# Domestic Service Robots in the Real World: More on the Case of Intelligent Robots Following Humans

Jean-Daniel Dessimoz[1] and Pierre-François Gauthey[1]

[1] HESSO // Western Switzerland University of Applied Sciences,
HEIG-VD // School of Management and Engineering,
CH-1400 Yverdon-les-Bains, Switzerland
{ Jean-Daniel.Dessimoz or Pierre-Francois.Gauthey } @heig-vd.ch

**Abstract.** The international initiative "Robocup", and in particular its "@Home" league of Robocup, are excellent environments for focusing robotics research and AI as well as, more specifically, for testing the abilities of domestic service robots. Following humans has long been recognized as a basic capability in this context. It allows in our case for convenient path programming (teaching of itineraries). Although, the cognitive requirements are quite high (20 lin of knowledge, 200 lin/s of expertise), humans usually proceed in the same way. The environment is dynamic and disturbances may occur, which may cause errors. Therefore, safety measures must be devised, such as close human-robot interaction to prevent path crossing by third parties; the availability of light signals as a discrete warning; close interaction for accurate positioning in complex trajectories; coordinated, unidirectional blocking; vocally warnings and the ability to stop when people cross the path between the robot and the guide; the definition of a maximal radius of influence beyond which stopping is triggered; procedures for emergency stopping; robust vision-methods; and ultrasonic sensors and map-based obstacle avoidance. At the most abstract semantic level, about 15 bits per second of information must be acquired. For this purpose a variety of sensors are considered, each with specific advantages: a color camera, a planar laser range scanner, a 3D-ranger, ultrasonic sensors, and joint sensors. Smooth and stable real-time behavior is ensured by a 5-level hierarchical control structure and agents implemented in different technologies (computers, PLC, servo controllers, etc.), inheriting some developments resulting from research in Eurobot context.

**Keywords:** Standardization, knowledge, cognition, cognitics, ontology, information, model, memory, service robotics, domestic applications, following and guiding.

## 1 Introduction

Robotics and AI research have made significant progress to the point where many application fields are now being considered. The required functionalities of autonomous robots are varied and complex. To handle such varied applications, researchers and developers should develop standards and common platforms, so

Jean-Daniel Dessimoz and Pierre-François Gauthey, " Domestic Service Robots in the Real World: More on the Case of Intelligent Robots Following Humans ", Proc. Eurobot 2011, Internat. Conf. on Robotics Research and Education, Prague, Czech Republic, pp.8, 13-15 June 2011; also Springer Communications in Computer and Information Science, 2011, Volume 161, 88-101, DOI: 10.1007/978-3-642-21975-7_9, http://www.springerlink.com/content/x37m188216m5353t/

reasonable levels of predictability and efficiency can be achieved, and the considered applications can really materialize.

A special area of interest for the authors includes AI and more widely, cognitive sciences or "cognitics", where cognitive processes are automated. A book is now available on this topic [1]. Cognitive theory and quantitative approaches have now made evident that a prerequisite for all cognitive processing and effective developments is a clear identification of goals. The goal and area of special interest in the context of this paper is the progress of cooperative robotics and human robot interaction for the domestic environment [2, 3]. The international initiative "Robocup", and in particular the "@Home" league of Robocup provide excellent environments for testing the abilities of domestic service robots. In particular, they offer the possibility of validating novel concepts in the real world and identifying the most relevant open questions and problems.

More specifically, "following humans" has been recognized for a long time as a basic and necessary capability of domestic service robots and research has already been performed for similar cases (e.g. [4] [5]). In @Home competitions, among other tests, variations on the mentioned capability have been explored through the years and are presented here as "Follow and Guide"(2007), "FastFollow"(2008), and "Follow Me" (2009, 2010 with the new concept of "checkpoints").

This paper is a complementary version of a variant recently published [6], some of the previous content (in particular, a taxonomy in 5 classes of human-following capabilities) being not replicated here, while more information is given here on the need for path programming and on implementing security measures. The paper focuses on Class 1 human-following case, the main application of human-following at home: to guide a robot for training it in new grounds, without contact between guide and robot, and a typical distance of about 1 meter between them.

