# TeCaRob: Tele-Care using Telepresence and Robotic Technology for Assisting People with Special Needs

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*Abstract*— **This paper discusses a new concept of home care delivery benefiting frail People with Special Needs (PwSN[1]). This new concept is an extension of the existing Smart House (SH) concept, which is challenged when PwSN occupants need physical assistance. The TeCaRob concept explores the use of robotics to remotely assist frail elders and other PwSN in diverse tasks of daily living.**

## 1. Introduction

Home caregivers play a critical role in maintaining a decent quality of life for older adults and other PwSN. Simple manual assistance in handling daily living tasks such as moving from one place to another, performing hygiene, feeding, and administering medications makes a world of difference in the lives of PwSN. This problem is especially important given the sharp increase in the aging population around the world. In 2002, the elderly population was estimated to be about 13% in the US and 20.0% in Europe. It was also estimated that the elderly population would double by 2030 [1,2]. This population will need more home nursing service as they age. Considering baby boomers will reach retirement age over the next 10 to 15 years, the HealthCare system in the US will experience an overwhelming demand for home care delivery. At the same time, the HealthCare system is facing an increasing shortage of qualified caregivers [3,4]; For example, an epidemiological study has shown that the current nursing shortage exceeds 10%. The shortage of skilled nurses is expected to reach 1 million by 2010 and 1.5 million by 2020. The American Hospital Association also reported in 2002 that 56% of hospitals face problems with nurse recruitment [5,6,7]. The Bureau of Health Professions also reported that about 20% of the U.S. population resides in primary medical care health professional shortage areas. This supply/demand mismatch will have critical implications on the adequacy and quality of HealthCare that can be delivered to the growing elderly population.

Several attempts have been made to use pervasive computing and ambient intelligence to develop “Assistive Environments” for the PwSN. These Smart Houses [8,9,10,11,12,13,14,15,16], utilize networks of sensors and actuators, devices, appliances, applications and services. SH’s assist PwSN in their daily living needs, allow them to live independently, help them keep a high quality of life and maintain a good health. They also help caregivers in their daily tasks. However, these SH’s have limitations. They may be able to schedule reminders to take the medications, but they cannot physically assist in dispending and giving the medications; they may assist in preparing and cooking food, but they offer no help in hand-feeding it; In short, SH’s, however smart they may be, are limited in that they do not offer close physical interaction with the end-user.

Assistive Robot (AR) is a technology that plays an increasingly important role in the life of PwSN. Indeed, numerous AR’s have been developed during the last three decades including Smart Wheelchairs for smooth navigation, Walker Assistances that aid users in their movement, AR tele-manipulators that allow users to manipulate objects [17,18,19]. These AR’s are helping PwSN to maintain a higher quality of life by improving work productivity and social activities. Meanwhile, AR systems also have

[1]PwSN includes elderly and for people with disabilities.

limitations. For example the structure of the existing AR's limits the number of tasks to be performed. The AR arm extremities, typically grippers, cannot be interchangeable and cannot be adapted for a variety of tasks. Which means that, AR's are not replaying to all PwSN needs.

Recent advances in telecommunication technology stimulated research in tele-nursing. This practice allows caregivers to partially assist patients at remote sites using phone or videoconference technologies. Indeed, numerous HealthCare systems employ the tele-nursing to reduce the cost of HealthCare delivery [20,21]. However, nurses and other caregivers are still needed to travel to the patient's residences to handle tasks that require physical interaction such as rise, feed and transfer users, hygiene and manage medication. Such home visits are very costly in terms of caregiver time and resources. It is also a costly service for the elderly people or their family members and for subsidized HealthCare. The existing tele-nursing/ tele-care is limited to verbal interventions, which restrains the practice of the tele-care.

