Automated Nursing Agent: A Software Agent for At-Home Elderly Care

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***Abstract*—The global increase in elderly population is a concern for many developed countries. The concern has to do with the financial and infrastructure challenges to assist, take care, and manage the aging population that typically requires more care, specialized personnel, and expensive facilities. While the population is indeed aging, particularly in developed countries, many of the elderly prefer remaining at home instead of moving to nursing homes. It has been demonstrated that companionship, such as other residents or pets, can significantly help preserve mental and physical health of the elderly. There has been considerable interest in building computer programs that work as an intelligent personal assistant such as Siri and Google Now, but these typically serve as knowledge navigators to search for information or do simple tasks on a smartphone. We propose an intelligent software agent that runs on tablet devices and operates as a companion to the elderly, assisting them in information retrieval, reminding them of relevant events, and more importantly, conversing with them as a human would do. In this paper, we introduce the Automated Nursing Agent (ANA) and present the technical challenges developing such a software agent.**

Keywords-Software Agent; Intelligent Agents; Automated Conversation; Natural Language Processing.

I. MOTIVATION

The need for companionship has been identified by many people and experts in psychology and geriatrics in different countries and cultures. Every human being feels the necessity of having a companion to some extent with whom to talk and share life events, and other important personal issues [1]. This need for having a companion is even more important for older people. Indeed, loneliness and social isolation can predict, for the elderly, declining health and poor quality of life [2]. Social interactions can reduce the mentioned effects of loneliness and social isolation. This is demonstrated to be true for the working people, let alone the elderly living alone [3][4].

Nowadays, thanks to advancements in healthcare and medicine, the life expectancy in developed countries has increased significantly [5][6]. Another noteworthy issue is the population decline in most of these countries [7]. These changes resulted in a higher percentage of elderly population compared to last decades. Many live assisted but many choose to live at home [8][9]. This trend will accentuate. According to the U.S. Census Bureau projections, by 2050, one-in-five Americans will be 65 or older, and at least 400,000 will be 100 years or older [10]. Today, the 65 or older represent 13% of the US population denoting around 41 million people. With a growing number of elderly in developed countries, there are not enough caregivers or nurses to take care of this aging population [11]. In Canada, 92% of the 5 million seniors aged 65 and over live in private homes [12]. Remaining at home will be encouraged for financial, social and health reasons. Services and facilities for the elderly, like nursing homes, will not always be available and the services cannot scale with the predicted demand of the senior population. Having a software agent at home could be a solution to help attenuate the need for companionship if this software agent running on a tablet-like device can indeed converse in a fluent manner and provide the required access to information and remote assistance.

The need for companionship has also been acknowledged for patients in hospitals [13][14]. Hospitals can be lonely places for patients. This is particularly more accentuated for older adults who may have few, if any, family members or acquaintances living close enough to visit them. Some hospitals even created Companion Care Programs where volunteers come to interact with patients, sharing small talk and activities.

Aside from companionship, the elderly have various needs and their living conditions can vary from one individual to another. Thus, personalized care and attention are required. The elderly who can take care of themselves often choose and remain at home instead of joining care facilities. More often than not, they opt for pets as companions. Pets have proven to be beneficial for mental health in the case of lonely seniors [15][16], but their entertaining interaction falls short from intelligent and knowledgeable conversation. In many cases, while choosing to remain at home, some seniors are not totally autonomous and capable of looking after themselves, therefore, there is a need to have a family member or a caregiver to live with them or check on them frequently. When it is not possible, a software agent could communicate with caregivers in cases of emergency. Moreover, doctors, caregivers, or family members could remotely inquire about the state of the senior, communicating directly with the agent.

We present here the architecture of a software agent, ANA, to attempt to remediate the current shortcomings. ANA, for Automated Nursing Agent, is a software agent running on Android tablet devices, specifically designed for the companionship of the elderly. ANA verbally tends to a person,

at home, in need. It looks after an elderly at home so as to promote health through companionship. Nursing is about providing care and is an integral part of the health care system. It encompasses the promotion of health, prevention of illness, and care of someone in physical or mental need.