The theme is addressed below in details, with two main components: first a discussion about the need of path programming for mobile robots, and then the security measures to be planned, along with modes of functional implementation.

**Fig. 1.** Examples of use of the human-following capability *(on the left, FastFollow; re. text)*

.The need to teach pathways is discussed below, then successively refined into finer questions: why to follow, whom to follow, and what to follow.

## 2 The need for path programming - why to follow; whom to follow whom; and what to follow.

To bring domestic service robots into the real world to address the most relevant problems, one pressing requirement is the need for path programming; e.g. how to specify a robot the way from the TV set in the living room to the fridge in the kitchen.

In traditional programming, trajectories can be defined textually as a set of locations in a script, or clicked with a mouse on a map. But it is far more convivial just to guide the robot once through the path.

Fig. 1 presents two examples in Suzhou (China) of Robocup 2008: 1. FastFollow challenge, with RH3-Y following its guide, then crossing another team, and finally successfully finishing first the walk through home; and 2. RH-Y as a cooperating caddie.

### 2.1 The need for path programming

Robotics include many capabilities, such as AI or vision, which also make sense on their own. But from a scientific and technical point of view, robotics is most specifically motion. Robots have many joints, which require coordination. For example, Nao humanoids have more than 20 motors to control.

It is therefore no surprise that to control robots, some kind of path programming must be performed by users.

In general, the path is mostly determined by its end, and in this sense, the details of the path are not critical. Usual solutions consist of interpolating in joint space for industrial robots and limb motions and to move in straight lines for mobile robots.

In domestic applications, it is obvious that straight lines can validly be traveled only for small path increments. At medium to large scales, trajectories must be more complex, and largely unpredictable intermediary constraints must be brought into account. To some extent, robots may autonomously explore space and progressively learn what are the constraints, but for complex cases like for humans in Suntec City, Singapore, to have other humans guiding the way from @Home2010 area to ToysRUs test place is quite a necessity.

### 2.2 Why to follow

In domestic applications, trajectories are relatively complex, and the current location and the desired final goal intermediary constraints must be brought into account.

It is interesting to see how the problem is handled in the case of humans. Two cases are considered. 1. The traditional and most comfortable way to define a path for a human is to have another human guiding him or her. In cognitive terms, the task is quite demanding, implying on the order of 15 bit per second of information that must be acquired (re. detailed estimation in Sect.3.1) while classical psychometric studies indicate that humans can consciously process a maximum of 30 bit/s. 2. When a path is extremely deterministic, constant for a long time, and useful for many, maps and topographic indications are usually worked out; this approach has a rather high initial cost (both for the elaboration of directions and for the training of agents using them); however, over time and as many people use the developed tools, it can become competitive with guiding.

For robots, schematically two classes of solutions may develop: in the first case, programming is performed in a more or less declarative way by programmers; and the alternate type of solutions calls for something similar to the human way. Whenever possible, the first class of solutions should apply, to load humans as little as possible; nevertheless, as for humans, the ability to learn a new path just by following potentially brings the most convenient type of solutions, especially in complex and dynamically changing home environments.

In recent years in the @Home competitions, a priority has been set on robots being able to follow humans, rather than on humans to guide robots. This priority may be useful from the perspective of fostering advances in technology. However, in the long term and for general use in society, in authors' view the final responsibility must shift again to the human guide in this context; robots should make guiding a simpler exercise by following humans as conveniently as possible, but the main responsibility for successful path following should in no way lie on their side.

### 2.3 Whom to Follow

In domestic applications, many tasks must be done. Yet to have a chance to master them, consideration should be focused progressively on each task. In particular, a question commonly addressed in the context of the "Follow" task refers to the ability of robots to recognize a specific human as the guide.

In our approach, the tasks of human identification and of following are schematically split.

In the first case, human identification, traditional solutions for humans call for keys; in recent times and the advent of digital society, PINs, passwords and code numbers are widespread. In special contexts, ID-cards, passports, RFIDs or biometric tests provide the proper answers. Robots are machines that include computers and are more and more connected to networks; therefore, all of these solutions can similarly be envisioned for making robots capable to identify potential guides.