PwSN home HealthCare needs have been increasing, the existing HealthCare delivery faces a shortage of professionals, and the existing technology (including AR's and SH's) lack the ability to provide a complete solution for PwSN. This implies that there is an urgent need for a new, more effective solution. In this paper, we will introduce a novel concept for tele-care, which we call TeCaRob, which relies on a remotely guided robot that interacts with the resident in his smart home, and that allows caregivers to tele-presence to deliver detailed care or assistance that often requires close physical interaction. Our system extends the definition of telecare to include the virtual and interactive physical presence aspect. TeCaRob explores research of robotics, pervasive computing, tele-presence, and virtual and augmented reality. In Section two, we present the TeCaRob in details. In Section three we give scenarios of daily uses of TeCaRob. In the Section four we will address the TeCaRob principal characteristics whereas Section five is the conclusion.

## 2. A New Vision of Tele-Care

The TeCaRob aims to provide customized, on-demand remote assistance. The idea is to create a system that allows caregivers to provide assistance and services remotely. TeCaRob is a generic platform that can be used by diverse caregivers, which enables various tele-care practices including tele-rehabilitation, tele-nursing, tele-medicine, tele-psychotherapy, or even simple telepresence with a close family member. The system consists of two subsystems: (a) the end-user residence subsystem, and (b) the caregiver's remote operation center subsystem.

### 2.1. The End-User Residence Subsystem

The TeCaRob subsystem at the end-user residences (Figure 1) is composed of (1) a robotic platform, (2) an environment-sensing and actuation platform, (3) an interaction platform, and (4) communication platform.

(1) The robotic platform uses a toolbox to select the appropriate set of instruments to implement a remote action or gesture (by the caregiver remotely). The robotic platform consists of: (a) a mobile base on rail that allows the robotic structure to move from one place to another; (b) robotic arms that can allow to reach any point in the space; (c) arm extremities (hand structures or diverse tools) that allow to perform action in their fitness.

(2) The environment-sensing platform is composed of the latest monitoring technologies. It includes a simple system such as stereo cameras, thermostats and on/off sensors, and complex systems such as the location tracking systems or security systems. The sensing platform creates an accurate 3D rendering of the end-user with respect to the remote caregiver. It is an important component necessary to enable precise actions by the care-giver.

(3) The interaction platform is composed of Human-Machine Interaction and multimedia technologies that allow friendly interaction between caregivers and end-users such as the videoconferences. This interaction platform favors the acceptability of the system. It also enhances social activity.

(4) The communication platform is based on a high QoS broadband connection that supports the tele-control as well as the different interactions between the end-user residence and the HealthCare center. This platform insures continuity of the connection between the center and the residence. It also insures security and privacy.

Using this TeCaRob system, caregivers are able to interact with end-user environment and perform most of the activities a caregiver would normally do at the PwSN residence. In other words, the robot system is acting, behaving and communicating as a "caregiver."

