RH5-Y – Toward a Cooperating Robot for Home Applications

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Abstract. RH5-Y is the fifth version of an autonomous robot designed for home applications, in Robocup-at-Home context. RH5-Y is accompanied by a second robot, OP3-Y, a similar system mounted on robust, 4-wheel, omnidirectional platform. The RH-Y family is characterized by numerous original elements, of hardware, software, and cognitic (automated and cognitive) nature. Innovative technologies include systemic aspects, our proprietary Piaget programming and control environment as well as some physical components. Research focus is on automated cognition, cognitics, with applications in home robotics and in manufacturing. A particular area of interest is in the quantitative assessment of cognitive entities. Reusability is ensured by classical means, such as publications or licensing, but also by the use of COTS. A simulation environment has also been created, which is publicly available, except for third party components (e.g. camera driver). RH5-Y can be applied for real world in several ways: interaction with physical world; in robust and fully autonomous way; with the goal of solving well-defined, socially relevant tasks, at home. This year, improvements are notable in cognition dynamics theory, and in conceptual stage, the problem of moving up and down stairs has been newly addressed.

1 Introduction

RH5-Y is the name of our current autonomous and cooperating robot, designed for domestic help and for participation in Robocup-at-Home (RAH) world competition 2010 in Singapore [1, 2]. RH5-Y is also the name of our team. Our current robot is the most recent evolution of our RH-Y robots, which themselves inherited key components from previous robots of our ARY family. We shall not describe again here in full details what has already been presented in other publications [e.g. 3-10]. Instead, we focus below on additional data as recommended in RAH guidelines; nevertheless, some elements are also briefly repeated here in order to provide a convenient, updated system overview.

The paper is organized as follows. Section 2 presents an overview of RH5-Y. Section 3 gives additional information in terms of innovation, research focus, resource sharing and applicability.

2 Brief overview of RH5-Y

RH5-Y is described below under three angles: hardware, software, and cognition.

In short, and from a hardware perspective, RH-Y robots are typically about 50x50x100cm large, weight about 30 kg, consist in a mobile platform including 70W active wheels, arm, end-effector, power units and energy storage (batteries), many sensors (color camera, 3D ranger, 2D scanning ranger, wireless microphone, ultrasonic sensor, etc.) and control units interconnected with Ethernet, TCP-IP technology (incl. switch) and USB hub.

In terms of software, RH-Y robots are programmed in our original Piaget, multi-agent, real-time environment, mostly implemented currently in C++ with Windows; but in fact control is hierarchically organized with various resources matching specific needs in terms of reactivity(agility), robustness, and global optimization; therefore Linux and IEC61'131, for example, are also present in some of RH-Y components.

Cognitive capabilities of RH5-Y are numerous, including, to a very good degree for an embedded system: visual and 3D ranger-based recognition, vocal dialogue, 2D-distance perception, non verbal communication by gestures, pose management and trajectory planning, joint coordination, monitoring and recovery from trajectory errors, learning, extensive modeling and simulation capabilities, prehension and manipulation, hierarchical and distributed control, and expertise in most of Robocup-at-Home test domains, in particular "Introduce" itself and the team, "Follow me", "Walk & Talk" and autonomously navigate through home locations, "Fetch & Carry" an object, perform a "Competitive Lost & Found" challenge, or recognize "Who Is Who" .

Our lab has also designed various test systems with other, classical AI, techniques (genetic algorithms, neural networks, fuzzy logic, expert systems, etc.). This is useful for educational purpose, but for contexts as demanding as in RAH, such techniques are not found to globally provide the required level of cognitive/cognitic performance.

3 Points of particular interest, in the context of RAH guidelines

At Robocup, specific guidelines have been established for the "at-Home" League, which require a special attention for innovation, research, resource sharing and applicability. These aspects are considered below in sequence.

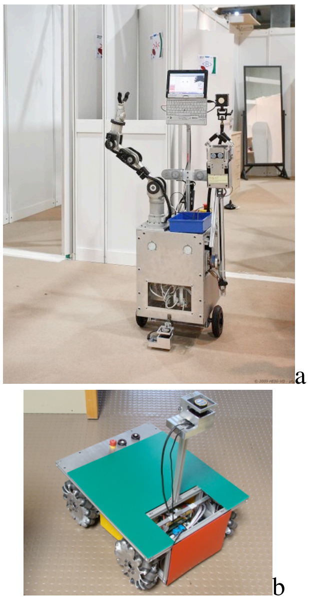
3.1 Innovative technology

Innovative technology will be discussed here in several points, ranging from market-mature solutions to prototype-level contributions.