In the second case, following a human, it is sufficient to ensure the continuity in time and location of the perceived guide's path. With RH-Y (re. Fig. 1) resources, the location of the guide can be estimated 10 times per second, with an accuracy of about 1 cm. This is sufficient to guarantee also guide's ID continuity.

### 2.4 What to Follow

The paradox of learning trajectories, and consequently of following humans, is that dynamic changes and long-term stationarity are assumed at the same time. Unfortunately, there are still many other factors that behave in between and create disturbances.

Learning implies here that new trajectories are desirable, which are yet unknown for the robot. In these circumstances, it is appropriate for humans just to walk about to teach the robot by guiding.

However, learning trajectories also implies that in the future those trajectories will keep their adequacy, i.e., the domestic environment will be essentially stable.

To a large extent, the ability to follow a human can naturally lead to the ability to follow the environment; but there are also major differences, for example, in principle the human guide keeps moving, while the environment is stable.

In fact, there may be numerous other cases, e.g., doors will sometimes open or close, chairs are often moved, and humans may stand still, talk, watch television, or sleep for hours. To cope with all these phenomena requires the robot to acquire, while following a person, much more than just the trajectory; anyway, it is most probably impossible to achieve full success in all cases; occasional failures are bound to happen. Therefore, it is also important to devise appropriate security measures.

## 3 Implementing security measures and functional capabilities

The previous sections have shown the need for robots to follow human guides. The experience gained since the beginning of the @Home competitions, in 2006, and related research have allowed us to sketch the most appropriate security measures for the context of robots following humans[1], and to present how to implement them.

Some of the techniques presented below have also inherited from developments previously made for our proprietary "ARY" family, initially developed in the context of Eurobot [7] and dating for some as far back as in 1998. Some years up to 10 mobile units could cooperatively be engaged under the control of a main autonomous robotic structure [8].

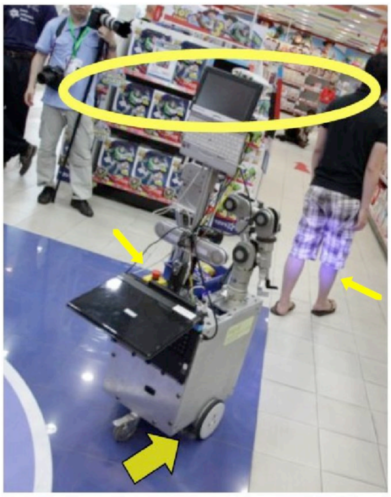

**Fig. 3.** Overview of some security measures *(see text for more information)*; 1. The blue warning blinking light reflected on the legs of the guide (*arrow on the right*). 2. If a wheel is blocked, the other wheel gets stopped as well, in a properly coordinated way (*lower arrow*). 3. The unidirectional blocking capability is also active (*same lower arrow*). 4. In principle, the top circle illustrates the concept of the maximal radius of influence; in fact, the effective circle at that very moment is larger than the

[1] This has already been briefly presented in the second part of the "Open challenge" presentation, in the 2010 Robocup competition in Singapore [15], and this is developed here in written form.

one drawn. It must encompass the guide, otherwise all motion would stop. 5. Emergency stop mechanism (*left arrow*).

Fig. 3 illustrates several of the safety measures advocated below, with our RH5-Y robot shown during the test "In the Mall" of @Home 2010 in Singapore, following one of our team members through the store: 1. The blue warning blinking light (re. Sect.3.4). 2. Coordinated blocking (Sect. 3.6). 3. Unidirectional blocking capability (Sect. 3.7). 4. The concept of the maximal radius of influence (Sect. 3.9); 5. emergency stop mechanism (Sect. 3.10).