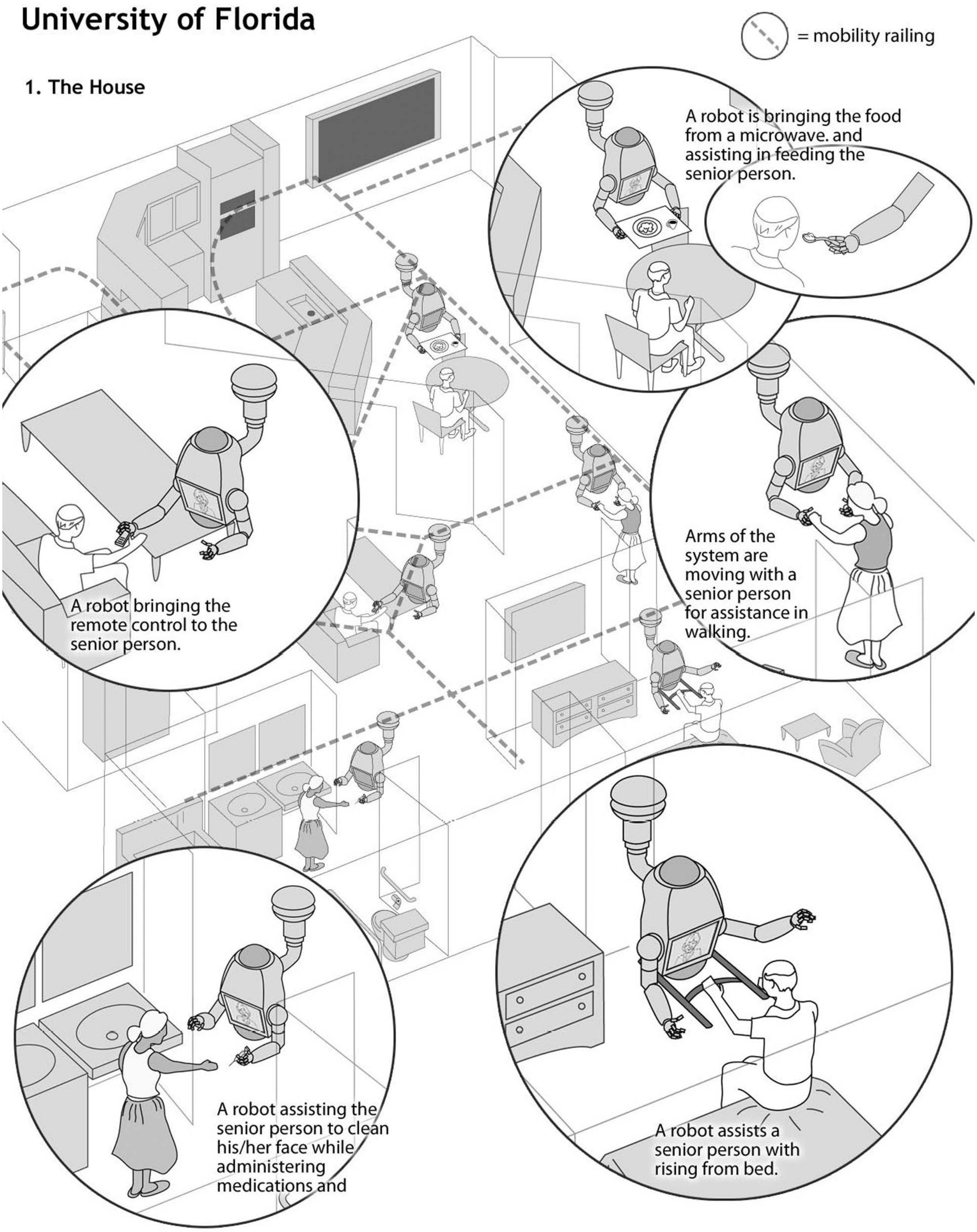


Fig. 1 Visions: Tele-care Scenarios

## 2.2. The Remote Caregiver Operation Center Subsystem

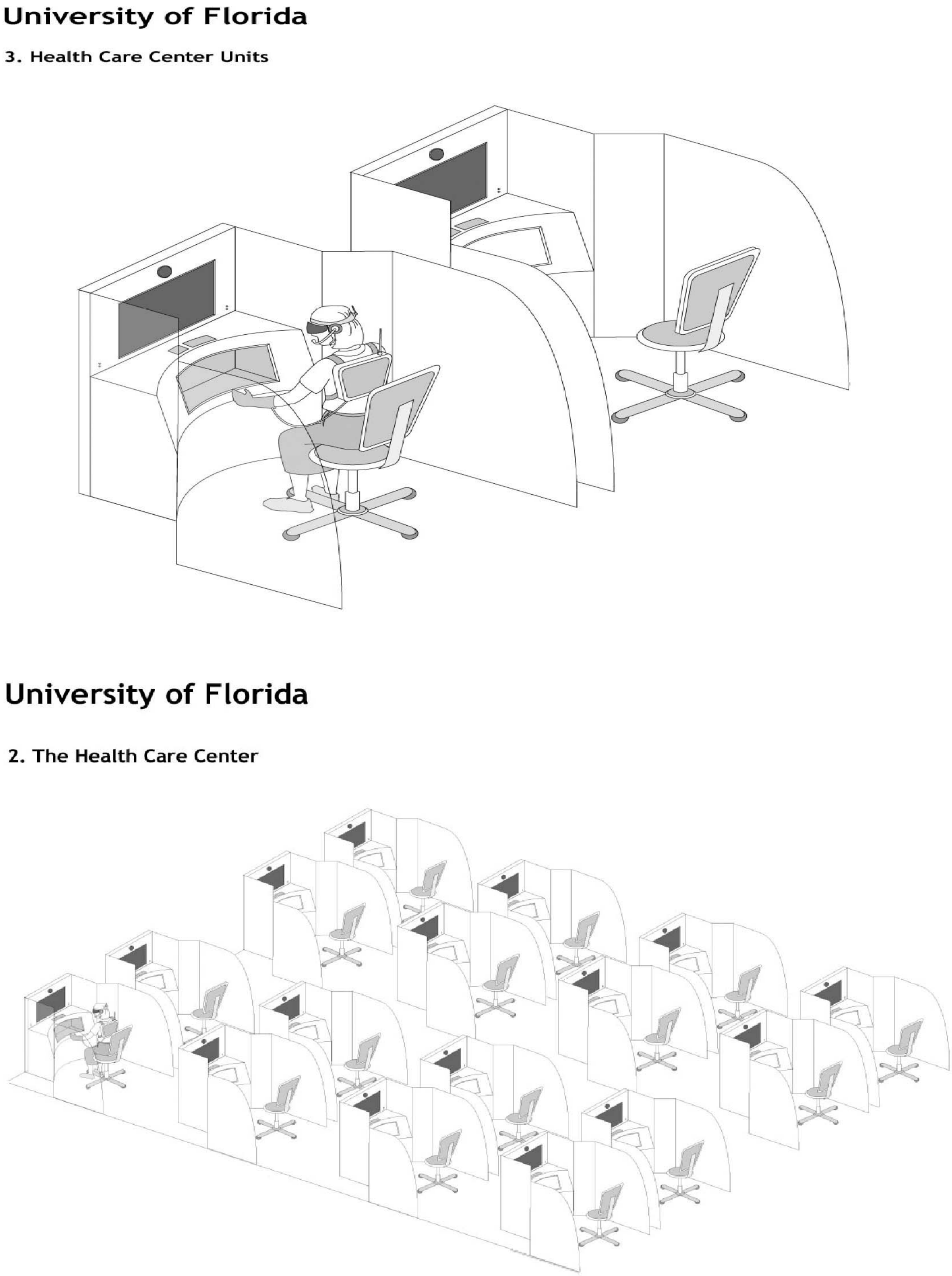


Fig. 2 A remote health-care center

The remote caregiver operation center consists of an array of tele-care stations (Figure 2), with caregiver operators on standby, waiting for control signals from the users' smart homes. Each operator station (Figure 2) has interfaces that carefully reproduce (model) the end-user environment, and that augment the operator's reality and immerses him/her into the end-user's environment (the system senses precisely the end-user's environment).

The station also has input interfaces that allow control of the robot and interaction with the entire TeCaRob system. We can imagine that the nurse wears or haunts the robot, to be transferred in the environment of the end-user.

There is no doubt that both a good end-user system and end-user caregiver interactions are critical to the acceptability of the system. TeCaRob allows a virtual presence of the caregiver; it allows multi-communication modalities. The caregivers are able to express themselves through a speech system, robot gestures and screen displays (Figure 1).

## 3. Scenarios

In order to understand the usage and effectiveness of our system within the senior end-users everyday life, let us imagine an ordinary day of three elder end-users: Ms. Aseel, Ms. Muusa and Ms. Sulaymaan. The situations of these women symbolize that of elder persons living independently in smart houses. It also illustrates diverse levels of disability associated with various ages.

Due to their ages and health conditions, these three women need varying level of assistance. Ms. Aseel is fairly independent. Ms. Muusa needs assistance and Ms. Sulaymaan needs extensive assistance. The situation of Ms. Sulaymaan is similar to that of a person with motor disability. The three women use home nursing care. Recently they switched from the traditional health system that requires physical presence to TeCaRob system. Here are some scenarios of a day of these women before and after using TeCaRob.

### 3.1. Rising

The three women wake up in the morning ready to rise and start their daily activities.

- Ms. Aseel has relied on "fixed helms/bars" to rise from bed.

  *Now the TeCaRob robotic platform is moving with her to get off the bed smoothly (Figure 1).*

- Ms. Muusa needs more assistance then Ms. Aseel. When she wakes up, she calls for assistance. After certain time, a caregiver used to come, help her rise from bed into a wheelchair.

