RH4-Y – Toward a Cooperating Robot for Home Applications

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Abstract. RH4-Y is the fourth version of an autonomous robot designed for home applications, in Robocup-at-Home context. The 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). RH4-Y can be applied in 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, RH4-Y is accompanied by OP1-Y, a similar concept mounted on a 4-wheel, omnidirectional platform, with Katana arm.

1 Introduction

RH4-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 2009 in Graz, Austria [1, 2]. RH4-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 RH4-Y. Section 3 gives additional information in terms of innovation, research focus, resource sharing and applicability.

2 Brief overview of RH4-Y

RH4-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 RH4-Y are numerous, including, to a very good degree for an embedded system: visual and 3D ranged recognition, vocal dialogue, 2D-distance perception, non verbal communication by gesture, 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 additionally the possibility to parameterize motion laws and to ensure good synchronicity. In another respect, we are using "subversion" technology for collaborative development.

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 RH4-Y, with omnidirectional platform OP1-Y (left), and a view in Suzhou of Robocup competition 2008: FastFollow challenge, with RH3-Y following its guide, crossing another team, and successfully finishing first (right)

Innovative components can also be found in physical domain. First let us propose an analogy: trains might have other wheels. Instead of the old technology whereby wheels feature a special shape (large lateral disks) in order to be kept within rails, one could consider orientable (direction-adjustable) "flat" wheels and to control the latter by digital processors along with appropriate sensors. But in fact centering feedback control can classically be performed in the physical domain: current wheels can be seen as performing parallel, closed-loop proportional control with the elastic property of metal yielding a lateral acceleration force which is proportional to instantaneous trajectory error. In a similar way, our end-effector is much more sophisticated than a fast glance might tell. In addition to 1. encoder and limit sensors directly connected to an active device, with current, voltage, acceleration, speed, and position control capabilities, the “hand” includes 2. a Swedish wheel which ensures a secure minimal distance to ground, 3. a support plate, for relatively high payload, 4. three fingers in a classic centering capability, 5. augmented by a passive fourth one, in order to allow for grasping of small objects and 6. finger joints adjustable by hardware in opening range and force/torque capabilities.

For what concerns the arm, our concept is to consider it as inheriting platform dof’s. Thus in addition to the capability of the platform to be posed according to 3 coordinates in the plane, the arm includes now a motorized shoulder joint, for hand motion in a fourth, vertical coordinate. (An omnidirectional platform featuring 4 mechanum wheels has been designed; this yields a different tradeoff between economical cost and robot capabilities).

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 as 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.

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 [11, 12].

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 RH4-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

RH4-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, RH4-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, Bauemer 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 RH4-Y. Here we meet the essential goal of our RAH league; in as much as we collectively succeed in defining socially relevant tasks, and RH4-Y passes the tests, we must conclude that RH4-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 4^{th} in final ranking; in 2008 in Suzhou RH3-Y won its “FastFollow”, one-to-one competition.

4 Conclusion

RH4-Y is one of the most recent occurrences of our ARY line of robots, and specifically the third 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 many months. 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. RH4-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 OP1-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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References

1 Tijn van der Zant and Thomas Wisspeintner, « RoboCup X: A proposal for a new league where RoboCup goes real world » In: Itsuki Noda et al.(Eds.) RoboCup-2005: Robot Soccer World Cup IX, Lecture Notes in Artificial Intelligence, Springer, 7pp (2006)

2 Website of Robocup 2009 in Graz: http://www.robocup2009.org/

3 Jean-Daniel Dessimoz, 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)

4 Jean-Daniel Dessimoz. et al.: Ontology for Cognitics, Closed-Loop Agility Constraint, and Case Study – a Mobile Robot with Industrial-Grade Components , *Proc. 5nd IEEE Intern. Conf. on Industrial Informatics INDIN'06*, Singapore, August (2006)

5 Jean-Daniel Dessimoz,: Contributions to Standards and Common Platforms in Robotics; Prerequisites for Quantitative Cognitics, International Conference on Simulation, Modeling, and Programming for Autonomous Robots (SIMPAR) 2008. First International Workshop on Standards and Common Platform for Robotics, Venice, Italy, 3-7 Oct. (2008)

