Man-Machine Interaction for Robot Applications in Everyday Environments

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Abstract

Man-machine interaction plays a key role in the growing field of service robotics. In this paper, we will discuss the role, importance and implementation aspects of robot-machine interaction in two application scenarios – cleaning robot navigation and robotic household assistance.

1 Introduction

Man-Machine Interaction is one of the core technologies in the wide range of applications covered by Siemens products. Today, various channels of interaction are used in current products, e.g.

- Touch panels in automation applications (for instance for SIMATIC) or for mobile, easy web access (the DECT-based SIMpad system),
- Visual communication and interfaces using gesture recognition (the SIVIT walkboard),
- Speech recognition (for instance for comfort functions in Siemens cellular phones or in call center automation).

Man-machine interaction evidently also plays a key role in the growing field of service robotics where in many cases robots and humans share the same workspace and to some extent even have to work together. Two years ago Siemens has released the product SINAS, a navigation system for mobile service robots which is currently used on cleaning robots operating in areas accessible to the public. Still in the stage of research is a mobile manipulator which also serves as a test and integration platform in the German MORPHA project which is partially publicly funded and targeted towards the study of man-machine interaction in robot assistant tasks. The demonstrator (developed in collaboration with several partners in the MORPHA consortium) will operate in a household scenario, and various forms of interaction will be used to allow cooperation with and control and guidance of the robot assistant. In this paper, we will discuss the role and importance of robot-machine interaction using these two systems and application scenarios as examples.

2 Example: Cleaning Robots

The SINAS [1, 2] system which sits on top of a (slightly modified) conventional cleaning machine (the complete system is shown in figure 1) consists of a Pentium-based controller, a safety-approved laser scanner, a scalable sonar system and a gyroscope. The cleaning machine has an additional simple controller of its own, which controls e.g. the various motors (drive/steering, cleaning aggregates like brushes, turbine, water pump); a small dedicated safety logic designed according to usual safety standards evaluates signals from e.g. the wheel encoders, the laser scanner and from tactile switches. SINAS and the machine control share a small LCD and an 8-key keyboard (plus some special operation devices) which provide the primary interface to the user. Either status information is displayed, or the user can, by browsing through various menus, define, edit or select cleaning programs, customize the machine or access administration or service routines. SINAS can also indicate the intended driving direction using blinkers and can utter recorded sounds – event-driven or at random. Via a serial interface SINAS can be connected to a remote PC which runs a powerful service program ("Robot Information Browser") under Windows.

Clearly any cleaning robot is essentially a means of improving productivity by doing as much of the cleaning task as possible autonomously. Nevertheless interaction with and feedback to the user play an important role – especially for installation and service tasks, but also during normal cleaning:

- Any machine requires some amount of initialization. This is done in an interactive way, one of the goals being to keep the procedure as simple as possible. For the robot, this requires the machine to be driven manually according to specific patterns. A series of calibration steps has to be conducted where the operator is guided by the program. The plausibility of the respective results is checked by the system.

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Figure 1: An autonomous cleaning robot based on the Siemens navigation system SINAS.

- Installation in a new (or changed) environment is done by a teaching procedure. First a map (that is later used for localization) is built up (automatically) while the robot is driven manually in the area of interest – for this the so called SLAM (simultaneous localization and mapping) problem has to be solved. Here, the critical issue is the loop closing problem – that one area is represented several times in the map which would make the map useless. Algorithms are provided which restore consistency and correctness online, at least if the environment is sufficiently well-behaved. The system can be supported by the operator if he confirms the revisiting of earlier defined "auxiliary points". Online and final assessment of the status of the process and of the map are a necessity. Two ways of feedback to the user are foreseen in the system: Evidently it is difficult (and maybe sometimes even impossible) for the machine to perform this assessment automatically. Nevertheless some heuristics (e.g. a frequent occurrence of seemingly doubled landmarks) can be applied to calculate a map quality measure which in most cases is realistic. An alternative is offered using the remote PC, where the current status of the map can be displayed. So again in this case the cognitive and sensorial capabilities of the operator are used. A nice idea which we also pursue (but which is not part of the product) is that based on the current state of the map the machine requests the operator for help or for moves in special directions in order to resolve ambiguities or confirm or improve the robot's localization estimate. After completion of the mapping, map viewer and editor modules allow an online check of the map and removal of unreliable, e.g. only temporary features (which are potentially dangerous for localization).

- For the definition of cleaning programs (which comprises both the nominal route and the respective state of the aggregates) another teaching procedure is chosen. The philosophy is to exploit the operator's expertise for this purpose. During teaching the area already covered can be displayed on the remote PC as a valuable feedback to the operator. In this procedure implicitly also areas are defined which the robot later never should enter.

- During execution of a cleaning program, expressing of the robot's intention by simple means like blinkers of by sound (e.g. when the robot feels blocked) have proved to be very effective. It also helps if the robot can distinguish between stationary and potentially moving obstacles. If the robot is in a situation which it definitely cannot solve by itself (e.g. because it is completely blocked) of course it makes sense to call for human assistance.