In terms of strategy, our team favors (re-)using available solutions, whenever possible. In particular and obviously, a lot can be found on the market. We had been advocating for many years computer-based automation and Ethernet/TCP/IP as valid solutions for communication and control in most manufacturing contexts. Now this has become very common in practice. Similarly, since more than 10 years computer-based supervision and since more than 5 years an Ethernet hub are the key components for communication within ARY/RH-Y robots; out of necessity for COTS, a USB hub is also used additionally. Small-size, portable computers, as well as Ethernet-compatible PLC, cameras, and motor controllers have been integrated as soon as available on the market. A key property for motion control is moreover the possibility to parameterize motion laws and to ensure good synchronicity. In another respect, we are using "subversion" technology for collaborative developments.

Major innovative components of our own include those visible at systemic level: software and hardware architectures (Piaget environment, multiple distributed heterogeneous agents, communication topology and protocols) ; the key idea is to match specific agility and technology solutions to specific elementary requirements at all levels, in a variable yet coherent approach.

Other aspects relating to Piaget environment consist e.g. in the capability in this context, 1. to a very advanced degree, to dynamically tune up the level of simulation versus real-world implementation of the application (re. also §3.3); 2. to efficiently parametrize cognitic processes, 3. to perform, in a unique way, "programming" tasks at 4 different levels of complexity as well as 4. to include numerous cognitive components, such as e.g. 4a. possibility to map object locations from image coordinates to robot and home coordinates; or 4b. possibility to efficiently manage vocal dialogues along with all other robot functions, and non verbal communication by gesture.



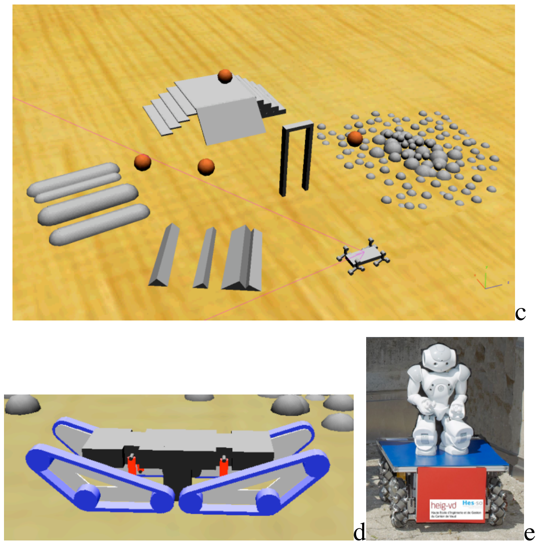


Fig.1 Our RH4-Y in Graz, with omnidirectional platform OP2-Y (a,b), and a view of our non-flat , simulated, domestic benchmark environment in Webots, along with FT0-Y, our conceptual four track kinematic and physical prototype for climbing stairs (c, d) [11] and NAO-Y cultural mediator (e). Configurations often change, thus not all components are visible here.

Innovative components of our recent RH-Y robot include a second arm, Katana, added to our traditional arm, along with the necessary expertise for cooperating motions, on mobile platform, as well as a 3D-ranger sensor, along with necessary support for data fusion with our classical sensors, in particular planar ranger and color camera. In the concept stage, a study has been made for a domestic platform appropriate for moving up and down stairs as well as through uneven ground, with robustness and economy of resources. Moreover, adding a NAO humanoid robot and an iPad or tablet-PC to the current RH-Y and OP-Y robots allows for the creation of an interesting Robot Group (RG1-Y), in which NAO-Y (re. Aldebaran and Robocup Standard Platform) can play the role of a cultural mediator between humans and the rest of the robot group; communicating with humans by speech, vision, gestures, tactile conventions, and with the other robot group resources by wifi and own language and culture.

3.2 Focus of research (research interests)

The context of RAH League is precious for us in several ways relating to research. Very specifically, we are interested in automating cognitive processes, i.e, in the science and techniques of automated cognition; cognitics. Another interest is in the design of autonomous, cooperating *system* technologies, for domestic applications, but also for manufacturing goals.