  *Now immediately after Ms. Muusa rings for assistance, a caregiver employs the robotic platform to remotely give her a hand, help her rise from bed into a wheel chair smoothly*.

- Ms. Sulaymaan needs the most assistance. She cannot get out the bed by herself. When she wakes up, she also calls for assistance. The caregiver used to operate an existing lift system to transfer Ms. Sulaymaan into a mobile base such as wheelchair. For this task, the caregiver needs to start by helping Ms. Sulaymaan to wear the lift jacket.

  *Now the caregiver remotely operates the TeCaRob adapted arms to raise Ms. Sulaymaan from the bed smoothly*.

### 3.2. Mobility

After rising, the first activity of these three women is to use the bathroom.

- Ms. Aseel used to employ fixed bars or canes to move to the toilet.

  *Now the TeCaRob robot smoothly moves with Ms. Aseel and assists her in walking.*

- Ms. Muusa and Ms. Sulaymaan used to drive the wheelchair to go from one place to another. , Ms. Muusa occasionally asks the caregiver to drive her When, Ms. Sulaymaan frequently do that.

  *Now whenever these two women request an assistance in moving, the caregiver remotely quickly assists them.*

### 3.3. Hygiene

During the day, these three women need to use the bathroom and to wash. Ms. Aseel and Ms. Muusa do not need much continuous assistance in this task. Most of the time, they can perform the hygiene tasks by themselves. However, human assistance is convenient for Ms. Sulaymaan. Frequently, Ms. Sulaymaan needs a human presence for the hygiene tasks.

Now the caregiver does not have to move to Ms. Sulaymaan residence. Using the TeCaRob, the caregiver can keep assisting her remotely. The robotic system is equipped with many extremities and tools enabling caregivers to assist end-user to perform hygiene tasks.

### 3.4. Feeding

Ms. Aseel, Ms. Muusa and Ms. Sulaymaan rarely cook. They eat pre-prepared food delivered by a home food service. The kitchen in their smart houses are equipped with features allowing food preparation. Nonetheless, feeding tasks (eating and drinking) are not easy for them.

Ms. Aseel is able to serve food, eat and drink slowly. Ms. Muusa is able to serve her food with difficulty, and eat and drink slowly. Ms. Sulaymaan can eat and drink with difficulty, but unable to serve the food. She always needs human aid.

Similar to the hygiene activities, now the TeCaRob enables the caregivers to assist these three women in feeding at any time, without needing to travel. Using adapted tools connected to the robot system, caregivers remotely open boxes, serve food on the dish, serve drink in the mugs, and feed if necessary.

### 3.5. Health Check

The health condition of these three women needs continuous examination and checking. Caregivers used to travel to residences of these three women for diverse examinations. Generally, these checks are simple such as take a look to a patient. The most thorough checks such as a temperature or blood pressure test are less frequent.

Now the TeCaRob enable caregivers to handle complex thorough examinations remotely by using special tools connected to the robot. The simple checks are now a simple multimedia communication check.

### 3.6. Dressing

Ms. Aseel and Ms. Muusa are able to dress/undress and put/remove shoes by themselves. Occasionally, caregivers help these three women in those tasks. Usually, human support consists of taking the clothes when these women dress/undress, helping these women to open/close buttonholes, helping them to put on/off shoes or socks, helping them to put on/off jewels.

Similar to the other tasks, now caregivers are able to help these three women to dress/undress easily without need to travel to their residences. Caregivers have only to use the diverse tools associated to the TeCaRob, such as an opener/closer for buttonholes and a device to put on/off shoes.

### 3.7. Rescue

A big number of calls to emergency call centers is from aging people that want to communicate with somebody. The operator at center cannot distinguish an emergency call from a false alert. Usually when Ms. Aseel sends an alert, a group of caregivers (a nurse, a doctor or an emergency person) is sent to her location.

- If the call is a false alert, there is a loss of both the caregivers' time and the cost associate to their travels.
- If the call is for a simple intervention, the monopolization of a specialized group is not justified.
- If the call is a serious alert, time of travel is a very important factor. Depending on the traffic and the distance the help can be late.