Unlike intelligent personal assistant software agents such as Apple Siri, Google Now, Microsoft Cortana, and many others, which are designed to answer information requests or to help owners of handheld devices to verbally express commands on their devices, ANA piggybacks on Google APIs for information requests but extends this capability by building a personalized knowledge base to provide personalized conversations with answers but also questions and general statements. We are currently focusing on conversations related to family, weather, health, and cooking. Moreover, ANA also reminds the senior about events and facts recorded in previous conversations, documents health-related events, and is accessible remotely by authorized caregivers and family members.

In Section 2, we first present some scenarios illustrating the usefulness of the agent and in Section 3, we discuss our methodology to address those scenarios. In Section 4, we conclude the paper and talk about the current state of our project.

II. SCENARIOS

ANA is not competing with intelligent personal assistants. In fact, it uses Google APIs to access information and search the Web knowledge. However, it adds new capabilities to make it more personal. For instance, it uses a database of jokes and learns to choose jokes to tell based on the appreciations of the previous jokes by the senior using reinforcement learning. Other activities provided by ANA include reading, playing games, and providing means to tell their life story. By encouraging the elderly to share life experiences, it improves the connection between the agent and the user. ANA stores personal information in a personalized knowledge base in addition to using a general knowledge base like Freebase [17] or Google Knowledge Graph [18]. In the following, we present some example scenarios using ANA.

A. Scenario 1. Conversations initiated by the elderly

One of the main characteristics that an intelligent system needs to have to be considered as a companion is the ability to have a normal, fluent conversation similar to human verbal interactions. There are three types of interactions in conversations: making a statement (declarative), asking a question (Interrogative), and giving an order (Imperative).

1) Declarative statements

There are different types of declarative statements. All the statements in talking about a past or future event or telling a story are considered declarative. People talk about how they are feeling, who they met, family members and friends, and also, the events that may happen during that day or in the near future. A person who is being talked to usually acknowledges the understanding of the story by saying some other declarative statements. This acknowledgment also shows that the person is interested in the story. Also, there can be some questions that may come up to the listener's mind, in case of having some vague details in the story. It is very common to ask about some details when you are listening to someone. Also, people expect that the others that they are talking to remember some details of the previous conversations and when they are referring to those told stories later, that person remembers some of it and is not completely clueless.
All these details should be implemented in our system to make elderly feel comfortable talking to a machine because without having these details, the conversation will seem unnatural and they would rather not use the system. ANA stores such information in a personalized knowledge base as well as a calendar for events and medical conditions.

2) Interrogative statements

Questions are considered as interrogative statements. There can be different types of questions that need different responses. In a normal conversation, it is usual to ask something personal from the person that we are talking to. Although the system that we are talking about is not a person, it should give some kind of a response that makes sense and keeps the conversation going.

The other form of questions can be related to the person who is talking. They can ask about how they look or want to know your opinion about some related issues and problems. This kind of question is very hard to handle by a machine since it needs to have opinions about things that are happening around it, but like the previous type of question that we talked about, it needs to give answers that make sense.

The third type of question is related to the subjects that have been talked about before and need remembering. To answer these questions, we should refer to the previous conversations that we had with the person. The system should gather information from conversations that it had with the person in order to answer these questions. Remembering details will make the conversations more natural and closer to what happens in real life. Even missing some details by the system is not a big deal since it can happen with real people too.

Questions can be about general knowledge. They are easier to handle compared to the others that we have talked about. To answer these questions, we can check different online knowledge bases that are available widely. If the answer is not found, the machine says it does not know it. It is very unlikely that someone knows answers to every question hence our system is not an exception. This is similar to what current intelligent personal assistants do. Also, the goal is not answering questions but being a companion, so missing answers to some questions in this context is fine.

There also can be other questions that are imperative in essence. These statements should be handled like imperative statements.