This section is structured with two initial paragraphs presenting the specific task, Follow-a-person, first in terms of the requirements and second in terms of the general solution. Then several security measures are successively addressed, which deal with issues, such as the possibility of close human-robot interaction to prevent crossing by third parties; the availability of light signals as a discrete warning; the benefit of close interaction for accurate positioning in complex trajectories; the necessity of coordinated, unidirectional blocking; the benefits of issuing a warning and stopping for a while if people cross the path between the robot and the guide; the definition of a maximal radius of influence beyond which stopping and staying still are triggered; and the necessity of an emergency stop procedure. Those points complement a previous publication [6], some items being shortened here and other ones expanded.

In most of the discussions below, the solutions adopted for our RH-Y robot are the ones presented. This kind of experimental validation brings a particularly concrete, validated character to the discussion and does not restrict the scope of applicability of the presented items to only this case. However, in cases where alternatives appear preferable, the latter are explicitly mentioned.

### 3.1 Requirements

Before attempting to implement a function, it is wise to review the main requirements. And like for deciding about the possibility of jumping over a wall, it is critical to go quantitative and know in particular the height of the wall (in "meter"). We shall focus here on the cognitive aspects. As defined in particular in [1], based on modeling (in state space and associated probabilities), time ( in "second") and an information (in "bit") based calculus, key cognitive properties include knowledge (the ability to deliver the right answer, in "lin"), and expertise (the ability to deliver the right answer quickly, in "lin/s").

For a robot to follow a person and learn a new trajectory, a speed on the order of 1 m/s should be expected. Positional accuracy should be, as usual in common technical matters, on the order of 1%, e.g., of about 10 cm in a 10 m range. A trajectory can be viewed as a sequence of locations via points at intervals on the order of one location per meter considering that locations are specified in a 2-dimensional space.

This information amounts to about $n_i = 2 \cdot \log_2(10/0.1) \cong 15[bit]$ per second, assuming equiprobability of locations of interest) and is the minimum information that the robot must acquire. Sensor configurations acquiring less information could not do the job; now if they acquire more than that, processing can in principle also be done. Considering a similar accuracy in the plane (1%, 3 coordinates, e.g. x,y, and orientation) about 21 bit of control must be elaborated. Required knowledge is consequently $K = \log_2\left(n_o \cdot 2^{n_i}\right) = \log_2\left(21 \cdot 2^{15}\right) \cong 20\left[lin\right]$, and expertise $E = K/\Delta t = 20/0.1 \cong 200\left[lin/s\right]$ .

In early phases, such as in Bremen and Atlanta for @Home context, the "Follow" task could be implemented in a somewhat jerky way, with start-stop increments that are similar to point-to-point motions in industrial robots. Then indirectly, with the "Fast-Follow", new specifications were elaborated for the Suzhou competition, in which "smooth" motions were required (smooth versus time, not versus trajectory in space ).

### 3.2 Overview of solution

For the kind of perceptive capacity estimated in the previous paragraph, and for the "Follow a person" test of @Home, vision instruments or rangers are adequate (re. e.g. Fig.2); an alternative, albeit slower mode, might rely on compliant motion, i.e. on a kind of force and torque perception. In all cases, a complex hierarchy of functions and devices are necessary.

At lower levels, depending on the considered test phase, either the position or speed controls provide the best solutions for ensuring either positional accuracy or smooth motions. During the active following phase, the speed mode is in operation, and for the previous and next navigation phases, the position mode.

**Fig. 2.** General view of RH5-Y (*see text for more information*). From top, the yellow arrows successively point at 1. a planar laser ranger; 2. an ultrasonic distance sensor; 3. a color camera; and 4. a 2-D time-of-flight ranger, i.e., a 3D camera.

From the top down, the hierarchy of controls is described here in five steps :

1. At the uppermost level (level 1), the linear and rotational robot motion commands are elaborated as speed targets based on the walker's location relative to the robot. At this point, two parallel controls are in operation. Attention is also given to possible overall mode commands, such as "sleep", "follow", or "observe and interpret remote gestures". Distance discontinuities are monitored for possible path cutting, and excessive errors are also monitored to guarantee orderly phasing out.

