ASIBOT Assistive Robot in a Domestic Environment

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ABSTRACT

New mobile robotic devices are conquering homes. From automatic shades to motorized vacuum cleaning units, advanced technologies are progressively being introduced into real domestic home environments. Technology is no longer being introduced to simply serve information or environmental control. Dynamic and mobile elements are being introduced to perform “household chores” that require dexterous manipulation and advanced sensing and reasoning. This is a huge objective that implies great improvement and advances in current robotic technologies related to anytime availability, safety, and user satisfaction. From the point of view of dependability, the most complex part of a house is the kitchen, attending to the number of static-fixed task devices (white appliances). This is the proposed working scenario, to test the acceptance of a new modular type of robotic aids for handicapped. The ASIBOT-based Domestic Aided Kitchen is the adaptation of a handicapped-adapted kitchen for the operation of the portable climbing robot ASIBOT. This paper presents the first results of simulation of ASIBOT and derived synthesized models in a dynamic VR model of the kitchen, and the current state of investigation for ASIBOT2 and its full integration with the kitchen and user.

Categories and Subject Descriptors

J.3 [**Life and Medical Sciences**]

General Terms

Design, Experimentation, Algorithms, Human Factors…

Keywords

Assistive Robot, VR Simulation, Task-Oriented Design...

1. INTRODUCTION

Historically, technology used in homes has been in the form of electrical appliances such as washing machines, ovens, etc. Later, the classic “Home Automation” concept was introduced, which involves improvements such as computer-controlled lights, alarms, sensors, etc. Still, these are all static, classic consumer devices. They are installed in a house, and stay there during all their useful life performing the same task repeatively. The Ambient Intelligent paradigm (AmI) [1] is contributing to integrate and simultaneously disallocate all the devices to work together, presenting an Ubiquitous Computing Environment that provides IT services. As AmI technology is intrinsically designed for everybody everywhere, it is the low-cost and effective solution to make robotic assistants reliable, useful, and autonomous in close interaction with real, smart environments [2].

A. Related Previous Works

If we consider the potential services and functionalities that this kind of mobile domestic technologies could provide to the elderly and disabled population, we must keep in mind that the design process must generate solutions to their special needs. Even though this idea is not new [3], [4], [5], [6], previous attempts failed to achieve the desired functionality for several reasons: complex intelligence needed on-board makes it too expensive, not enough flexibility to be used by many kinds of users, or over-sized functionalities that did not fit user's expectations. In order to improve the profit/cost ratio, several strategies are revised [7]. Alternative approaches are provided for the “Design for All” paradigm. The idea is to redesign our surroundings in order to make them accessible for all. Some special designs of furniture and domestic adaptations are very interesting for simplifying robot modeling and planning task. The Robotic Kitchen Counter [8], was a novel kitchen counter with sensors to monitor a user's actions, and had the capability of changing its top plate height according to his preference. Another example of introduction of robotic aid in a kitchen was CAPDI [9]. It proposed a Cartesian ceiling hanged manipulator. A radically different approach is the scenario proposed by the Integrated Kitchen [10], which describes a design concept that explores future domestic kitchens where pantries communicate with refrigerators, and ovens coordinate meal preparation. From our point of view, all sorts of futuristic models can serve as inspiration for developing new creative real solutions.

B. ASIBOT

ASIBOT (Figure 1) is a climbing robot drawn from the inspiration of robotics for use as a domestic aid [11]. It is a 5 DOF self-contained portable manipulator. All of its control systems are included on-board, and it only needs power supply to operate. This is why only a cheap Docking Station (DS) and a 24V supply are necessary to connect it and use it anywhere. The user can use a simple PDA, joystick, or PC-based HMI to launch pre-programmed tasks or teleoperation commands.

Figure 1. ASIBOT Portability Test

The arm currently executes a wide variety of preprogrammed tasks: feeding, washing, small size object transportation, etc. A main advantage of this robot is its light weight, about 11 kg, for a 1.3m reach. Another of the most amazing features of the ASIBOT system, presented in previous papers, [12], [13] is its capability of moving around wall, ceiling and furniture via serially-mounted docking stations. This ability to "jump" through connectors located along an adapted environment allows it to unlimitedly increase its workspace. The fact that it is anchored to a single point at a time allows it to manipulate with tools attached to its free end, such as a retractile three-finger gripper [14]. The robot can also transfer itself to DS fixed to a wheelchair, and take power from the chair batteries. This is of great interest for people with motor disabilities in their upper extremities. It allows them to bring objects closer, and pick up and move utensils to a work area nearer to themselves. These features partially restore users' autonomy for everyday activities.

Figure 2. ASIBOT in Kitchen situated on Wheelchair DS

Compared to any classical electrical appliance, the robot can be used in a much wider variety of locations within the house, and for a much wider range of applications. As an assistant manipulator designed to help people, full tasks can be performed under control of motion impaired.

