ICIC Express Letters
Part B: Applications
Volume **14**, Number **9**, September **2023**

ICIC International ©2023 ISSN 2185-2766
pp. **945–949**

IDENTIFICATION OF THE PHYSIOLOGICAL NEEDS BASED ON DISTANCE-TYPE FUZZY REASONING METHOD CONSIDERING KNOWLEDGE RADIUS

Guang Yang[1,*], Shuoyu Wang[1], Junyou Yang[2] and Peng Shi[3]

[1]School of Systems Engineering
Kochi University of Technology
185 Miyanokuchi, Tosayamada, Kami City, Kochi 782-8502, Japan
wang.shuoyu@kochi-tech.ac.jp
[*]Corresponding author: yang.guang@kochi-tech.ac.jp

[2]School of Electrical Engineering
Shenyang University of Technology
No. 111, Shenliao West Road, Shenyang 110870, P. R. China
junyouyang@sut.edu.cn

[3]School of Electrical and Electronic Engineering
The University of Adelaide
Adelaide, South Australia 5005, Australia
peng.shi@adelaide.edu.au

Received January 2023; accepted April 2023

Abstract. *Caring for the bedridden elderly has been an increasing burden considering the lack of young labors in an increasing number of countries. Facing the challenge, autonomous care robots capable of providing basic daily care would be of great help. However, the requests from the bedridden elderly are typically not clear commands, but highly abstract psychological desires (e.g., "hungry" and "cold"). In previous work, we proposed a desire-driven reasoning approach and adopted the distance-type fuzzy reasoning method. In this work, the knowledge radius is introduced upon the previous reasoning method, which could improve the efficiency of reasoning, by considering only most relevant knowledge. The efficiency of the proposed method has been proved with simulation considering a household environment.*
Keywords: Care robot, Distance-type fuzzy reasoning, Knowledge radius

1. **Introduction.** Caring for the bedridden elderly has been an increasing burden considering the lack of young labors in more and more countries. Facing the challenge, autonomous care robots capable of providing basic daily care would be of great help. Clear and precise commands are necessary in order for care robots to provide appropriate services. However, the requests from the bedridden elderly are typically not clear commands, but highly abstract psychological desires (e.g., "thirsty" and "cold").

Figure 1 illustrates a possible scenario of caring for a bedridden elderly person. Only by bridging the gap between the desires of the care recipient and the care robot with the help of a reasoning approach, the questions asked by the care recipient can be responded to by the robot with a reasonable service.

For care robots to understand how different care services are related to addressing certain physiological desires, we firstly proposed a desire-driven reasoning approach in [1] and then adopted the distance-type fuzzy reasoning method-based desire-driven reasoning in [2]. As a result, commonsense knowledge considering how daily needs could be fulfilled with available care operations could be properly described and modeled. Although the proposed reasoning approach has been proved to be effective, the efficiency of

DOI: 10.24507/icicelb.14.09.945

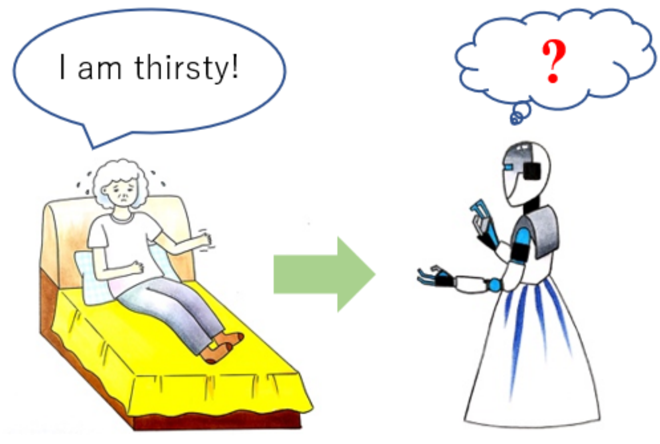

FIGURE 1. Image of a caring scenario

the method has not been discussed. Usually, as the type, quantity of objects in the care domain increases and more care knowledge is considered in the form of fuzzy rules, the reasoning cost will increase and result in unguaranteed efficiency. Therefore, in this work, we adopted the concept of knowledge radius into the usage in a desire-driven reasoning process.