Perception is best done with a planar ranger (240 degree aperture, 10 Hz refresh rate, about 700 radii between 0 and 400 cm, with 1 cm accuracy; this translates into about 50'000 bit/s of raw, low-level input acquired information flow; a lot of redundancy helps to reliably cope with the complexity of the environment and noise). Nevertheless, other modes are feasible, and some have been performed in competition (e.g., color vision or ultrasonic sensors, with much less aperture though, less angular resolution and lower distance reliability). A 2D time of flight range sensor (as used in our @Home applications) is also beneficial in terms of dimensionality, but at the expense of relatively low aperture angles and signal to noise ratio. Multi-agent approaches, e.g. with our original Piaget environment [e.g. 9], and vocal channels also act in parallel to help prevent errors and cope with them when they occur.

2. At an intermediary level (level 2), a MIMO stage performs inverse kinematics, providing the necessary joint commands (wheel 1 and 2) based on the linear and rotational speed targets naturally expressed in world, Cartesian or polar coordinates. In particular, a parameterized gain matrix is used.

The functions described in points 1 and 2 are implemented on a supervisory computer (e.g., an embedded laptop).

3. Then, the motion law stage is entered (level 3), and parameterized accelerations are used for interpolating speed target values.

4. At level 4, the wheel velocity control is accomplished with two independent PID closed loop controllers with encoder management. Coordination is implicitly ensured by simultaneous commands and appropriate respective accelerations and speed targets.

Information between the laptop and servo-controllers is conveyed via Ethernet with the TCP-IP mode.

5. Finally (level 5), amplifiers manage the motor currents, ensuring that limits are not transgressed (two on/off action, closed-loop controls).

### 3.3 Possible close interaction to prevent crossing

Guides should adapt their walking speed to the circumstances, and, in our classical solutions, the speed evolves as the distance between guide and robot (re. [6]).

### 3.4 Blue blinking as a discrete warning signal

It is usual for vehicles to have some warning signals, especially when visibility is poor or the risk of collisions and consequent casualties is high. In our mobile robots, we have always had a blinking signal composed of LEDs of various powers and colors that were initially meant for informing team members that operations and, in particular, parallel processes were running correctly. After the 2nd year at @Home, this signal has increased in visibility and is currently a freely programmable double blue light, which typically blinks as a discrete warning signal during following tasks.

Even though the objective risks are typically small and should remain so, laypersons are often afraid of machines (we are not aware of systemic and formal studies on this though). To communicate clearly and early about presence and activity however can reduce the possibility of surprise. This measure appears experimentally useful and may, in particular, contribute to increase awareness and confidence among laypersons. Because cooperative robots in domestic environment interact with people, such a measure should become a normal custom.

In RH-Y robots, the light management in performed in several steps: 1. Asynchronous commands can be given in Boolean mode independently on both lights (right and left) by the “strategy” agent of our proprietary, “Piaget” environment. 2. For dynamic behavior, such as blinking, the task is handed over to a parallel Piaget agent, occasionally with parameters, and is asynchronously decided by the “strategy” agent. Steps 1 and 2 occur on the supervising computer. 3. A PLC receives through Ethernet and a TCP-IP channel the instantaneous Boolean orders, and on this basis autonomously elaborates and provides robust output controls. 4. Variations are possible, whereby the PLC is ordered to modulate output signals in specified ways and R-G-B lights replace the blue lights in Fig. 2.

### 3.5 Close interaction for accuracy in complicated trajectories

As mentioned in Sect. 3.1, guides should adapt their walking speed to the circumstances. In particular, complicated trajectories may require a lower speed than the average. A lower speed decreases the requirements for expertise. A complex trajectory has higher requirements in terms of local perception by definition (re. [6]).

