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The Concept of Intelligent Space with a Robot

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Abstract: Intelligent space is where people may easily interact with computers and robots, changing the environmental conditions based on users' needs to create more comfortable and satisfying surroundings. In our proposed system, we would integrate an intelligent space with a robot that would act as an active part of the environment. The system is illustrated in a few caregiver scenarios, showing the actions of a robot. The skills of a robot are explained, presenting the advantages and contributions of the system.
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1. INTRODUCTION

"Intelligent space can be defined as space with functions that can provide appropriate services for human beings by capturing events in the space and by utilizing the information intelligently with computers and robots." [1] With the fast development of technology and artificial intelligence, intelligent spaces and social robots are becoming widespread in order to improve users' wellbeing and supporting them more effectively through personalization. Intelligent workspace has already proven its potential to increase the effectivity of work and decrease its cost. With the robot present in the environment, users would not only get a system that measures and alters the environment, but also a unit with which they may actively interact.

In present, all the developed economies are predicting a significant shortage of nursing care workers. This is especially true for Japan, which reached the state of hyper-aged society in 2007. In spite of roughly tripling the number of nursing personnel since 2000, Japan will need additional 800,000 nursing care workers by 2025 [2].

In the article, we will discuss the proposed system of intelligent space with a robot, usable in environments such as caregiver support and workspace. The proposed system would not only be able to change the environment of users (lighting, temperature), but would have an active unit, a robot, helping users in certain situations. Within the scope of this paper, scenarios for a caregiver support will be illustrated, showing the benefits of the system.

The steps already conducted in creation of the proposed system were simulated in a laboratory. The initial idea is of a space fully covered by cameras, light sensors and thermometers, in order to collect accurate information about room conditions. The room would also contain a humanoid robot that would interact with lab members.

2. SIMILAR CONCEPTS

Because the prognostics of rapidly aging population of Japan and decrease of nursing staff is getting serious, more robotics research is trying to come up with assistive robots that would help address the problem. In 2016, the global market for nursing care and disabled aid robots, which is made up of mostly Japanese manufacturers, was $19.2 million according to the International Federation of Robotics. According to estimates of METI, the domestic industry of Japan alone will grow to $3.8 billion by 2035 [3]. Currently, more than 5,000 nursing-care homes are testing robots. This chapter will serve as an overview of robots available to be used in caregiver environment.

Robear [4] (robotic nurse bear) is specially created to lift people from a standing position or from a floor and transfer them to a wheelchair or turn them in bed. Danish company created a robot named Melvin [5], which assists an elderly with dressing and undressing at the toilet. There are other devices for people who have trouble walking independently, such as exoskeleton from Rex Bionics [6] or walking rehabilitation support tool named Tree [7].

Many other robots concentrate on the social aspect of the help. One of them is Dinsow mini [8], which is a small humanoid robot with a display for a head. It is created to communicate with people, serve to call family members, watch exercising videos or remind an elderly to take their medicine. Paro robot [9] is created to entertain and comfort shy patients. It has a form of a baby seal and by movements and noises it reacts to being petted and touched. It has been proven that Paro has similar effects on people as animal therapy. Another humanoid assistive robot is Pepper [10], which we used in our experimental setting. It can function in a more clinical manner, helping to schedule appointments or interpret patterns in labs in proper medical context.

A nationwide survey conducted by ORIX Living Corporation, which is an operator of elderly homes, showed that 80% of the participants were positive to introduction of robots [11]. That is the reason why we believe that our proposed system would help in a medical environment by not only easing the job of caregivers, but mostly emotionally helping patients.

3. FUNCTIONS OF THE PROPOSED SYSTEM

This chapter will illustrate the situations, in which the proposed system may be used in real life. Based on the scenarios, functional system architecture and robot's functions are listed.

3.1 Scenarios

The utilization of the proposed system is explained on the following set of scenarios designated for caregiver support situations.

A. Patient's family comes into a designated hospital wing. At the door, it is greeted by a robot, asking for a patient to be visited. The robot sends a notification of visit to a nurse in charge and leads family to patient's bed.

