arguments and counter-arguments that can persuade specific people in specific situations is not taken into account. However, both on persuasion in the real world and on applications that promote behavior change, the generation and explicit representation of convincing arguments and arguments against the arguments of other users is crucial. Therefore, persuasion technologies should include computational models of argument that allow:

- Generating and managing arguments and counter-arguments explicitly;
- Creating dialogue protocols controlling the exchange of persuasive arguments between the parties involved; and
- Creating persuasion strategies that make use of a model of the persuadee to select the potentially most effective arguments for each individual at a specific time of the dialogue.

Following with the running example provided in Table 2.1, if the user wants to know the reasons behind the decision of the PA to contact pharmacy Y, the system could generate the following textual argument to provide an explanation:

(A) "You need to take pill B, so you should call pharmacy Y" (from items 3 and 7).

In this way, the PA would be able to appeal the user's logical reasoning and persuade her by proving that its decisions are based on truthful facts (as an instance of the *logos* mode of persuasion). Furthermore, the PA could also include an interface to interact with the user following a persuasion dialogue protocol. Thus, the user could query the PA for taking pill A, and the PA could generate a textual argument to explain to the user the reasons why it cannot advise this.

(B) "You cannot call pharmacy X to take pill A, since today is Saturday and it is closed" (from items 1–2, and 4–6).

In addition, depending on the user's profile and preferences, the PA may follow a particular persuasion strategy. For instance, if the PA's model of the persuadee defines her as a *pragmatic person* who prefers quick and short action recommendations, the PA may only show argument A to explain its line of reasoning. Instead, if the PA considers the user to be a *rational person*, it may also show argument B to expose all reasons for calling pharmacy Y and not X.

Currently, the research community has acknowledged the lack of formal argumentation approaches in persuasion technologies and new projects[5] and initiatives have been started to deal with this challenge. On the specific domain of AAL, persuasive PAs can provide understandable justifications for medical diagnosis and health-care recommendations, motivating users' engagement and behavior change. These justifications can come from different sources of knowledge (e.g. scientific texts and clinical practice guidelines [22], randomized controlled trials [30], previous experiences formatted as clinical cases [16], etc.). In the literature, we can find an ambiguous use of the terms 'justification', and 'argument'. The general term 'justification' is used to denote any element that supports the decisions of a system (a PA in our application domain). A justification can be a text, an inspection on the data used by the system to derive a conclusion, a set of rules, etc. Here, we use the term argument to denote

[5] Framework for Computational Persuasion Project: http://www.computationalpersuasion.com/.

the formal representation of the justification for each suggestion or decision (as it is understood by argumentation theory). Thus, arguments are made up of a conclusion and a set of elements that support them, which are typically facts and rules, cases, or schemes, depending on the argumentation formalism used to develop the system.

Several well-known concepts of the argumentation theory have been adopted by the AI community to manage persuasion dialogues in computational systems. Among them, the theory of argumentation schemes has been widely applied. Argumentation schemes represent stereotyped patterns of common reasoning whose instantiation provides an alleged justification for the conclusion drawn from the scheme. The arguments inferred from argumentation schemes adopt the form of a set of general rules by which, given a set of premises, a conclusion can be derived. Different authors have proposed several sets of argumentation schemes, but the work of Walton [53], who presented a set of 25 different argumentation schemes, has been the most used by its simplicity and the fact that his schemes have associated a set of critical questions. If instantiated, these questions can represent potential attacks to the conclusion drawn from the scheme. Therefore, if the opponent asks a critical question, the argument that supports this argumentation scheme remains temporally rebutted until the question is conveniently answered. This characteristic of Walton's argumentation schemes makes them very suitable to reflect reasoning patterns that the system can follow to bring about conclusions and, what is more important, to devise ways of attacking any other alternative conclusions.