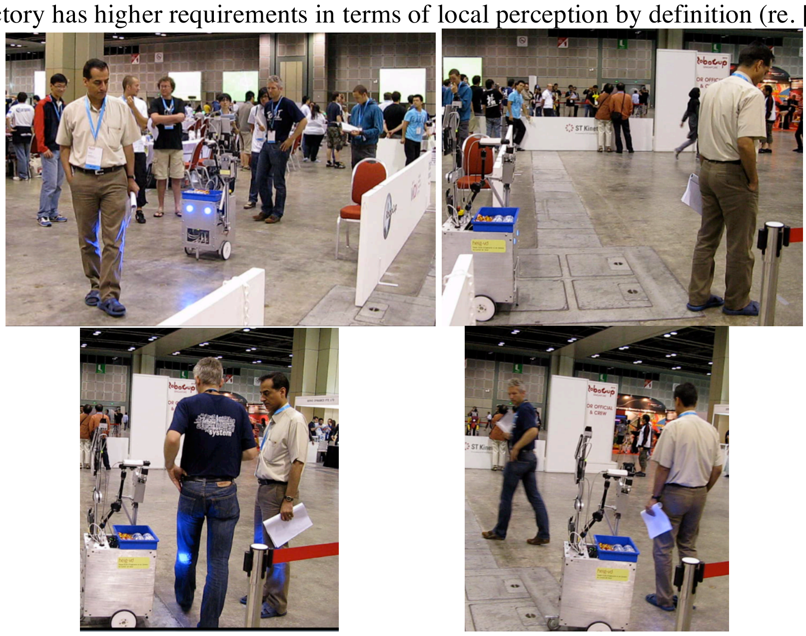

**Fig. 4.** Example: RH-Y in @Home 2010, Singapore. *Left to right, top to bottom*: The robot starts, its light starts blinking, and it follows the official guide (1), then turns and passes the wall (2), detects a path cutter and consequently announces it will stop for 3 seconds (3); when the time is elapsed, however, the guide has gone beyond limits and the robot stands still, observing the maximum safety radius (4).

For the mentioned “Follow me” test of @Home 2010 competition in Singapore (re. Fig.4), the strategy adopted by the RH5-Y robot was of the type advocated here, i.e., if and when people crossed the path between the robot and the guide, to stop for a while, to warn the guide with a vocal message of the situation and if possible, after the path cutter had gone, to restore normal operations.

### 3.6 Blocking in a coordinated way

In the real world, many disturbances occur unavoidably. Therefore, developing solutions for ideal cases is not sufficient; on the contrary, additional appropriate failure management procedures must be devised for situations when the main task, following the guide, cannot be achieved (re. [6]).

### 3.7 Unidirectional blocking

As guides drive robots, errors occur and sometimes robots collide with hard to move obstacles, such as heavy pieces of furniture (re. [6]).

### 3.8 Coping with path-cutters

As a consequence of measures advocated in Sect.3.3 and Sect.3.4, no one should attempt to cross the path between a robot and a guide. However, people, and especially children, like to play; therefore, it is tempting for many to ignore warnings and common sense and to explore what happens when a driving path is cut. Thus, paths may be cut, and appropriate measures should be devised in anticipation (re. [6]).

### 3.9 Maximal radius of influence

As the distances between the robot and the guide increase, the risk also increases that they miss each other. To prevent problems, it is wise to define a maximal radius of influence (re. [6]).

### 3.10 Emergency Stop and other factors

Seven measures for security are listed above. This list is not exhaustive though and some other considerations are mentioned here, giving additional examples of ways that robots can safely follow a guide, including some approaches that have already been conducted in a @Home context.

The ultimate measure for stopping robots is to cut the power. This measure is already enforced in the @Home context. Cutting power can be viewed in several ways. In particular, the tradeoffs between a completely hard-type power breaking approach and a completely software-based emergency management approach should be considered. In most of our proprietary mobile autonomous robots (“ARY” family), the circuit-breakers only affect the power circuits of the wheel drives, and power remains in resources that do not directly affect the lowest structural stages, which ensure that the robot maintains some ability to act. For low-power elements, such as for the Katana arm, or the NAO humanoid, the question of an emergency stop is not mandatory because the risks of casualty are low. As a general guideline, a safety limit in the range of 10 W seems appropriate for this mode. More formal, international standards have come (ISO 10218-1, 2006; ISO 10218-2, 2010 and 2011).

Another trend for security is to limit as much as possible power, speed and force (for arm motions, the Katana arm of RH5-Y is already certified in this regard).