B. Robot acts as an observer, walking among patients in a room. Once it detects signs of stress, sadness or pain, it approaches a patient and starts a conversation with him/her. If patient feels pain or needs any medical help, it immediately notifies a nurse in charge. If patient is feeling sad or stressed, robot proposes going for a walk or involving patient in playing a game on its tablet. If patient chooses to go for a walk outside of the room, robot again notifies a nurse in charge and accompanies patient on a walk, streaming patient's current location during the walk.

C. Upon a call, robot approaches a patient and asks how it may be of assistance. Patient may choose from a set of predefined actions either by saying the command out loud or choosing from an option from a menu on the tablet. Patient may choose to watch a video, play a game, see who his doctor is for a day, see a day menu, etc.

D. Robot remembers the appointments and medication of each patient and is able to approach them and remind them to take their pill or prepare for a meeting with doctor.

3.2 Functions

The robot's proposed methods and skills have been abstracted, creating a layered system architecture displayed in Figure 1. Within the scope of this paper, behavioral and skill layers are explained.

Functions of the behavioral layer are of a direct connection to human-machine interaction. They describe the basic set of skills, which robot would be able to conduct, taking into consideration effectiveness of task fulfillment and comfort of people.

Task-oriented Conversation: This skill was illustrated in a first scenario, when approaching family members of a patient. In the conversation, he would ask about the name of a patient who they came to visit. In work environment, upon arriving into office, robot would approach a person to conduct face recognition and find out whether person is an employee or not. If person works in a company, robot would welcome a person and mark him/her in his database as currently present. If the person does not work there, robot would ask for a name and reason for a visit.

User Guidance: Robot would hold information about all the people in the facility (hospital wing or workspace) and their location (room/bed or office/table). Based on its current and goal position, it would conduct path planning and safely guide people to the required place.

User Observance: One of the main objectives of a robot in caregiver support or work is to observe the emotions of people, in order to interact with them when showing signs of sadness, stress, etc. In case of caregiver support, robot would call for a nurse in charge, if medical care is needed.

User Approaching: It is vital for a robot to approach a person in such a manner, as to respect their personal space. To fulfill this, person recognition, person motion prediction, localization and path planning will be used.

Engaging User in an Activity: As was mentioned in scenarios, one of the tasks of a proposed system is to relieve patient when showing signs of stress or boredom. This would also apply in a work environment; if employee shows signs of stress or overwork, he/she would have an option to choose from a set of options on its tablet.

User Following: In case of walking assistance or introduction of a new location, robot would be able to

Behavior Layer	Task-oriented Conversation	User Guidance	User Observance	User Approaching	Engaging User in an Activity	User Following	Memorization of New Faces and Locations
Skill Layer	Person Recognition	Person Tracking	Emotion Recognition	Localization	Local Mapping	Path Planning	Obstacle Detection
	Person Motion Prediction	Speech Synthesis	Person Recognition Training	Tablet Application Functions			

Figure 1: Functional system architecture

safely follow the person. Along the process, person tracking, person motion prediction, localization and obstacle detection would come into process.

Memorization of New Faces and Locations: Robot would hold database of people along with locations where they may be found. If the new patient or employee comes into place, robot would take series of photos to train itself to recognize the person next time, and would be also led to their designated location to connect it with each person.

The following set of skill layer functions conducts separate functions, which are on the lower level of system architecture. Each of them is responsible for a single task, being brought together by functions in a behavioral level.

Person Recognition: This function is responsible for face recognition. Because all the person recognition computation would run on robot, we would use python's face_recognition library [12]. It is easy to use and is built using dlib with deep learning library, which reached 99.38% accuracy on Labeled Faces in the Wild dataset.

Person Tracking: This function is necessary for tasks such as user following and user observance. Python's OpenPTrack library [13] would be used, which enables multi-person tracking and person detection.

Emotion Recognition: In order to train our robot to distinguish human emotions, we would use python's OpenCV library. The function is used for user observance.

Localization: In the proposed system, the whole area would be covered with cameras. Thanks to them, robot would know his precise location within the environment, as well as location of all the users in the area. The camera stream and computations would be done on a server. This way, robot will get a general overview of the room and will not be slowed down by constant computations.

Path Planning: Autonomy is necessary for a robot in a proposed environment. In our testing environment, we already conducted path planning task using D* Lite graph search algorithm [14]. Chapter 4 explains the experiment.

