R3-COP
Resilient Reasoning Robotic Co-operating Systems
Extended Abstract

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Abstract. The ARTEMIS-project R3-COP aims at providing European industry with methodologies and technologies to enable production of advanced robust and safe cognitive, reasoning autonomous and co-operative robotic systems at reduced cost. Three major topics are addressed: advanced robotic capabilities, methodologies for design and development of robotic systems, and new V&V technologies for robotic features for which existing technologies are insufficient. This extended abstract gives an overview of R3-COP, with some focus on the new V&V techniques.

Keywords: R3-COP, robots, autonomous systems, V&V techniques for robotic systems.

1 Introduction

The robotic and autonomous systems sector is currently one of the most growing industrial domains, based on recent breakthroughs in mechanical, electronic, sensorial, and computational (recognition, reasoning etc.) disciplines. For the most evolved sector, industrial automation, the International Federation of Robotics (IFR) 2008 study Industrial Robot Statistics[1] valued the world market for industrial robot systems at EUR 19Bn (including software, peripherals, services), with an annual growth of approximately 10%. This development was accompanied by fragmentation of both the units and tools market, as it is typical for rapidly growing technologies. In addition, existing verification and validation methods rendered inappropriate for new robotic capabilities such as advanced visual perception, behavior control, or cooperation.

In order to alleviate this situation, in 2011 the ARTEMIS-project R3-COP started with the following main objectives:

- Establishment of a common design and development methodology,
- Development of new V&V methods,
- Development of new robotic features,
- Application of results in several uses cases (industrial demonstrators).

[1] http://www.ifr.org/industrial-robots/statistics/

In the following, a short overview about these topics and results is given. It should be noted that further contributions to this workshop will address selected topics.

2 Design and Development Methodology

In (traditional) Robotics- and Control Engineering, some broader approaches to system-level design and integration exist but they are mostly concerned with designing kinematic configurations of modular robots to suit given application contexts. Other approaches are more focused on the mechatronical parts of systems. Though all these approaches consider to some extent both the tasks and the environment, they mainly address the design and physical assembly of the robots. No guidelines are proposed for integrating these systems into a real-world system context and such a process will therefore most likely rely on ad-hoc methods.

During the course of the project, several existing methods such as PAPRIKA (Potentially All Pairwise RanKings of all possible Alternatives) were investigated and experimentally applied in some use cases. Based in these experiences, a methodology is under development, which will help to answer questions like “which software architecture to choose?” and “which sensor configuration is the optimal choice?”, but also “which design concept and which V&V methods are the best?”

3 New V&V Methods

If systems shall be commercially used in safety-critical environments, it has to be assured that they are sufficiently safe. This also applies to autonomous systems. However, for capabilities such as visual perception, adaptive behaviour, or cooperation, existing V&V technologies are inappropriate, in particular for assessing reliability and robustness, due to the vast input space and openness of the respective application space.

While the absence of implementation faults such as access violation or division-by-zero, can be achieved with conventional V&V (validation and verification) methods for visual perception software, the question “how robust is a solution, i.e. how well does it cope with the huge number of challenges present in the input data, e.g. shadows, reflections, or occlusions?” remains open.

A similar open question is related to the robustness and safety of the adaptive behaviour in extreme or complex environments. To verify this, methods should be developed for the systematic generation of challenging test contexts (to be used in simulator-based or real test environments), and for the evaluation of safety and robustness criteria on the collected test traces.

In case of testing cooperating autonomous systems, providing measurable criteria for interaction coverage and instruments supporting the automatic achievement of these criteria are needed.

R3-COP addressed these issues in a number of activities. Their results will be addressed in further contributions to this workshop.

4 New Robotic Features

A special focus of R3-COP was development of new features or their advancement, respectively, in the areas

- Robust perception,
- Reasoning and mission planning,
- Communication and positioning.

Robust perception is dealing interpretation of visual sensory data, either from mono or from stereo cameras. R3-COP settled on recent advances in this domain such as SIFT (scale-invariant feature transform) and Adaboost for object classification, and probabilistic pose representation for improving the scene recognition robustness.

Reasoning and mission planning are core capabilities for intelligent robotic systems. In R3-COP, general strategies were developed for situation-dependent selection of appropriate algorithms. In a first step realized as an interactive procedure for supporting developers in the decision process, it is envisaged to integrate them into robotic software for automatic algorithm selection, e.g. in the framework of RoboEarth[2].

Communication and positioning, finally, deals with adapting wireless technologies for inter-robot communication and (self-)localisation, both outdoors and indoors. While for ground- and airborne robots, electromagnetic waves can be used, for underwater communication ultra-short baseline sensors or laser vision systems are used.

5 Use Cases (Demonstrators)

The R3-COP use cases not only serve for demonstrating the results outlined before in industrial environments, but also contribute actively to development of new features. Following use cases are realized:

- *Industrial robots*: classification and manipulation of wooden parts.
- *Service robots*: tidy-up a kitchen table (i.e. classification of food boxes and bottles on a table, and putting them to type-specific locations); following a patient through the hospital, while carrying the connected infusion; material transport platform for building construction sites.
- *Transport robots*: cooperating forklifts in a storehouse.
- *Unmanned Aerial Vehicles* (UAV): cooperating with UGV (unmanned ground vehicle): UAV uses UGV for recharging – UGV has to locate UAV and bring itself close to UAV.
- *Unmanned Unterwater Vehicles (UUV)*: inspection of ship hull with several UUVs (which cooperate for task optimization).

At end of 2013, the results of R3-COP will be demonstrated with these use cases in the course of the final project review.

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[2] http://www.roboearth.org/