In [12], authors presented a persuasive module that has been integrated in a cognitive assistant framework, the iGenda framework [11]. The proposed persuasive module tried to improve user engagement by generating arguments that allow the system to select such health-care activities that best suit to the users' profile. These arguments were based on previous similar cases stored in a case-base, which provided a justification based on the information of the clinical guidelines used to select a specific action. This PA implements a value-based argumentation framework that allows it to automatically schedule the most persuasive activities for each user (those with a higher amount of warranted arguments that support them) by following a case-based reasoning approach. This work covers both recommendation and persuasion areas, but actually persuasion is viewed as an internal process that simulates the interaction between the system and the user.

In a subsequent work [13], authors extended their PA with a new argumentation resource that consists on a set of argumentation schemes that capture the way of reasoning that physicians and caregivers follow to recommend activities to patients. Thus, they provide a way to generate more elaborated arguments (e.g. based on analogy, on the opinion of an expert, or on popular practice) and to determine the relation among arguments (e.g. specifying clearly how an argument can receive attacks). Following a similar approach, although not based on Walton's argumentation schemes, biomedical argumentation schemes are presented as logical programs to be able to automatically mining arguments from clinical guidelines in [22].

The role of argumentation schemes to represent fallacious reasoning in public health was analyzed in [14]. Also, in [5], the author presented ongoing research on testing the effectiveness and usability of argumentation schemes to improve the persuasion power of doctors. The purpose of this system was to enhance elderly diabetes patient's self-management abilities in chronic care. However, those works focus on formal argumentation and linguistics, and do not apply their findings in a computational system. Despite that, they tested argumentation theories with real people in AAL domains, and hence, pave the way for implementing such theories in persuasion technologies developed in PAs.

In addition to argumentation schemes, further work has investigated the general role of argumentation theory to persuade people in the context of medical diagnosis and health care. In [21], authors presented a theory of *informal argumentation* to promote behavior change, focused on the audience's perception of the argument rather than on the soundness of the argument itself. This theory was implemented in a system called *Daphne*, which uses dialectical argumentation for providing healthy nutrition education. In [36], *Portia*, a dialogue system that includes an argumentation module to persuade users to adopt healthy-eating habits, was presented. This system explored different types of argumentation strategies that combine rational arguments and emotional arguments that appeal to the users' expected emotions. Finally, in [24], authors presented an assistive technology that recommends daily activities to its users. The system follows a non-intrusive approach that tracks and monitors individuals' activities and generates recommendations supported by arguments that try to persuade the user towards healthier life styles (e.g. eat healthy, socializing, and maintaining good physical conditions). One of the most interesting contributions of this work is how arguments are translated into pseudo-natural language sentences in order to encourage and give positive feedback to the users.

Although not specifically called PAs after their authors, all these works proposed computational systems that help their users to improve their welfare to some extent by persuading them to change their behavior. Therefore, despite still being reductionist (interfaces to a collection of independent functionalities), they establish a solid background for the application of argumentation-based persuasion technologies in AAL domains.

2.4 Conclusion and Open Issues

Despite not many work in argumentation is specifically devoted to develop PAs in AAL, there is a clear link between these areas. Furthermore, recommendation and persuasion are key functionalities that PAs must have to interact naturally with their users and provide really useful support services to them. In this chapter, we have explored the connection among those technologies and reviewed related work that can play an important role for the development of the next generation of PAs in AAL.

As a summary of our review, Table 2.2 shows how these related work[6] compare in terms of their main research topic, application domain, argumentation formalism,

[6]For the sake of clarity, we have only included in Table 2.2 those reviewed works whose main objective is to provide any type of assistance to their users in an AAL-related domain.