6 Jean-Daniel Dessimoz, "Measuring Knowledge and Other Cognitive Properties ; Consequences in Terms of Ethics", World Knowledge Dialogue Symposium 2008, 10-13 September 2008, Crans-Montana, Switzerland

7 Jean-Daniel Dessimoz : La Cognitique - Définitions et métrique pour les sciences cognitives et la cognition automatisée, ISBN 978-2-9700629-0-5, Roboptics (eds.), Cheseaux-Noréaz, Switzerland, and www.lulu.com, Aug. (2008)

8 Jean-Daniel Dessimoz: Cognitique: la cognition automatisée; yc modération de deux tables rondes concernant les aspects scientifiques, économiques et industriels, ainsi que les applications en robotique des services, Forum RobotX organisé par Robot-CH, Y-Parc, Rosam-Diff, et al., Parc scientifique et technologique, Yverdon-les-Bains, 18 juin (2008).

9 Jean-Daniel Dessimoz: Ten Years of Experience with Eurobot ; Achievements, Lessons Learned and General Comments, Proc. Eurobot Conference 2008, Heidelberg, Germany, 22-24 May 2008, ISBN: 978-80-7378-042-5 (2008)

10 Jean-Daniel Dessimoz and Pierre-François Gauthey: Quantitative Cognitics and Agility Requirements in the Design of Cooperating Autonomous Robots, Proc. Eurobot Conference 2008, Heidelberg, Germany,22-24 May 2008, ISBN: 978-80-7378-042-5 (2008)

11 Website of the Swiss component of the European research platform for advanced manufacturing: www.manufuture.ch.

12 More info. on ARY and RH-Y robots: http://ary1.populus.ch, and http://rahe.populus.ch

Appendix – Team members

This year, our group has been qualified again for Robocup at Home, and it has also been invited to compete in the new Festo Robotic Hockey Challenge. Synergies have developed, with 4 members being especially active in both teams (the use of Robotinos is also envisioned by some of us for some ancillary functions in the context of ageing society).

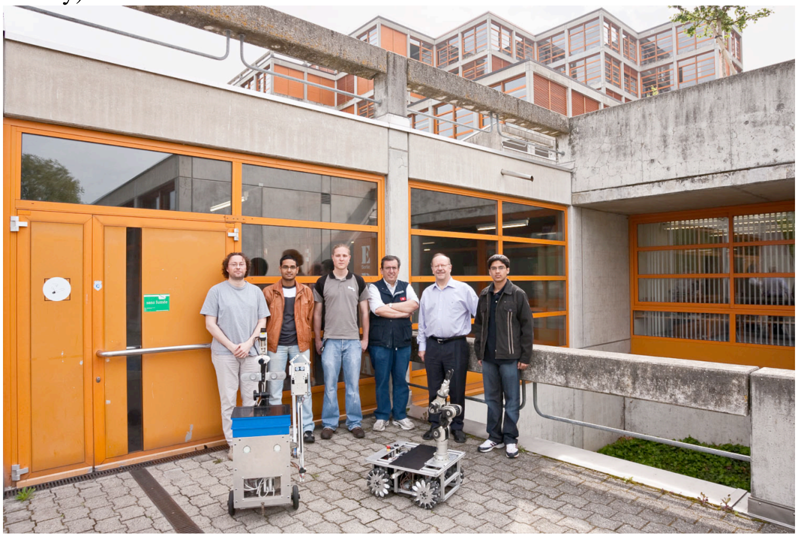

Fig.2 From left to right, the main members of our RAH-team include Pierre-François Gauthey, Ankur Edkie, Max Manier, Enrico Staderini, Jean-Daniel Dessimoz, and Palkush Rai Chawla; in front: RH4-Y and OP1-Y.

Fig.3 In addition to core RAH-team above, Graziano Varrotto (fourth from left) and Romain Bersier (second from right), two core-members of the Festo team, will also provide a valuable support for RAH. Additional robot: Festo Robotino (re. Hockey Challenge).