Cognitics is a new field. When addressing a scientific field, the first thing to do is to build up a clear model, a theory with its proper objects and laws. For that, RAH context allows us to proceed schematically in three ways: in one direction, to test how useful our current proposals can be ("MCS" theory); in another direction, to possibly identify new requirements, which would call for theoretical revision and development; and in the third way we hope to be in a place where the benefits of our MCS theory can be recognized and widespread. Our current conclusion is that the MCS approach easily allows to estimate amounts of cognitive properties and to point at where the main cognitive components lie (in as much as users are familiar with classical modeling and information estimation); quantitative cognitive/cognitic estimation has been systematically performed for our past solutions in RAH tests and challenges. New developments have been done in the direction of cognition dynamics, a proper and novel way to address changes and time aspects in quantitative cognitics, which paves the way for improving control and multiagent architectures.

Another area of interest for our research is the design and operation of complete autonomous cooperating *systems*, and in this sense, it is very interesting for us (and for society) to identify and integrate, especially in critical areas, the best partial solutions developed at world level. Domestic applications are a focus domain for us, and as a byproduct, progress made in RAH context can be, in addition, also transferred to manufacturing environments; we are part of the (Swiss component of) European "Manufuture" platform [12, 13].

In Robocup, the most established leagues relate to soccer, and the league at-Home has been introduced much later. This specialization however may be of significance mostly for short to medium term. Even if differences exist, in terms of apparent social utility and time horizon for widespread availability of soccer players versus domestic helpers, and thus in terms of communication possibility with the broad public, it appears that the roads through homes and through soccer fields may eventually converge.

In the short term, differences are large between robots designed for playing soccer and those for helping at home. The main reason maybe the necessity initially to set a very narrow focus on respective application domains. In the latter case for example, current economic and reliability reasons call for locomotion systems adapted to surfaces quite perfectly flat and hard. In the long term however, applications will expand as broader fields and numerous overlaps should occur.

Finally, a world-class soccer player might well prove to be a valuable helper for home, or reciprocally, the ultimate artificial home servant may also turn out to be a respectable soccer player. They may sometimes just need to exchange shoes and attire and get a briefing from their coach and/or home master to exchange roles temporarily!

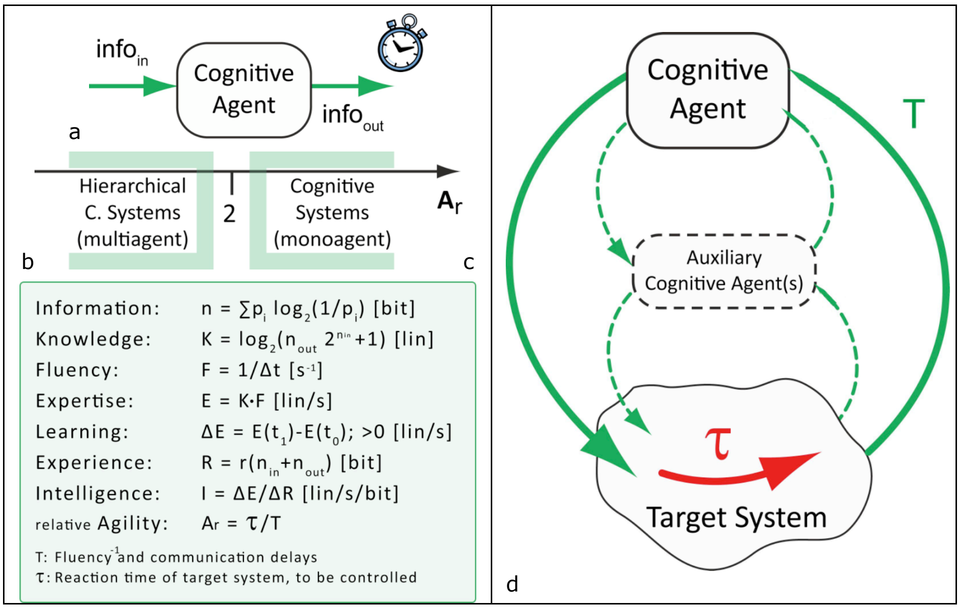


Fig. 2. The MCS framework [7, 8] provides essential definitions and metrics to evaluate complexity, information flows (re. Shannon), knowledge, expertise and other cognitive and dynamic properties, quantitatively and conveniently, in particular as useful for RaH competition task specifications; and/or for rating demonstrated performance level of participating robots. Just as meters conveniently allow for describing the height of a wall. Behavioral description of cognitive agents (a), structure adapted to system dynamics (b), core definitions and metrical equations in MCS (c), structure and critical dynamic aspects of embedded control systems (d).