Table 2.2 Summary of the related work

Authors	Research topic	Application domain	Argumentation formalism	Argumentation objective	Architecture	HCI style
Bigi [5]	Persuasion	Diabetes chronic care self-management	Formal Argumentation, Linguistics, Argumentation schemes	Patient education and counseling	n/a	n/a
Costa et al. [12, 13]	Recommendation, Persuasion	AAL, Schedule activities to improve elders' health	Value-based, Case-Based, Argumentation schemes	Recommend most persuasive activity	Modular, Mobile App	Textual alerts
Grasso et al. [21]	Persuasion	Healthy nutrition education	New rhetoric schemes [54]	Engage in persuasive dialogue	Agent-based	Textual utterances
Guerrero et al. [24]	Recommendation, Persuasion	Recommend daily activities to improve health	Rule-based, Possibilistic logic programming	Encourage users, Guide users to healthier behavior	Modular, Mobile App	Pseudo-natural language sentences

(continued)

Table 2.2 (continued)

Authors	Research topic	Application domain	Argumentation formalism	Argumentation objective	Architecture	HCI Style
Hunter and Williams [29]	Recommendation	Aggregation of clinical evidence	Structured arguments based on evidence tables. Argumentation graphs	Decide the best treatment	n/a	n/a
Marcais et al. [34]	Decision making	AAL, Assist elders with Alzheimer disease	Rule-based, Gorgias argumentation framework (preference reasoning and abduction) [31]	Reasoning on pills dosage, Assigning priority to schedule conflicting tasks	Multi-agent system service platform	Textual alerts on Internet-enabled TVs
Mazzotta et al. [36]	Recommendation, Persuasion	Healthy eating habits education	Rule-based, Probabilistic reasoning	Convince users to change eating habits	Agent-based dialogue system	Natural language messages
Muñoz et al. [39]	Decision making	AAL, Monitor elders at home and alert to problems	Rule-based, OWL-DL reasoning	Decide the most reliable sensors information	Multi-agent system	SMS textual alerts, Phone calls

objective of the argumentation process, architecture, and HCI style (i.e. how arguments and information are presented to the user).

As shown in the table, there is a great variability among the argumentation formalism used by the related work, but all have in common their focus on argument generation and evaluation. Hence, argumentation is mainly used to provide a personalized support to users by making decisions or recommendations that suit their profile and objectives, or by generating personalized justifications aimed at convincing them to change their behavior. This establishes a good background to cope with one of the open challenges of PAs; the provision of personalized assistance to users.

Notwithstanding, PAs still have many challenges to overcome in order to declare their success in all of their application domains [10]:

1. To get a real *agency*: they must be able to recognize users' goals, act proactively and collaborate with other people and PAs to accomplish them, and engage in conversations;
2. To provide a *personalized assistance*: they must fit the users' profiles and preferences, interact with their family and social context, solve potential conflicts, take into account their emotional estates; and
3. To deal with *trust, privacy, security and ethical issues*.

Adding up to the provision of personalized assistance, argumentation protocols and argumentation strategies can also elicit actual proactive behavior and natural interaction between PAs and their users. Argumentation research has provided many formal argumentation protocols [37] whose adaptation to AAL domains may provide a formal way to model different types of human-like dialogues between PAs and users. An important open issue here would be to go beyond the usual approach of argumentation systems to assume 'asymmetric dialogues', which simulate users rather than directly interacting with them. This approach is commonly followed due to the difficulties of computational systems to understand the natural language of the user. However, work on computational models of natural argument [43] and contributions on the newly research topic of argument mining [6] provide tools to cope with this challenge. Furthermore, they can also pave the way for improving HCI interfaces, which currently are usually based on the presentation of basic textual pre-compiled messages to the user.

Similarly, recent research on argumentation theory to investigate persuasion strategies in dialogues can advance the current state of the art on PAs and allow them to actually achieve changes in the behavior of their users [27, 44]. Proposals on this area have to pay particular attention on the evaluation of their actual persuasive power and their ability to maintain these behavior changes over time [40].

Finally, interacting with people entails big challenges to build people's trust on the PA and to preserve people's privacy and security. These issues have also been investigated on computational argumentation, and contributions in this domain may inspire new approaches to deal with similar challenges in the PAs for AAL domain. For instance, arguments can be used to justify trust values and support the reputation of a specific PA [50].

Acknowledgements This work was supported by the projects TIN2015-65515-C4-1-R and TIN2014-55206-R of the Spanish government, and by the grant program for the recruitment of doctors for the Spanish system of science and technology (PAID-10–14) of the Universitat Politècnica de València. Authors also acknowledge partial support by PICT-ANPCyT 2014-0624, PIP-CONICET 112-2012010-0487, PGI-UNS 24/N039, and PGI-UNS 24/N040.