The advantages of adopting knowledge radius are as the following.

1) The speed and accuracy of reasoning could be effectively increased, as the influence from irrelevant knowledge would be hugely decreased.
2) The reasoning method can be performed without the loss of efficiency, even if the caregiving environment becomes very complex, and various types of caring knowledge are considered during reasoning.

In this work, we examine the reasoning system in detail with the usage of knowledge radius. The rest of the paper is organized as follows: Section 2 reviews the related work considering care robots and fuzzy reasoning; the desire reasoning method adopting distance-type fuzzy reasoning is introduced in Section 3; Section 4 presents how the idea of knowledge radius can be integrated in the reasoning system, and Section 5 shows the simulation results; Section 6 gives the discussion and Section 7 concludes the work.

2. **Related Work.** There are several different types of care robots that have been designed to provide daily care or support for disabled or aged people. For example, the Hobbit robot combines robotics, gerontology, and human-robot interaction therefore is capable of fall prevention and detection as well as emergency detection and handling [3]. And HSR developed by Toyota has been successfully used in various caring domains [4]. And a review of the use of socially assistive robot technology in elderly care could be found in [5]. And in general, the discussion of bridging the gap between robotic technology and health care has been presented in [6].

While these robots can provide a variety of support by completing navigation and operation, they cannot provide effective assistance when faced with a bedridden elderly person who is unable to make clear requests.

The other related filed of this work is fuzzy reasoning which has been applied to various fields considering the development of robots. A neuro-fuzzy reasoning system for mobile robot navigation is shown in [7], which allows an autonomous mobile robot to travel in unknown environments. A fall detection method based on fuzzy reasoning for an omni-directional walking training robot is introduced in [8]. As for humanoid robots, [9] investigates a comprehensive literature review considering the recent technological developments and the theories associated with fuzzy set models.

We can see that in robotic-related research, fuzzy reasoning is mostly applied in the field of motion control while the discussion regarding its application in the field of knowledge reasoning is rare.

3. **Desire Reasoning Considering Distance-Type Fuzzy Reasoning Method.** The distance-type fuzzy reasoning method [10] could be adopted into the usage of desire-driven reasoning by describing commonsense knowledge (e.g., "services fulfill desires") with fuzzy rules.

As a result, the desire reasoning system considering distance-type fuzzy reasoning method has the following three advantages compared with traditional fuzzy reasoning methods.

1) The reasoning follows modus ponens; therefore, the reasoning result will be the same of the consequent of the rule whose antecedent agrees with the input. As in the care domains, all the existing care knowledge in the knowledge base could be conducted as expected.
2) The reasoning result will be convex fuzzy sets if fuzzy sets in the consequent are convex, which makes it convenient to be adopted for further applications with suitable mathematical theories.
3) Both non-sparse and sparse input fuzzy sets could be adopted describing sensor readings or physiological; therefore, the complicated daily care domains could be properly described with only fuzzy rules of limited quantity.

Based on the above three characteristics, the distance-type reasoning can fit the whole continuous knowledge space using discrete finite knowledge and is suitable for application in the scenario of care robots in household domains.

4. **Fuzzy Reasoning Considering Knowledge Radius.** The purpose of conducting desire-driven reasoning is to allow care robots to conduct care services like human caregivers. In practice, however, human caregivers will not use all their knowledge to figure out the most appropriate service for a given request. Instead, they will only consider knowledge that is closely related to the given request. For instance, given "Hungry", only food and some drinks will be considered; other knowledge about the air conditioning or lighting will not be considered because they are irrelevant.

In the case of distance-type fuzzy reasoning, not all the fuzzy rules need to be evaluated given a certain request, but only the rules that are most relevant. The knowledge radius is defined as one parameter k $(2 < k < N)$, where N is the number of fuzzy rules [11]. When the reasoning is conducted, only the k rules whose antecedents are mostly close to the facts will be used.