2. ASIBOT II - Objectives and Approaches

We are about to discuss some improvements needed for the ASIBOT complete assistive system in order to achieve the desired level of safety and reliability. The proposed software module architecture was presented at [15]. Its implantation implies physical distribution of agents operating in a modular way, and low-cost components. One of the agents is the light-weight manipulator ASIBOT, acting as a slave of the user also assisted by the Ubiquitous Intelligent domestic environment. In order to add all of the demanded functionalities and fulfill the most assistance requests possible, a huge range of control challenges must be addressed to assure robustness, easiness of use, efficiency and safety. The modular assistance architecture makes commanding the robot by means of direct control commands possible, and also running preprogrammed movements, delegating to the user task reasoning, experience, global status knowledge, and understanding for a correct execution of tasks. Re-adaptation to new functional demands and to variations in the patient's condition is simple. The ASIBOT's PDA-based HMI is also portable, so it can be used by several users. This reduces economical barriers for the adoption of robotic aid and promotes universal access.

A. Safety Review

Assistive robots need to operate close, and also in contact, with humans - more than any other kind of robot. Their design must follow different requirements than those for conventional industrial applications: safety is first and foremost. An inherently safe system is a clever designed mechanical arrangement that cannot be made to cause harm. We are interested in fail-safe systems, one that intrinsically can not cause harm on failure. A change to brushless motors, for example, should ease automatic breaking on electrical failure. The trade-off between safety and performance is the key issue for PhRI. Last years' trend is shifting from stiff, heavy, complex compliance controlled robots, towards friendly, soft robots. As a light-weight manipulator, motor inertia can cause much more severe damage than simple segment weight force, since reduction acts as a force multiplier. Both active and passive safety mechanisms must be incorporated, and may be situated on-board or in the Ubiquitous Environment. Other features related to human-robot interaction scheme include that accurate positioning is secondary to "natural", soft interaction. Also, in assistive devices, timing in performing a task is not so critical. Slow motions are welcome.

B. User-related Design Criteria

Assistive robots are created to be specialized in helping and ensuring reliable support for people with needs, giving them daily independence. Like any product used regularly, technical aids must satisfy users' expectations regarding the functions they hope to perform. In the case of products designed for the field of disabled people, this requirement becomes even more important, due to the fact that the functions to be replaced are generally essential for personal autonomy. Service robot designers measure results in terms of technical quality regulations, which evaluate hardness, durability, and safety. These standards and procedures are related to the characteristics of the technical device itself or at most, to the user's mechanical relationship with the product. The big challenge and final goal from the authors' point of view is to reach wide acceptance of developed technical aids. The users' main interest and worry is how well a product performs its functions from users' point of view, not how sophisticated and technologically advanced it is. All design proposals are studied from the point of view of usability, availability, and dependability. For this, augmented reality is being incorporated into the PDA's HMI to simplify and of interaction, and intelligent modules are being accommodated into the new framework.

C. Task-Oriented Design Criteria

As part of the studies being mentioned, mechanical design is being synthesized directly from task specifications. This is, high-level task accomplishment's priority is above that of any low-level design decision. Table 1 represents a high-level activity diagram from the user side's perspective. From the study of these high-level activity specifications, trajectories and design constraints are drawn from the mapped 3D kitchen. These position-orientation trajectories are fed into an inference motor developed to synthesize optimal link configuration. Maintaining arm configuration symmetrical is part of the climbing robot paradigm. Future publications will describe the symmetrical arm synthesis motor developed in further depth.

Table 1. Tasks from User Point of View

Related to user:	Wipe/scratch face Eat from spoon/fork Drink from glass/cup/bottle	
Related to "free" objects in environment:	Pick up and place objects on/in:	Floor Surfaces Cabinets Drawers Refrigerator Oven Dishwasher
	Fill glass/cup from tap Fill spoon/fork from food container Pour glass/cup/bottle into sink Pour bottle into glass/cup	
Related to "structured" objects in environment:	Open and close:	Cabinets Drawers Refrigerator Oven Dishwasher
	Turn on and off:	Water tap Light Switch Oven Dishwasher
Related to robot mobility:	Move from:	Fixed DS to Fixed DS Fixed DS to Wheelchair Wheelchair to Fixed DS

Results of the synthesis motor are looped back into the simulator to contrast and verify results, as seen in Figure 4.

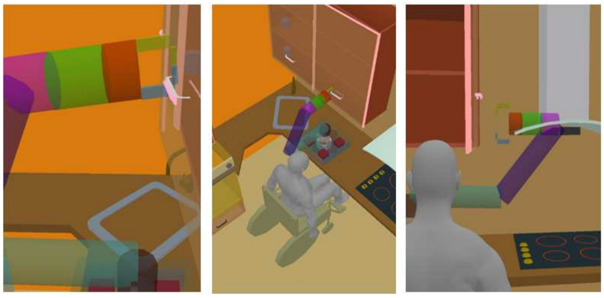

Figure 4. Configuration Verification of Handle-Gripping

At simulation level, multi-arm coordination software is already being studied (Figure 5). This involves various factors: arms from various dependencies and owners can group together, decentralized coordination can take place, and tasks more similar to those performed by a human being (cutting meat on a plate) can some time be accomplished.