References

1. Akbaraly, T., Portet, F., Fustinoni, S., Dartigues, J.-F., Artero, S., Rouaud, O., Touchon, J., Ritchie, K., Berr, C.: Leisure activities and the risk of dementia in the elderly results from the three-city study. Neurology **73**(11), 854–861 (2009)
2. Amgoud, L., Demolombe, R.: An argumentation-based approach for reasoning about trust in information sources. Argum. Comput. **5**(2–3), 191–215 (2014)
3. Atkinson, K., Cerutti, F., McBurney, P., Parsons, S., Rahwan, I.: Special issue on argumentation in multi-agent systems. Argum. Comput. **7**(2–3), 109–112 (2016)
4. Besnard, P., Hunter, A.: Elements of Argumentation. The MIT Press (2008). ISBN 0262026430, 9780262026437
5. Bigi, S.: Healthy reasoning: the role of effective argumentation for enhancing elderly patients' self-management abilities in chronic care. Active Ageing Healthy Living A Hum. Cent. Approach Res. Innov. Sour. Qual. Life **203**, 193 (2014)
6. Cabrio, E., Hirst, G., Villata, S., Wyner, A.: Natural language argumentation: Mining, processing, and reasoning over textual arguments (dagstuhl seminar 16161). In: Dagstuhl Reports, vol. 6. Schloss Dagstuhl-Leibniz-Zentrum fuer Informatik (2016)
7. Chesñevar, C.I., Maguitman, A.G.: Combining argumentation and web search technology: towards a qualitative approach for ranking results. JACIII **9**(1), 53–60 (2005)
8. Chesñevar, C.I., Maguitman, A.G., González, M.P.: Empowering recommendation technologies through argumentation. In Simari and Rahwan [47], p. 403–422. ISBN 978-0-387-98196-3
9. Cocarascu, O., Toni, F.: Argumentation for machine learning: a survey. In: Baroni, P., Gordon, T.F., Scheffler, T., Stede, M. (eds.), Computational Models of Argument—Proceedings of COMMA 2016, Potsdam, Germany, 12-16 September, 2016. volume 287 of Frontiers in Artificial Intelligence and Applications, pp. 219–230. IOS Press (2016). ISBN 978-1-61499-685-9
10. Cohen, P., Cheyer, A., Horvitz, E., El Kaliouby, R., Whittaker, S.: On the future of personal assistants. In: Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems, pp. 1032–1037. ACM (2016)
11. Costa, A., Novais, P., Simoes, R.: A caregiver support platform within the scope of an ambient assisted living ecosystem. Sensors **14**(3), 5654–5676 (2014)
12. Costa, A., Heras, S., Palanca, J., Novais, P., Julián, V.: A persuasive cognitive assistant system. In: Ambient Intelligence-Software and Applications–7th International Symposium on Ambient Intelligence (ISAmI 2016), pp. 151–160. Springer International Publishing (2016)
13. Costa, A., Heras, S., Palanca, J., Jordán, J., Novais, P., Julián, V.: Argumentation schemes for events suggestion in an e-health platform. In: XII International Conference on Persuasive Technology XII. To Appear (2017)
14. Cummings, L.: Reasoning and public health: New ways of coping with uncertainty. Springer (2015)
15. Dale, R.: The limits of intelligent personal assistants. Natural Lang. Eng. **21**(02), 325–329 (2015)
16. El-Sappagh, S., Elmogy, M.M.: Medical case based reasoning frameworks: Current developments and future directions. Int. J. Decis. Support Syst. Technol. (IJDSST) **8**(3), 31–62 (2016)
17. EuropeanCommission: The ageing report economic and budgetary projections for the 28 eu member states (2013–2060). Technical report, European Commission, Directorate-General for Economic and Financial Affairs (2015)