A similar feature is offered by compliant control. The latter principle may provide an alternative to the paradigm of "following". Inherently, the compliant approach ensures minimal distance and contact between the robot and the guide.

In reverse mode, a low, constant, linear speed is provided for safe and easy motions. Implementation is most simple when the ability already exists to follow humans. This is done in our case in speed servo mode, with constant acceleration speed changes

It should be mentioned again that in as much as circumstances allow, guides should take their leading role actively and not just expect that robots are smart enough to solve all difficulties on their own; thus more is typically achievable, in results and safety.

As can be judged from professional guides of tourist groups, a special visibility feature, such as an umbrella may help to safely increase the influence radius introduced above.

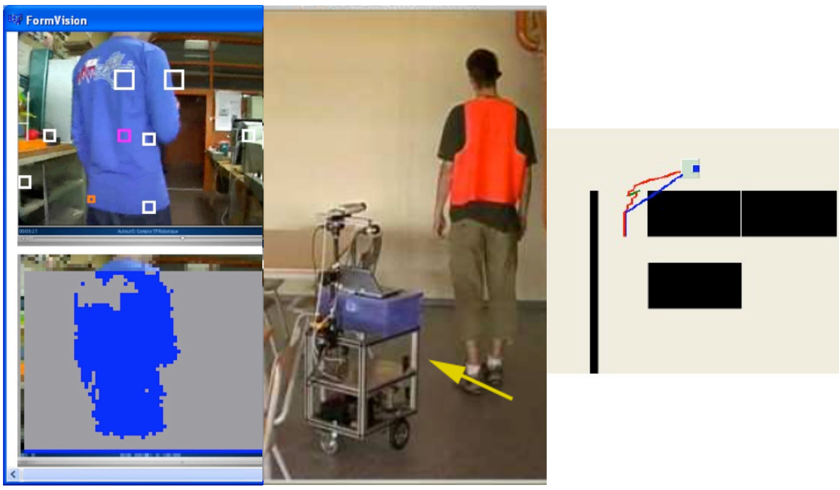


**Fig. 5.** Other possible safety measures: Re. text in Sect. 3.10. Left, vision-based, following techniques with "one of nine" optimized colors (@Home 2006); using high-visibility guide attire (*middle*),; with lateral ultrasonic sensors (*same image, arrow in the middle*); and map-registered environment properties (*right*).

Fig. 5. illustrates yet some other possible safety measures: In the context of vision-based following techniques, safety may be improved with robust vision approaches, such as the SbWCD (saturation-based, weighted intensity and hue, color differences)

correlation, which is documented in a separate paper [10] and/or by using high-visibility guide attire, such as the vests that are worn on high-speed roads .

Continuous recognition of the guide may be an advantage, even if not strictly required. In @Home 2010, in a checkpoint the guide was asked to get out of robot signt for a while. To recognize him or her, our RH-5 robot was given an original, robust, visual, saturation-based weighted color difference correlation capability [10].

Additional explored methods include the use of lateral ultrasonic sensors to avoid lateral obstacles, and map-registered environment properties for the same purpose. In the latter case, the guide position may be reached, while avoiding a table by adapting behavior to map-based constraints.

## 4. Conclusion

The international initiative “Robocup”, and in particular the “At-Home” league of Robocup, provide an excellent environment for focusing research in robotics and AI and, more specifically, for testing the abilities of domestic service robots. Following humans has long been recognized as a basic capability in this context. Following humans allows for convenient path programming, and although the cognitive requirements are quite high, all humans usually proceed in this same way.

The environment is dynamic and disturbances occur, which may cause errors; therefore, safety measures must be devised, in particular, close human-robot interaction to prevent crossing by third parties; light signals as discrete warnings; close interaction for accurate positioning in complex trajectories; coordinated, unidirectional blocking; vocal warnings and the ability to stop while people cross the path between the robot and the guide; the definition of a maximal radius of influence beyond which stopping is triggered; emergency stopping capabilities; and robust vision-methods ultrasonic sensors and map-based obstacle avoidance. At the most abstract semantic level, about 15 bits per second of information must be acquired; for this purpose, a variety of sensors are considered, each with specific advantages, including a color camera, a planar laser range scanner, a 3D-ranger, ultrasonic sensors, and joint sensors. Smooth and stable real-time behavior is ensured by a 5-level hierarchical control structure and agents implemented in different technologies (computers, PLC, servo controllers, etc.).