Figure 5. Two ASIBOTs Working Cooperatively

D. Arm & ambient Sensor Selection

The selection, arrangement, and number of sensors (as well as their single reliability) contribute to the measure of dependability for the overall domestic system. If we assume dependable performance for communications and smart home services, the location of the control modules will not influence at all if all the modules work together, responding to the user's needs and making personalization easier. Inference systems may organize sensory sources and data taking into account the information about the specific implementation of the Ubiquitous Infrastructure for each phase of an interaction task. Fusion of the information coming from multiple sensors may help provide a coherent and reliable description of the world surrounding the robot. We would like to connect new sensors on ASIBOT; force and torque, IP or fire-wire cameras on each tip, without losing portability. They may be modular (detachable), and simply need to be connected to the infrastructure's data bus in some way. Bandwidth consumption and protocols are under study. The selection of the on-board sensors is not finished, but is intrinsically linked to user and task table described in sections B and C.

E. Advanced Control Schema

Our goal is to build, integrate and operate a portable aid with several enhanced manipulation skills. Integrating and operating a portable butler robot to make dinner or clean up real domestic scenarios involves complex reasoning. Several sequences of steps and sophisticated monitoring of user safety are needed for adjustment of actions. Though these routine tasks can be considered simple and trivial by most humans, they require advanced, 3D visually guided manipulation skills to be performed for a severely impaired user by means of a manipulator device. Adaptative adjustment of recorded or path-planned trajectories must be executed transparently and in coordination with the user.

ASIBOT's on-board computer now runs a Real-Time Linux and uses a CANOpen protocol to communicate with internal axis controllers. This implies real-time processing and real-time action. Wireless communications are available for interaction with PDA and alternative interface devices. Fast and robust software development is now a key objective, so advances are being made in two senses. A high-level data representation layer is being developed for modeling common objects, and a highly compatible hardware architecture study is near conclusion. Real-time capabilities will not be lost. This new distributed architecture permits integration and binding of low-level control modules with intelligent high-level abstraction decisional layers through a common interface. Simulation also plays an essential role, as interchangeable software modules permit control of ASIBOT real robot and virtual model indistinctly. Figure 6 shows a representation of the actual software architecture diagram.

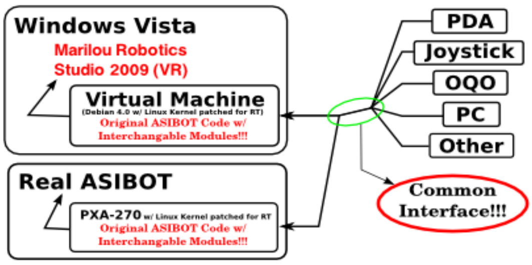

Figure 6. Actual Common-Interface ASIBOT Framework

G. End-Effectors

Human-like manipulation strategies implemented on-board are very complex to achieve due to mechanical and control issues needed for autonomous or partially assisted grasp planning and execution. ASIBOT2's definitive end-effector must achieve mechanical fixing in the DS and electrical contact for power supply. Preliminary designs were discarded due to their excessive cost and complexity, so the currently end-effector under redesign [14]. Meanwhile, a huge set of low-cost tools has been developed by rapid prototyping techniques to be able to proceed with verification tests with severely motion impaired that could be aided using the robot and its adapted tools at the kitchen.

3. FRAMEWORK: REAL KITCHEN

The adaptation of the environment to let the system works is simple. It just requires installing the connectors (DS) in the right place in order to let the robot move around the house, minimizing the number of them and maximizing the reach. As said, the ASIBOT-based Domestic Aided Kitchen is the adaptation of a handicapped adapted kitchen for the operation of the portable climbing robot ASIBOT. The kitchen surface is about $25m^2$ and now located at *Laboratorio de Robótica Asistencial* at UC3M. It consists in a fully furnished kitchen provided with fixed and rail-mounted DS, to support ASIBOT fixation and energy requirements. Four IP-server cameras have already been placed at ceiling to send image raw data to be processed by the controller. These devices are linked by the smart controller and exchange services to keep tabs on each other and, most important, the user.

Figure 5. Machine Vision for Real Kitchen IP Camera View

4. CONCLUSIONS

ASIBOT's ability to travel around the house between fixed or mobile stations has been deeply tested [11],[12],[13]. But previously programmed based behavior is not enough to meet the user's expectations and deeply usability improvements areas been detected. The light-weight ASIBOT2 robot, aims to be a domestic robot assistant, secure and reliable with its intrinsically safe mechatronic design and force-torque sensing, cameras at the tips, and control along the entire robot structure. Our target is to develop and test this new light-weight domestic climbing robot specifically designed and programmed for human-robot interaction in our domestic environments, "dependability proved". Extensive experimental and clinical trials and direct user implications on design stages are needed to find a widely accepted solution. Path-planning and adapted friendly HMI are necessary.

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