18. Ferretti, E., Tamargo, L.H., García, A.J., Errecalde, M.L., Simari, G.R.: An approach to decision making based on dynamic argumentation systems. Artif. Intell. **242**, 107–131 (2017)
19. Freese, J.: Aristotle, The Art of Rhetoric. With Greek text (English translation). Cambridge, Loeb Classical Library/Harvard University Press (1924)
20. Giarratano, J.C., Riley, G.D.: Expert Syst. Princ. Program. Brooks/Cole Publishing Co., Pacific Grove, CA, USA (2005)
21. Grasso, F., Cawsey, A., Jones, R.: Dialectical argumentation to solve conflicts in advice giving: a case study in the promotion of healthy nutrition. Int. J. Hum.-Comput. Stud., 53(6):1077–1115 (2000). ISSN 1071-5819
22. Green, N.: Implementing argumentation schemes as logic programs. In: The 16th Workshop on Computational Models of Natural Argument. CEUR Workshop Proceedings (2016)
23. Grosse, K., González, M.P., Chesñevar, C.I., Maguitman, A.G.: Integrating argumentation and sentiment analysis for mining opinions from twitter. AI Commun. **28**(3), 387–401 (2015)
24. Guerrero, E., Nieves, J.C., Lindgren, H.: An activity-centric argumentation framework for assistive technology aimed at improving health. Argum. Comput., (Preprint), 1–29 (2016)
25. Heras, S., Atkinson, K., Botti, V.J., Grasso, F., Julián, V., McBurney, P.: Research opportunities for argumentation in social networks. Artif. Intell. Rev. **39**(1), 39–62 (2013)
26. Hunter, A.: Opportunities for argument-centric persuasion in behaviour change. In: European Workshop on Logics in Artificial Intelligence, pp. 48–61. Springer (2014)
27. Hunter, A.: Modelling the persuadee in asymmetric argumentation dialogues for persuasion. In: 24th International Joint Conference on Artificial Intelligence, pp. 3055–3061 (2015)
28. Hunter, A.: Two dimensional uncertainty in persuadee modelling in argumentation. In: Kaminka, G.A., Fox, M., Bouquet, P., Hüllermeier, E., Dignum, V., Dignum, F., van Harmelen, F. (eds.), ECAI 2016—22nd European Conference on Artificial Intelligence, 29 August-2 September 2016, The Hague, The Netherlands - Including Prestigious Applications of Artificial Intelligence (PAIS 2016), volume 285 of Frontiers in Artificial Intelligence and Applications, pp. 150–157. IOS Press (2016). ISBN 978-1-61499-671-2
29. Hunter, A., Williams, M.: Aggregation of clinical evidence using argumentation: a tutorial introduction. In: Foundations of Biomedical Knowledge Representation, pp. 317–337. Springer (2015)
30. Jackson, S., Schneider, J.: Argumentation devices in reasoning about health. In: The 16th Workshop on Computational Models of Natural Argument. CEUR Workshop Proceedings (2016)
31. Kakas, A., Moraitis, P.: Argumentation based decision making for autonomous agents. In: Proceedings of the Second International Joint Conference on Autonomous Agents and Multiagent Systems, pp. 883–890. ACM (2003)
32. Konstan, J.A.: Introduction to recommender systems: algorithms and evaluation. ACM Trans. Inf. Syst., 22(1), 1–4 (2004). ISSN 1046-8188
33. Kruse, K.: 15 Secrets Successful People Know About Time Management: The Productivity Habits of 7 Billionaires, 13 Olympic Athletes, 29 Straight-A Students, and 239 Entrepreneurs. The Kruse Group; 1 edition, 1 (2015). ISBN 0985056436
34. Marcais, J., Spanoudakis, N., Moraitis, P.: Using argumentation for ambient assisted living. In: Artificial Intelligence Applications and Innovations, pp. 410–419. Springer (2011)
35. Marsh, S., Dibben, M.R.: Trust, untrust, distrust and mistrust–an exploration of the dark (er) side. In: International Conference on Trust Management, pp. 17–33. Springer (2005)
36. Mazzotta, I., de Rosis, F., Carofiglio, V.: Portia: a user-adapted persuasion system in the healthy-eating domain. IEEE Intell. Syst. **22**(6), 42–51 (2007)
37. McBurney, P., Parsons, S.: Games that agents play: a formal framework for dialogues between autonomous agents. J. Logic Lang. Inf. **11**(3), 315–334 (2002)
38. McCarthy, J.: Some expert systems need common sense. Ann. N.Y. Acad. Sci., 426(1), 129–137 (1984). ISSN 1749-6632
39. Muñoz, A., Augusto, J.C., Villa, A., Botía, J.A.: Design and evaluation of an ambient assisted living system based on an argumentative multi-agent system. Personal Ubiquitous Comput. **15**(4), 377–387 (2011)