Figure 2 demonstrates a diagram of the reasoning system. The service generator is used to generate a series of fuzzy rules considering the existence of different objects in the environment (a knowledge base is used to keep and update the rules). While the quantity of rules in the knowledge base could be quite large (orange dots) in a complex environment, where fuzzy rules in the knowledge base will not be used entirely, but with only those that are within the knowledge radius (green dots). As a result, despite the growth of dot numbers in the knowledge base, only a fixed number of them will be sent to the module of "Distance-Type Fuzzy Reasoning" for further evaluation.

In other words, the knowledge based could be extended continuously as more types or quantity of objects are available for operation, or the type of operations that a robot can conduct increases, yet only a part of the knowledge base with a fixed size (knowledge radius) will be used for reasoning. Reasoning systems can remain efficient while keeping accuracy.

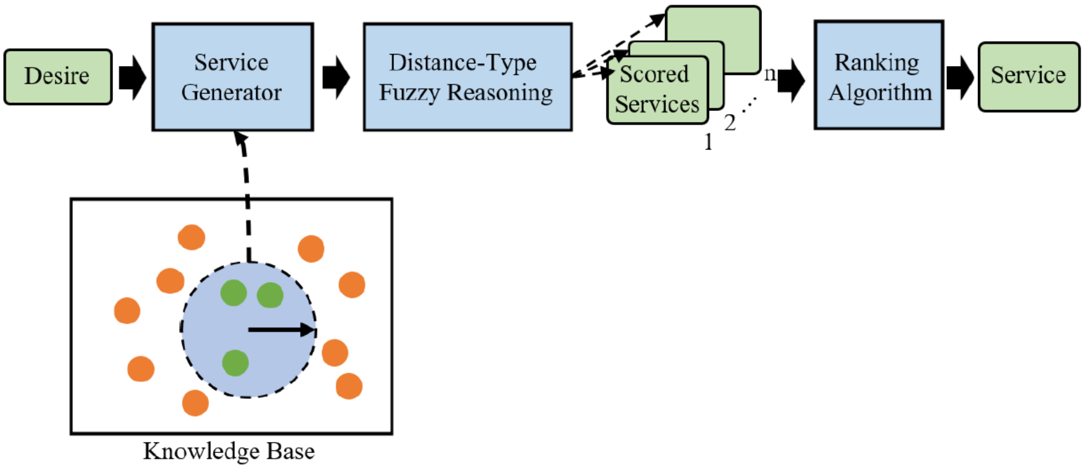

FIGURE 2. Workflow of the distance-type fuzzy reasoning considering knowledge radius

5. **Simulation.** The efficiency of the proposed method has been evaluated in simulation considering a care robot [12]. Figure 3 shows an example of the simulated home care services of a bedridden elderly in a household environment. Taking the desire of "Thirsty" for example, although there are various types of objects available in the table and the refrigerator, only the most related ones will be considered for further evaluation with distance-type fuzzy reasoning. Here the knowledge radius is 3, indicating only the top-3 rated types of objects will be considered. In this way, the reasoning could stay efficient even as the types of objects and services considered during home care increase dramatically.

It is worth noting that the ratings in Figure 3 are only an example, which could be adjusted freely according to the preferences of the care recipient.

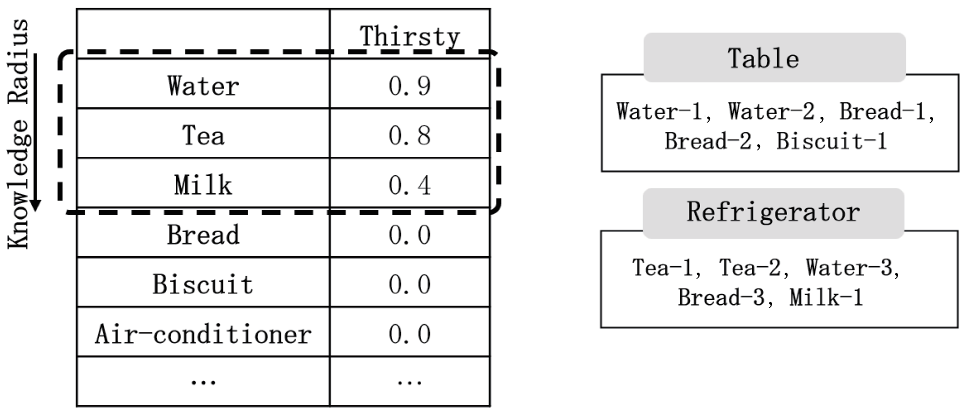

FIGURE 3. Simulation of distance-type fuzzy reasoning considering knowledge radius