- In the system, lots of interactive service tools for testing the hardware components are provided. They run either on the remote PC (where use of the graphics display can be made) or on the robot alone. For most of these tests the human definitely has to be in the loop, but is guided and informed by the system.

3 Example: Household Assistant Robots

The previous section discussed how man-robot interaction is important for today's service robots, even if they are designed for primarily autonomous operation. It is obvious that this demand for properly designed interaction schemes increases if future robots shall be used in more cooperative assisting tasks in industry, elderly care or even private households. The above mentioned autonomous cleaning robots passively share the same workspace with people walking around. Future robots will solve problems in direct and active cooperation with their users.

Interaction with such systems will of course take place when the user commands the robot, but offers even more interesting options for improving the overall performance of the system. Current robot systems are able only to a very limited extent to cope with the full complexity of real everyday environments. A certain amount of interaction and communication capabilities would enable the robot to make use of its user's intelligence and thus to extend its directly accessible competence.

This requires that the interaction with the robot is natural and convenient for its human interaction partner and that it does not occur annoyingly often. Such a demand for interaction of robot and human user will rise in several areas:

Figure 2: A mobile manipulator engaged in tactile interaction through its sensitive artificial skin.

- *For commanding the robot and receiving feedback on the state of the robot:* This is the most obvious area. Interaction should be based on speech and gestures for this purpose.
- *During installation and adaptation to the specific application environment:* Human assistance will be relevant to the robot for teaching environmental features, for teaching objects (visual appearance, functionality, ...) relevant to the foreseen tasks and for teaching solutions to given tasks (grasping and more complex manipulation tasks [3, 4, 5]).
- *During task execution:* Due to the not negligible limitations of current robot intelligence the robots will sometimes find themselves in complex situations which they cannot resolve autonomously either because of sensor ambiguities or due to limited environment models and planning capabilities. Such situations are critical if we are talking about real products rather than research systems. Complete failures will not be tolerated by the prospective users. To avoid them, we need to enable the robot to ask for and make use of help provided by the people sharing its workspace.

Interaction in the mentioned areas can take place by means of speech dialog (e.g for presenting and naming objects), by means of demonstration (e.g. of tasks) or by physically interacting with the robot (e.g. helping the robot to free its arm). Physical interactions require appropriate tactile sensors, which enable the robot to sense physical contacts with its user or environment.

Let us have a closer look at two types of tactile sensors that we implemented on our mobile manipulation test platform MobMan:

1. An artificial skin covering the whole arm and parts of the body. The skin sensors measure strength (force) and location of surface contacts. As shown in fig. 2 the user can move the arm by pushing. Our integrated arm and platform control systems will additionally allow the user to move the whole robot this way. This can be used to move the robot into desired positions. Because of the 13 degrees of freedom (arm and mobile platform) this is much more convenient than any form of joystick or mouse control. Such interaction is especially well suited for teaching arm/robot poses and motions. We will not discuss the importance of such sensors in the context of safety here, but it is obvious that current industrial robot safety standards do not fit to service robots and that tactile sensing is a key to new safety concepts.
2. A tactile gripper measuring external (object) and internal (grasp) forces and moments. While these sensors are designed to be used for manipulation tasks, they can also serve as input devices for man-robot interaction. Fig. 3 shows a situation where the robot is instructed to grasp a bottle. The ambiguity of the environment (several bottles are present) forces the robot to acquire additional information from the user. Instead of complex dialog or keyboard input the user simply grabs the arm (this is detected by means of the gripper sensors) and pushes the robot into a grasping position in front of the desired bottle. From there the robot can continue to pursue its task and autonomously pick up the bottle.

Besides these tactile channels of man-robot interaction we implemented (in cooperation with our research partners from the MORPHA project) rudimentary speech input and output channels. Speech is used for issuing commands to the robot and delivering status output from the robot. In addition we will see a simple gesture recognition on the demonstrator platform.

In this paper we do not discuss the necessity for real assistant robots to actively observe their users and understand as well as predict their actions. We have not yet addressed this topic in our research, but we are convinced that this will be relevant in the future.

Figure 3: A mobile manipulator receiving tactile help in an ambiguous situation.

4 Conclusion

In the past many robotics projects aimed at the construction of completely autonomous robot systems. This is a legitimate goal, since robots are automation devices and should save their user's time. However, the application experience shows, that current technology is not (yet) sufficient to build robots that are able to autonomously ”survive” in everyday environments. Does this prohibit the successful application of service robots? The answer to this question cannot easily be given and consists of two parts.

- *Current robots:* In many cases it will be acceptable to have the robot call for assistance, provided that this is done in an ”intelligent” way and that such situations occur in sensible intervals.

- *Future robots:* For tomorrow's applications, the situation will be even more difficult. The environments need to be understood to a much greater extent and their complexity will increase. The robots will depend even more on the use of the knowledge available from human users. To get access to this resource they need to be specifically designed to take advantage of cooperation with people in their neighborhood. For the user this kind of interaction needs to be easy and convenient.

In both cases interaction of man and robot proves to be crucial for the robot system's success.

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