3) Imperative statements

All the commands and requests are considered imperative. Human beings are usually able to help each other with different tasks but it does not necessarily mean that they can help with all the tasks. Our system also does not need to address all the commands, but it is favorable if it can do as many as possible. Right now, having physical abilities in the system is not one of our goals. Controlling physical objects can be done by a computerized system, but there is a need for

additional equipment to add this capability, which is against our current objective of having a cheap system for end users. Even if the system is not going to do anything about physical commands, it will try to give some sort of suggestions or try to come up with a witty response. For other types of commands, the system should be able to do them easily. These commands can be things like calling, texting, sending an email, checking up some information online, finding a recipe, or reminding the person of something. After doing any of these commands, there should be some sort of acknowledgment for the action in a way that the person knows that the command is done.

B. Scenario 2. Conversations initiated by system

In Scenario 1 we considered responses that are necessary for a natural conversation, however, in a normal conversation, each subtopic can be initiated by both sides of the conversation. If someone is always asking questions or making statements while the other person just responds to each one of them, the conversation will be one-sided and boring.

In order to avoid situations like this, we need to have functionalities in our system to sometimes initiate a conversation. One of the things that should be considered is that the subtopics in a discussion are usually related. Going completely off-topic can make the conversation feel unnatural. This is the case with chatterbots, software agents that are mostly built for fun.

To find related topics, we can refer to previous conversations between person and system. To Start a new topic, the system searches for empty facts or attributes in its personalized knowledge base and creates a statement to initiate a conversation that leads to filling the missing facts. These facts will be used later for other conversations.

Initiating conversation can be used for continuing current conversation after a long pause by the person. These long pauses are known as awkward silences and people try to fill them with starting a conversation. This human-like behavior can make the system very similar to a human companion.

C. Scenario 3. Caregiving functionality and remote access

In previous scenarios, we considered all the different characteristics that can make our system act like a human. While it is very interesting to mimic human behavior, the main purpose of this system is to ensure or improve the welfare of elderly when they live on their own and without direct human supervision.

Keeping track of medication for elderly can be challenging. Caregivers usually remind them of taking their medicines and they make sure that they took them. They also keep track of what medicine they took and when they took it. This information can be helpful for doctors. If we implement all the necessary components to handle scenario 1 and 2, it is easy to add these functionalities since they can be accommodated in the form of statements.

Caregivers also ask elderly about how they feel. Their responses in a period of time can be helpful in identifying unusual symptoms and patterns that can be caused by a disease. Like the previous case, it is also a very small extension to other scenarios that we have described.

One of the vital functionalities that is easy to spot by a human is seeing something unusual in elderly. Based on the severity of the situation, caregiver contacts the appropriate person. This can be a little tricky to implement but it is necessary to have in our system. A red flag for the system can be unresponsiveness of the person which can be a trigger for contacting a family member, doctor, or an ambulance. The system should be able to deal with this kind of situations in real-time.

Having a system keeping track of every aspect of elderly's life can be very helpful. This information can be monitored regularly by a doctor to see how well the person is doing and check on some unusual behavior patterns that can be a sign of a particular discomfort, disease, etc. Also, if it is necessary, this information can be viewed by family members to check on their loved ones and see how well they are doing. Because we have a computerized system, it can be possible to add remote access to this information via Internet to authorized people.

III. METHODOLOGY

The system design is the first concern that we need to deal with. The system should be able to the cases that we have described in the previous section. In order to cover those functionalities, a server-client model is necessary. The server side architecture is not a concern since we do not need separate servers for each client. Each server can support multiple clients but for the client side, the device price and availability are important. Having a device that is manufactured in large scale and support many functionalities, while keeping the price low for end users can be an ideal choice. Tablet devices satisfy our criteria. They have a large screen which makes reading easier for elderly that have vision impairment. They are affordable and they support many functionalities for keeping information like task management, contacts, emails, calling, and much more. Because of the affordability of Android devices compared to others, we consider Android tablets for our current prototype.

Most of the libraries that are dealing with natural language processing are designed to deal with text while input in Scenarios 1 and 2 is speech. To convert speech into text Android has built-in libraries for Speech to Text and Text to Speech conversion. We have used these libraries for current prototype.

In Scenario 1, we have talked about different types of statements that our system may encounter. Classification is necessary for categorizing statements. We have used a classifier developed by Quinn and Zaiane [17] for this purpose.