Now the TeCaRob system prevents unnecessarily interventions and expensive emergency service dispatching. Just by a simple remote check, we can define if it is a critical situation or not. If the robot resolves the problem, a caregiver intervenes quickly and remotely. If the case is serious and requires urgent intervention, a caregiver starts to intervene remotely, while waiting for the help to arrive to the patient residence.

## 4. Characteristics

The TeCaRob system has both functional and technical characteristics:

### 4.1. Functional characteristics

PwSN need special HealthCare and daily living assistance. Under the complete control of the caregiver, the TeCaRob is able to assist performing tasks in four interaction categories:

- Transfer and move end-user (e.g. giving end-users support in order to rise from bed into a chair and assisting end-user in their movement from one place to another).
- Perform tasks in end-user environment (e.g., manipulate, lift or carry objects such as mugs, bottles, plates, books and medicines).
- Interact closely with end-user body (e.g. feeding, cleaning and giving medications).
- Communicate and monitor end-user (e.g. chat with end-user and check his health condition).
- Perform above tasks according to schedule or on-demand bases.

### 4.2. Technical characteristics

The TeCaRob system enables a continuous tele-interaction between end-users and the caregivers and assists to accomplish tasks that require close interaction with human body. The main characteristics of the system are: (1) safety and security, (2) precision, (3) real time operation and (4) friendly and personalized interaction.

(1) Safety and security. The TeCaRob system is equipped with many safety and security services and can conduct many procedures. The robot path planner and obstacle avoidance guarantee that the end-user will not be hurt, nor objects at the end-user's environment will be damaged at any time. The system is equipped with safety (foolproof) procedures. The system also has other procedures (such as emergency stop) to anticipate problems such as power failure, interruption of communication, failure of mechanical or electronic components, etc.

(2) Precision. The system is based on the latest robotic technologies that allow execution of the right action with extreme accuracy.

(3) Real time operating. The system operates in an instantly. It has a real-time operating system and a real-time communication system.

(4) Friendly and personalized interaction. The TeCaRob employs the recent advances in ergonomics and human factor domains to increase end-user feelings of security, to stimulate end-user motivation, increase collaboration in execution of tasks, enhance end- user satisfaction, and promote the acceptance of the system.

## 5. Conclusion

The TeCaRob system enhances independent living and improves quality of life of people with special needs (PwSN) by providing customized and continuous remote physical assistance. TeCaRob is complimentary to Smart Home technology that is used as assistive environments (e.g., [8]). In case of critical situations, if assistance is needed or requested, the system allows caregivers to check the situation and intervene quickly.

TeCaRob provides national and international HealthCare systems with novel tools that promote the practices of telemedicine/tele-care. TeCaRob decreases time and distance barriers, which optimize use of limited HealthCare resources. The TeCaRob concept integrates the virtual physical presence, which eliminates both caregiver's travel time and travel cost. This system also considerably reduces the time needed to start interacting with end-user, which allows using it in the emergency cases.

A multidisciplinary R&D team is essential for building such a system. The aim is to address problems in a multidimensional way from the user needs definition to the prototype assessment. The process of building this system is organized in various groups of task-sets: user needs, technical requirements, mechanical design, control design, communication design, tele-control design, human machine interaction, security and privacy aspects, evaluation and validation.

## 6. References

[1] Census (2003). "Disability Status," U.S. Census Bureau, U.S. Department of Commerce Economics and Statistics Administration, Washington, March.

[2] RNIB (2002). Royal National Institute of the Blind, United Kingdom.

[3] L.H. Aiken, S.P. Clarke, D.M. Sloane, and al. (2002), " Hospital nurse staffing and patient mortality, nurse burnout, and job dissatisfaction," Journal of the American Medical Association, pp. 1987-1993.

[4] V.F. Caron (2004). "The Nursing Shortage in the United States: What Can be Done to solve the crisis?" Schmidt Labor Research Center Seminar Paper Series. University of Rhode Island.