6. **Discussion.** Efficiency is critical for a knowledge-based system, even if the reasoning meets the expectations, it cannot be applied to real caregiving sites if the speed of reasoning decreases rapidly as the scale of knowledge increases. Although the human brain stores a large variety of knowledge, only the most relevant knowledge is used when reasoning about a problem. For example, when responding to a "thirsty" need, people consider knowledge related to food and drink, but not other knowledge such as cars and animals. In this paper, we have simulated the human reasoning process by using knowledge radius to limit the reasoning to a small scale and keep the speed of reasoning.

The ultimate goal of care robots is to take care of the care recipients just like human caregivers. Therefore, we can gradually achieve the goal of making care robots practical by developing robots with reference of the thinking and action patterns of human beings.

7. **Conclusions.** In this work, we have discussed the possible usage of applying the concept of knowledge radius in the application of desire reasoning. With the adoption of knowledge radius, the reasoning is expected to remain efficient even if the number of fuzzy rules keeps increasing.

In future work, we plan to apply the presented approach to practical applications for further evaluation and development. More care knowledge will be considered and experiments in real household domains are expected.

Acknowledgment. This work was supported by JSPS KAKENHI Grant Number JP16K 12503, JP22K18244, the Canon Foundation, and the CASIO Science Promotion Foundation.

REFERENCES

[1] G. Yang, S. Wang and J. Yang, Desire-driven reasoning for personal care robots, *IEEE Access*, vol.7, pp.75203-75212, 2019.
[2] G. Yang, S. Wang, J. Yang and P. Shi, Identification of the physiological needs of bedridden elderly people based on distance-type fuzzy reasoning method, *AROB/ISBC/SWARM2022*, OS15-4, 2022.
[3] A. Sharkey and N. Sharkey, Granny and the robots: Ethical issues in robot care for the elderly, *Ethics Inf. Technol.*, vol.14, pp.27-40, 2012.
[4] T. Yamamoto, T. Nishino, H. Kajima, M. Ohta and K. Ikeda, Human Support Robot (HSR), *ACM SIGGRAPH 2018*, pp.1-2, 2018.
[5] H. F. M. Van der Loos, D. J. Reinkensmeyer and E. Guglielmelli, Rehabilitation and health care robotics, *Springer Handbook of Robotics*, pp.1685-1728, 2016.
[6] A. O. Andrade, A. A. Pereira, S. Walter et al., Bridging the gap between robotic technology and health care, *Bio. Sig. Proce. Cont.*, vol.10, pp.65-78, 2014.
[7] K. K. Tahboub and M. S. N. Al-Din, A neuro-fuzzy reasoning system for mobile robot navigation, *Jor. Jour. Mech. Indus. Eng.*, vol.3, no.1, pp.77-88, 2009.
[8] Y. Wang, W. Xiong, J. Yang and S. Wang, A new fall detection method based on fuzzy reasoning for an omni-directional walking training robot, *International Journal of Innovative Computing, Information and Control*, vol.16, no.2, pp.597-608, 2020.
[9] C. Kahraman, M. Deveci, E. Boltürk and S. Türk, Fuzzy controlled humanoid robots: A literature review, *Rob. Auto. Sys.*, vol.134, pp.1-12, 2020.
[10] S. Wang, T. Tsuchiya and M. Mizomoto, Distance-type fuzzy reasoning method, *Bio. Fuzzy Sys. Associa.*, vol.1, no.1, pp.61-78, 1999.
[11] S. Wang, *Human Reasoning Engine*, P2004-342064A, 2014.
[12] G. Yang, S. Wang and J. Yang, Hybrid knowledge base for care robots, *International Journal of Innovative Computing, Information and Control*, vol.17, no.1, pp.335-343, 2021.