For all the statements, natural language processing is necessary to extract information that we need. We have talked about remembering information in the conversation. After processing of the statements, we store them in a database that

we call Personalized Knowledge Base (PKB). This information can be used as described in the scenarios.

For answering questions, we first look into PKB. If we could not find the answer, we look in a global knowledge base. We are using Google Knowledge Graph as our general knowledge base. If look-up in general knowledge base was unsuccessful, the system is going to acknowledge that by saying it could not find the answer but it will show web search results for that question. For the imperative statements, all the necessary functionalities are included in the operating system.

In Scenario 2, we talked about starting conversations by the system. It is achievable by going through some templates and PKB to find an appropriate conversation opener in both cases of starting a conversation from the beginning or continuing the conversation that is started by elderly. Also, there can be different pointers for knowing when the system should start a conversation or continue it. A long pause while the conversation is not ended or not interacting with the system for a long time can be a sign to start a conversation.

For Scenario 3 all the cases except remote access can be considered an extension to Scenario 2. For calling people Android has communication abilities like phone calls that can take care of emergencies. The remote access part will be implemented by a Web-based user interface that can be accessed with all the internet enabled devices. To prevent unauthorized access, there will an authentication mechanism with unique identifiers. Figure 1 shows a simplified flowchart of the system.

It may seem that implementing such a system is a trivial task but it is not. Natural language processing and information extraction from plain text or voice are very complicated tasks. They are research topics that are actively being worked on in universities and research centers. By checking projects like Siri, Google Now, and Cortana, which are being supported by huge technology companies, it can be concluded that the conversing ability for machines is in its primary stages.

Companionship is important for the mental and physical wellbeing of an elderly. Seeking companionship can be disconcerting for seniors and often not possible. Building an intelligent automated software agent to converse with older people and provide information and verbal assistance is a goal of ours and would beneficial to society. We have started building a prototype but the undertaking is challenging and provides many interesting open research problems.

IV. Conclusion

In this paper, we talked about benefits of an automated system for elderly care, when they can live by themselves in their own places and. We talked about our proposed system, its specifications, and how we can implement it. Currently, we have a proof of concept prototype with some of these functionalities. We are working on improvements to the current system to be used in a field study. We will use the improved version to gather results about the effectiveness of the system and how people feel about conversations with the agent.

If a system with these specifications can be accepted by people, it can reduce imposed costs to national health care system by increasing the percentage of elderly population.

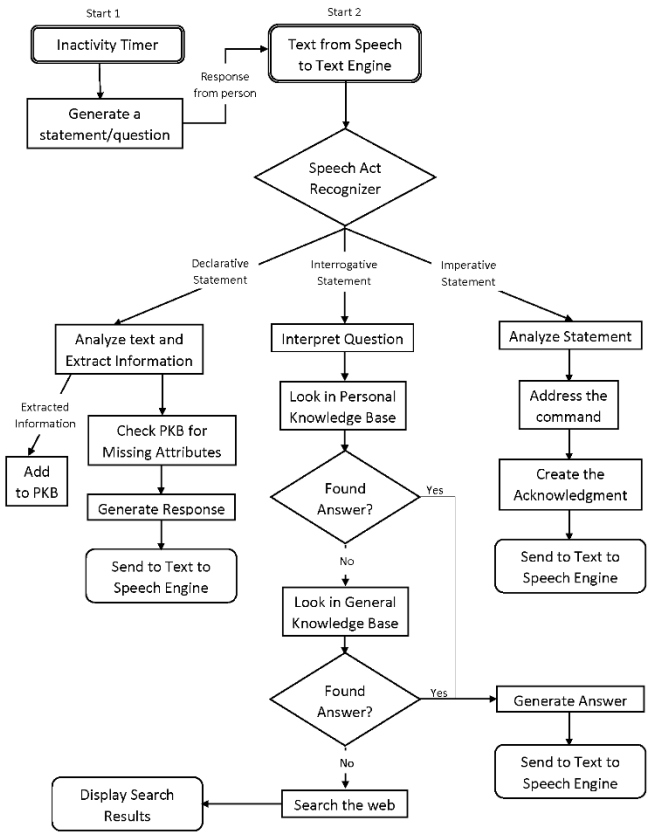

Figure 1. Flowchart of the system.