Obstacle Detection: This task would be conducted on two parallel levels; on the server from camera stream and on robot from his camera stream and sensors. Simple obstacle detection may be done using OpenCV library.

Person Motion Prediction: A necessary function for a robot moving among people. This function would be based on a human motion prediction algorithm created by Julieta Martinez, Michael J. Black, Javier Romero [15].

Speech Synthesis: Upon initiating a conversation with users, robot would not only show the text on his tablet, but also speak it out loud. To do this, Python's pyttsx library, which converts text to speech, would be used.

4. EXPERIMENT

We simulated the environment in one of our laboratories, using Pepper robot by Softbank robotics. The task of our experiment was to conduct mapping of the environment, graph creation, path planning and to move a robot in a real environment along the computed path [16].

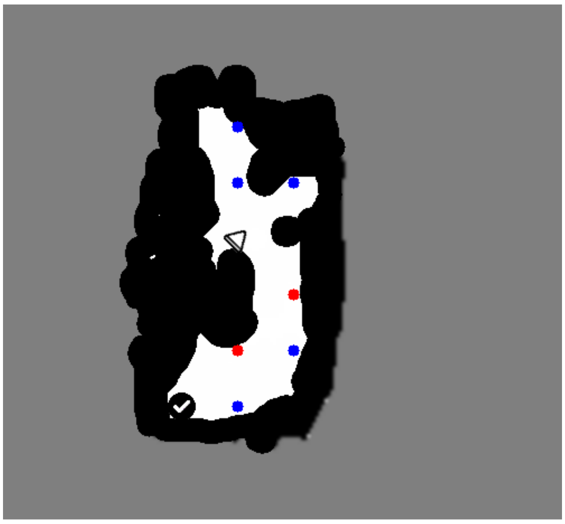

Figure 2: Path constructed from start point to goal point

Using Pepper's built-in *explore* function we obtained map of the environment, which we converted to configuration space and constructed a graph. The graph was created by approximate cell decomposition, where a distance within two neighboring nodes is 50px, representing half a meter in real environment. Within a graph, we chose start and goal point and also an initial orientation of a robot within in a real space. On Figure 2, robot's start point is illustrated by a triangle with rounded corners, facing towards the left bottom corner of the map, marking robot's initial orientation. Goal point is marked by a check symbol. Figure 2 also shows the computed path, marked by red color. All the other nodes of a graph are marked by blue color. Black color marks obstacles and white color shows the free space, where robot may move without being in collision with any object.

To implement the computed path on a robot located at starting point, we used robot's *moveAlong* function. Input parameters of this function represent a trajectory of a desired movement, which is built either by a direct trajectory or is composed from numerous trajectories. Trajectory is defined by X and Y coordinates of a final position, change of an orientation and a time period, which it takes to traverse the trajectory. We extended the functionality of our program to create a command, which would move robot along the computed path.

```
["Composed", ["Holonomic", ["Line", [0.0, 0.0]], 1.5708, 1.0], ["Holonomic", ["Line", [0.707, 0.0]], 0.0, 1.0], ["Holonomic", ["Line", [0.0, 0.0]], -1.5708, 1.0], ["Holonomic", ["Line", [0.707, 0.0]], 0.0, 1.0], ["Holonomic", ["Line", [0.707, 0.0]], 0.0, 1.0]]
```

Figure 3: Command to move robot along the computed path from Figure 2

Figure 3 represents an output of our program, which is a series of trajectories safely leading a robot from a start point to a goal point in a real environment. As opposed to approach taken in our paper [16], in this experiment we required robot to change its orientation before moving.

The contribution of the experiment is that within a few minutes, robot is ready to move in a new environment. The downfalls of the experiment were false obstacle detections by Pepper, which ended in a program termination even though nothing posed a threat to him. Thus it is crucial to bypass Pepper's security measures.

4. CONCLUSION

This paper focuses on a proposition of a system, which would integrate a humanoid robot in an intelligent space. As was stated in listed scenarios, robot would serve as a helper in caregiver environment, looking after the patients and engaging them in an activity, in order to enhance their mood. As was pointed, similar concepts already exist and are successful in accompanying the elderly people and improving their overall wellbeing. Thanks to the acceptance of the elderly towards the robotics, we believe that the proposed system would be successful. Moreover, thanks to its robustness, it may be used in other environments, such as work or school environment.

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