40. Nguyen, H., Masthoff, J.: Designing persuasive dialogue systems: using argumentation with care. In: International Conference on Persuasive Technology, pp. 201–212. Springer (2008)
41. Prakken, H.: Formal systems for persuasion dialogue. Knowl. Eng. Rev. **21**(02), 163–188 (2006)
42. Reed, C.: Dialogue frames in agent communication. In: Proceedings of International Conference on Multi Agent Systems, pp. 246–253. IEEE (1998)
43. Reed, C., Grasso, F.: Recent advances in computational models of natural argument. Int. J. Intell. Syst. **22**(1), 1–15 (2007)
44. Rosenfeld, A., Kraus, S.: Strategical argumentative agent for human persuasion. In: ECAI 2016: 22nd European Conference on Artificial Intelligence, 29 August-2 September 2016, The Hague, The Netherlands-Including Prestigious Applications of Artificial Intelligence (PAIS 2016), vol. 285, p. 320. IOS Press (2016)
45. Sandvig, J.J., Mobasher, B., Burke, R.D.: A survey of collaborative recommendation and the robustness of model-based algorithms. IEEE Data Eng. Bull. **31**(2), 3–13 (2008)
46. Schlesinger, F., Ferretti, E., Errecalde, M., Aguirre, G.: An argumentation-based BDI personal assistant. In: García-Pedrajas, N., Herrera, F., Fyfe, C., Benítez, J.M., Ali, M. (eds.), Trends in Applied Intelligent Systems - 23rd International Conference on Industrial Engineering and Other Applications of Applied Intelligent Systems, IEA/AIE 2010, Cordoba, Spain, June 1-4, 2010, Proceedings, Part I, vol. 6096 of Lecture Notes in Computer Science, pp. 701–710. Springer (2010). ISBN 978-3-642-13021-2
47. Simari, G.R., Rahwan, I. (eds.): Argumentation in Artificial Intelligence. Springer (2009). ISBN:978-0-387-98196-3
48. Sklar, E.I., Parsons, S., Li, Z., Salvit, J., Perumal, S., Wall, H., Mangels, J.A.: Evaluation of a trust-modulated argumentation-based interactive decision-making tool. Auton. Agents Multi-Agent Syst. **30**(1), 136–173 (2016)
49. Sycara, K.P.: Persuasive argumentation in negotiation. Theo. Decis. **28**(3), 203–242 (1990)
50. Tang, Y., Cai, K., McBurney, P., Sklar, E., Parsons, S.: Using argumentation to reason about trust and belief. J. Logic Comput., exr038 (2011)
51. Teze, J.C., Gottifredi, S., García, A.J., Simari, G.R.: Improving argumentation-based recommender systems through context-adaptable selection criteria. Expert Syst. Appl. **42**(21), 8243–8258 (2015)
52. Walton, D., Krabbe, E.C.: Commitment in dialogue: Basic concepts of interpersonal reasoning. SUNY Press (1995)
53. Walton, D., Reed, C., Macagno, F.: Argumentation Schemes. Cambridge University Press (2008)
54. Warnick, B., Kline, S.L.: The new rhetorics argument schemes, a rhetorical view of practical reasoning. Argum. Advocacy, 29(1), 1–15 (1992)