Also, it can reduce the number of caregivers or at least reduce their responsibilities and their working hours.

References

[1] R. F. Baumeister and M. R. Leary, "The need to belong: desire for interpersonal attachments as a fundamental human motivation," Psychological bulletin, vol. 117, no. 3, 1995, p. 497.

[2] R. P. Meyer and D. Schuyler, "Old Age and Loneliness," Prim Care Companion CNS Disord., vol. 13, no. 2, 2011, pp. e1-e2.

[3] B. Buunk and M. Peeters, "Stress at work, social support and companionship: Towards an event-contingent recording approach," Work and Stress, vol. 8, no. 2, 1994, pp. 177-190.

[4] J. B. Unger, A. C. Johnson and G. Marks, "Functional decline in the elderly: Evidence for direct and stress-buffering protective effects of social interactions and physical activity," Annals of Behavioral Medicine, vol. 19, no. 2, 1997, pp. 152-160.

[5] C. D. Mathers, G. A. Stevens, T. Boerma, R. A. White and M. I. Tobias, "Causes of international increases in older age life expectancy," The Lancet, vol. 9967, 2015, pp. 540-548.

[6] S. Katz, L. G. Branch, M. H. Branson, J. A. Papsidero, J. C. Beck and D. S. Greer, "Active Life Expectancy," N Engl J Med., vol. 309, 1983, pp. 1218-1224.

[7] A. H. Gauthier, The state and the family: A comparative analysis of family policies in industrialized countries, Oxford University Press Catalogue, 1998.

[8] P. Kemper, "The use of formal and informal home care by the disabled elderly," Health services research, vol. 27, no. 4, 1992, p. 421.

[9] R. Bernabei, F. Landi, G. Gambassi, A. Sgadari, G. Zuccala, V. Mor, L. Z. Rubenstein and P. Carbonin, "Randomised trial of impact of model of integrated care and case management for older people living in the community," BMJ, vol. 316, no. 7141, 1998, p. 1348.

[10] P. D. Census Bureau, "Projections of the Population by Selected Age Groups and Sex for the United States," 2012. [Online]. Available: http://www.census.gov/population/projections/data/national/2012/summarytables.html. [Accessed 2016.03.18].

[11] W. Lutz, W. Sanderson and S. Scherbov, "The coming acceleration of global population ageing," Nature, vol. 451, no. 7179, 2008, pp. 716-719.

[12] Canada Statistics, "Living Arrangements of Seniors," 2011. [Online]. Available: http://www12.statcan.ca/census-recensement/2011/as-sa/98-312-x/98-312-x2011003_4-eng.cfm. [Accessed 2016.03.18].

[13] J. J. Essen, F. Cardiello and M. M. Baun, "Avian Companionship in Alleviation of Depression Loneliness, and Low Morale of Older Adults in Skilled Rehabilitation Units," Psychological Reports, vol. 78, no. 1, 1996, pp. 339-348.

[14] J. A. Carletti, "Volunteers provide companionship therapy under social service supervision," Psychiatric Services, vol. 15, no. 12, 1964, pp. 691-693.

[15] F. Walsh, "Human-Animal Bonds I: The Relational Significance of Companion Animals," Family Process, vol. 48, no. 4, 2009, pp. 462-480.

[16] T. F. Garrity, L. F. Stallones, M. B. Marx and T. P. Johnson, "Pet ownership and attachment as supportive factors in the health of the elderly," Anthrozoös, vol. 3, no. 1, 1989, pp. 35-44.

[17] "Freebase," [Online]. Available: https://www.freebase.com/. [Accessed 2016.04.15].

[18] "Google Knowledge Graph Search API," [Online]. Available: https://developers.google.com/knowledge-graph/. [Accessed 2016.04.15].

[19] K. Quinn and O. Zaiane, "Identifying Questions & Requests in Conversation," in Proceedings of the 2014 International C* Conference on Computer Science & Software Engineering, 2014.