3.3 Re-usability of the system for other research groups

Re-usability of our results is addressed in many ways. Traditional approaches such as publications, education, possibly patents are normal ways to ensure that. We also maintain a website, train interns from other institutions and participate in demonstrations and fairs. Even a priori, our strategy calling for a maximal use of available resources, from the market (COTS) or from the general community, makes the whole transfer yet easier for other users and teams.

Our RH5-Y robot could be replicated relatively easily (IPR could be rather symbolic for non-commercial use, in RAH League), but nevertheless it would have to include a lot of different hardware and software resources. Much easier, the Piaget environment could be transferred, possibly with some minimal IPR restrictions, and with the goal of having it working in simulation mode. A special version of our environment has been released and is publicly available on the internet. It is fully operational after all standard COTS drivers are installed. It might be better to create a version exclusively for simulation mode; the gain would be that it would thus *not* require installation of various drivers, code, and actual devices necessary only for running in the real world, and thereby our RHn-Y application would be easier to install, program and use by other parties; to experiment to a large degree solutions for RAH and similar applications; a noticeable advantage of this approach is the completeness of the description and the inspiration one might get from it. Only prerequisites: C++ Borland (since 2009 , some new modules, related to the SR4000 ranger, are using MS Visual C++ in addition) and Windows.

Another approach would be to transfer Piaget to other environments (we have done such transfers into C /Piaget-light, and Pascal implementations; with DOS, and RTDOS on an integrated PC - re. Beck). This is relatively easily done in the sense that our Piaget kernel does not include that many lines, but the challenge might be to find out on the new implementation target all of the capabilities we now make use of, provided by Borland components and especially Windows OS.

3.4 Applicability of the robot into the real world

RH5-Y can be applied into the “real” world in several senses. Comments follow in an order going from the broader sense to a more restrictive one.

The statement is true in a first sense, where real means “physical” world: we do not only have a theory or a simulation in a non-physical world, but indeed, our robot is acquiring data from the physical world with sensors, and acting with forces and other physical means on the physical world as well.

The statement is true also in a more restrictive sense, as the system is autonomous, can behave in real-time, and in particular can react to unforeseen events.

To a large extent, RH5-Y is even applicable to the real world in a more restrictive sense yet, robustness: it includes mostly industrial-grade components (re. Maxon motors, chassis, Beckhoff PLC, Baumer Electric ultrasonic sensors, etc.) and components encapsulated in robust devices (laptop, batteries, Fiveco, Galil or Indel controllers, Axis camera, Mesa-imaging 3D ranger, etc.). There remain some elements however which may be functionally satisfactory in the context of RAH competitions, yet which would require some more effort in terms of proper packaging and certification (e.g. non-protected circuits, cables, bumpers and hand); this is however typical of production and market relating problems - industrialization.

Finally the most debatable point is whether any final user might benefit from using RH5-Y. Here we meet the essential goal of our RAH league; in as much as we collectively succeed in defining socially relevant tasks, and RH5-Y passes the tests, we must conclude that RH5-Y is successful in the quality of being applicable into the real world. The answer cannot be just Boolean, but should be assessed in a finer way. In 2007 in Atlanta, RH2-Y ranked second after technical tests, and 4th in final ranking; in 2008 in Suzhou RH3-Y won its “FastFollow”, one-to-one competition; in 2009 RH4-Y was in the top half of the league.

4 Conclusion

RH5-Y is one of the most recent occurrences of our ARY line of robots, and specifically the fifth version of an autonomous robot, designed for home applications, in Robocup-at-Home context. The family is characterized by numerous original elements, in terms of hardware, software, and cognitic nature. Innovative technologies include systemic aspects, our proprietary programming and control environment (“Piaget”) as well as some physical components. Research focus is on automated cognition, i.e. cognitics, in home robotics and in manufacturing applications. A particular area of interest, for our group, consists in the quantitative assessment of cognitive entities. Reusability is ensured by classical means, such as publications or licensing, but also by the strategic use of COTS components. A version of our Piaget environment environment is available to other RAH teams since several years. This version allows for full, real-time real-world operation, or just simulation, as chosen by users; in both cases however, standard COTS drivers must be installed by final users on their computers. RH5-Y can be applied in the real world in many ways: interaction with the physical world; in a robust and fully autonomous way; with a goal of solving well defined, socially relevant tasks, at home. Most of it (camera, Piaget environment, vocal dialogue, etc.) can also be replicated on OP3-Y platform, along with a Neuronics-Katana arm; the latter is particularly interesting in terms of compactness, light weight, and especially intrinsic security, i. e. its official certification for safe use in cooperation with humans.

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