[5] L.H. Aiken, S.P. Clarke, D.M. Sloane, and al. (2002). "Hospital nurse staffing and patient mortality, nurse burnout, and job dissatisfaction," Journal of the American Medical Association, pp. 1987-1993.

[6] V.F. Caron (2004). "The Nursing Shortage in the United States: What Can be Done to solve the crisis?" Schmidt Labor Research Center Seminar Paper Series. University of Rhode Island.

[7] www.aha.org

[8] A. Helal, W. Mann, H. Elzabadani, J. King, Y. Kaddoura, and E. Jansen (2005). "Gator Tech Smart House: A Programmable Pervasive Space," IEEE Computer Magazine, pp. 64-74.

[9] D. J. Cook and S. Das (2005), " Smart Environments," Wiley Publisher 2005.

[10] Abowd, G. A. Bobick, I. Essa, E. Mynatt, and W. Rogers (2002) "The Aware Home: Developing Technologies for Successful Aging," Proceedings of AAAI Workshop and Automation as a Care Giver Alberta, Canada, July 2002.

[11] B. Brumitt, B. Meyers, J. Krumm, A. Kern, and S. Shafer (2000), "EasyLiving: Technologies for Intelligent Environments," Handheld and Ubiquitous Computing.

[12] D. Stefanov, Z. Bien, and W. Bang (2004) "The Smart House for Older Persons and Persons With Physical Disabilities: Structure, Technology Arrangements, and Perspectives," IEEE Transaction on Neural Systems and Rehabilitation Engineering, Vol. 12, No. 2, pp 228-250.

[13] M. Mokhtari, B. Abdulrazak, M.A. Feki, R. Rodriguez, and B. Grandjean (2003) "Integration of Rehabilitation Robotics in the Context of Smart Homes: Application to Assistive Robotics," the International Journal of Human-friendly Welfare Robotic Systems (HWRSERS). Vol. 4, N°2, pp. 29-32.

[14] B. Abdulrazak, M. Mokhtari, M. A. Feki, and M. Ghorbel (2004). "Integration of home networking in a smart environment dedicated to people with disabilities," Proceeding of the IEEE International Conference on Information & Communication Technologies: From Theory to Application (IEEE-ICTTA). Damascus, Syria April, 2004.

[15] H. Pigot, A. Mayers, S. Giroux, B. Lefebvre, V. Rialle, and N. Noury (2002). "Smart house for frail and cognitive impaired elders," the first International Workshop on Ubiquitous Computing for Cognitive Aids (UbiCog), Göteborg, Sweden, September 29, 2002.

[16] N. Noury; G. Virone, and T. Creuzet, "The health integrated smart home information system (HIS2): rules based system for the localization of a human," the 2nd Annual International IEEE-EMB Special Topic Conference on Microtechnologies in Medicine & Biology, 2-4 May 2002, Madison, Wisconsin, USA, pp. 318-321.

[17] B. Abdulrazak and M. Mokhtari (2006). "Assistive Robotics for Independent Living," in, "Smart Technology for Aging, Disability and Independence," Eds. A. Helal, M. Mokhtari and B. Abdulrazak, Wiley Publisher 2007.

[18] M. Hillman (2003). "Rehabilitation robotics from past to present -a historical perspective," Proc. of the Eighth International Conference on Rehabilitation Robotics (ICORR), South Korea, April 2003.

[19] M. Van der Loos (1995). "VA/Stanford rehabilitation robotics research and development program: lessons learned in the application of robotics technology to the field of rehabilitation," IEEE Trans. on Rehabilitation Engineering, Vol. 3, Iss. 1, pp. 46-55.

[20] H.C. Noel, D.C. Vogl, J.J. Erdos, D. Cornwall, and F. Levin (2004), "Home Telehealth Reduces Healthcare Costs," Telemedicine Journal and e-Health, Vol. 10, Number 2, pp.170-183.

[21] A.B. Bynum, C.A. Irwin, C.O. Cranford, and G.S. Denny (2003) "The Impact of Telemedicine on Patients' Cost Savings: Some Preliminary Findings," Telemedicine Journal and e-Health, Vol. 9, Number 4, pp. 361-367.