Experience in @Home context confirms a general phenomenon by which perception is crucial in mapping some of the infinitely complex reality to a much simpler, useful cognitive representation. In the typical case discussed above, it allows for an abstraction index higher than 1’000, thereby very significantly extracting the necessary application-oriented, semantic essence, as used as starting point in the quantitative cognitive assessment of Sect. 3.1.

According to our opinion, above proposed methods are the best of the time and in the context of @Home the factor the most critical for success has appeared to be the ability of the guide to make use of robot capabilities.

Concerning the help at home, progress is regularly achieved, in a modest and incremental way, which can be translated in much use for society. For achieving results somehow similar or better than nowadays home helpers though, the @Home league will probably take a time similar to the soccer league in their effort. Their goal – to beat humans in world level competitions - is set in time for the year 2050.

The paper complements publication [6], each summarizing, or respectively developing different aspects.

The authors wish to acknowledge the useful suggestions of referees, numerous contributions of past RH-Y team members, as well as HESSO and HEIG-VD for their support of this research.

## References

1. Dessimoz, J.-D., "Cognitics - Definitions and metrics for cognitive sciences and thinking machines", ISBN 978-2-9700629-1-2 work in finalization, 31 Aug. 2010, already accessible on http://cognitics.populus.ch
2. Wisspeintner, T., T. van der Zant, L. Iocchi, S. Schiffer, "RoboCup@Home: Scientific Competition and Benchmarking for Domestic Service Robots", Interaction Studies, 10(3):393--428, 2009. ISSN: 1572-0373
3. Dessimoz, J.-D., Pierre-François Gauthey, "RH5-Y – Toward A Cooperating Robot for Home Applications", Robocup-at-Home League, Proceedings Robocup10 Symposium and World Competition, Singapore, June 2010
4 Gockley, R. and Forlizzi, Jodi and Simmons, Reid, "Natural person-following behavior for social robots ", Proceedings of the ACM/IEEE international conference on Human-robot interaction, HRI '07, 2007, pp17—24, http://doi.acm.org/10.1145/1228716.1228720
5 Kobayashi, Y. Kuno, Y., « People tracking using integrated sensors for human robot interaction », 2010 IEEE International Conference on Industrial Technology (ICIT), 14-17 March 2010, pp. 1617 – 1622, Valparaíso, Chile, ISBN: 978-1-4244-5695-6
6 Domestic Service Robots in the Real World: the Case of Robots Following Humans", Domestic Service Robots in the Real World Workshop, SIMPAR-2010 Second International Conference on Simulation, Modeling and Programming for Autonomous Robots, November 15-18, 2010, Darmstadt, Germany.
7 Research and Education in Robotics - EUROBOT 2009, International Conference, la Ferté-Bernard, France, May 21-23, 2009. Revised Selected Papers, Series: Communications in Computer and Information Science, Vol. 82, Gottscheber, Achim; Obdrzalek, David; Schmidt, Colin (Eds.), 2010, X, 173 p., ISBN: 978-3-642-16369-2
8 Eurobot Competitions, http://www.eurobot.org, http://www.eurobot.org/conference/ , http://www.planete-sciences.org/robot/video/cswis01.mpg , last visited on 31 March 2011
9 Dessimoz, J.-D., Pierre-François Gauthey, "RH3-Y – Toward A Cooperating Robot for Home Applications", Robocup-at-Home League, Proceedings Robocup08 Symposium and World Competition, Suzhou, China, 14-20 July 2008.
10 Dessimoz, J.-D., and Pierre-François Gauthey, "Contributions to Standards and Common Platforms in Robotics; The Role of Color and Recommended Modalities", Standards and Common Platform Workshop, SIMPAR-2010 Second International Conference on Simulation, Modeling and Programming for Autonomous Robots, November 15-18, 2010, Darmstadt, Germany.