Factory-in-a-day

Newsletter #5

Dear friends of Factory-in-a-day,

At the beginning of December 2016 we had our second review meeting in Brussels, reporting to the European Commission on the progress of our project Factory-in-a-day. So far, the developments made in our project are very satisfying and our Project Officer is happy with the progress we made.

In past 18 months, we managed to merge some of our technologies in a very successful demonstration during the Amazon Picking Challenge. This is a robotic competition, in which items had to be picked up and stowed in a shelf, like in a warehouse. We won this prestigious competition with a double victory. Thereby, Team Delft used a lot of technologies, developed by Factory-in-a-day.

We will now use these results in another demonstration – even more complex - which we will be shown at the next RoboBusiness 2017: a box filling case.

We are looking forward to seeing you then, in the meantime we hope that you had a good start into the new year,

Prof. Martijn Wisse, Coordinator

Spotlight on: KU Leuven

Dr. Erwin Aertbeliën, from the department of Mechanical Engineering at KU Leuven, is leading work package 5 of the Factory-in-a-day project. This work package deals with learnable skills. The idea of learnable skills is to deploy new robot applications quickly by combining reusable model-based task specifications with easy and fast ways to teach robots.

After establishing a learnable skill model in the first part of the project, the work package has now managed to complete milestone 3: "A first fully integrated demo of a learnable skill". More specifically, this skill picks, checks the quality, sorts, and packs oranges. This skill is taught intuitively by human instructors. In 2016, the work package focused on providing a framework that integrates six novel technologies:

1) safe robot arms with multi-modal and auto-calibrated sensing skin,

2) a robot control framework to generate dynamic behaviours fusing multiple sensor signals, and

3) an intuitive and fast programming-by-demonstration (PbD) method that segments and recognizes the robot activities on-line, based on reusable semantic descriptions. The Technical University of Munich (TUM) developed a

Dr. Erwin Aertbeliën, KU Leuven

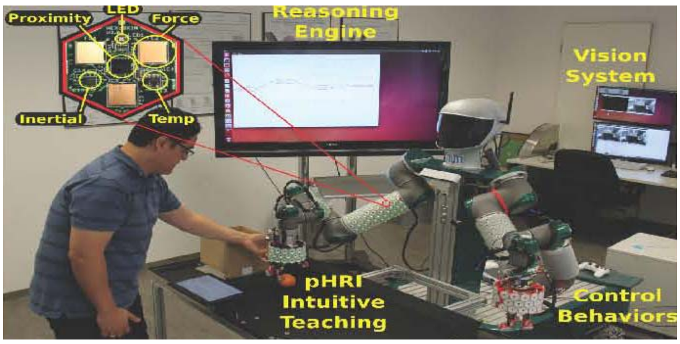
semantic-based reasoning approach that is used to integrate different input sensors, such as the joint encoders of a robot, skin sensors (tactile and proximity) and visual information from the cameras embedded in the robot (first view perspective).

4) Known (reactive) aspects of the robot task at hand are described in a model-based way using the eTaSL task specification language (https://people.mech.kuleuven.be/~eaertbel/etasl). etaSL is a language for reactive control tasks including sensor-interactions such as force sensing and vision. The goal is to use these specifications in both the demonstration phase and the execution phase. etaSL provides a strong separation between specification and execution, and it lets the application developer focus on the task specification instead of technical aspects such as Jacobians, control constants, etc. The language introduces concepts such as the automatic management of different types of variables, constraints, and monitors. The combination of these concepts makes eTaSL a very modular and composable language. Libraries are available for collision between convex objects, splines, different types of motion profiles, distances and angles, and integration with URDF-files.

5) Out of demonstrations, a model for the motions and their variations is extracted (using a methodology originally developed for predicting human gait patterns). eTaSL is then used to specify motion constraints that follow the demonstrations while still allowing the same variations as observed during demonstration. These motion models partially bridge the gap between instantaneous reactive control and motion planning.

6) The higher-level programming-by-demonstration and segmentation method (point 3) results in demonstration segments that are used as an input for the learnable skill models. These models are used inside an eTaSL specification and combined with application knowledge. In this way motions can be executed that not only are similar to the demonstrations and but also satisfy other constraints such as moving towards a position determined by the vision sensors, or avoiding collision with known objects in the environment.

As such, these technologies allow for a natural way to combine reusable model-based knowledge and physical demonstrations to quickly deploy new activities for industrial robots. This is achieved on both the lower-level (motion segments) and the higher-level (using reusable semantic information). As a demonstration scenario (see picture below), we considered the task of sorting fruits. Within this scenario we exploit the benefits of using the tactile and proximity sensors of the robotic skin to sense the quality of the products (oranges).



Robot TOMM sorting oranges – see also our YuoTube channel: https://www.youtube.com/channel/UCr-FPaBG3MJ5t_oyUSmt-ow (Movies D5.3a and D5.3b)

The human teaches the robot TOMM intermediate activities required to sort and pack oranges into boxes: by squeezing the oranges, the robot needs to determine whether the oranges are good or whether they are bad and have to be thrown in a trash container. This demonstration is done without any manual annotation. The robot uses its frontal cameras and the multi-modal artificial skin to infer the demonstrated activities. This complex task requires the integration of different sensors and a proper mapping method to infer the taught activities. After demonstration and segmentation, the demonstrated segments are used to extract a motion model and to specify an eTaSL learnable skill. This scenario was inspired by a real process of orange sorting where the humans use their tactile sensation to discriminate the good oranges from the bad oranges.

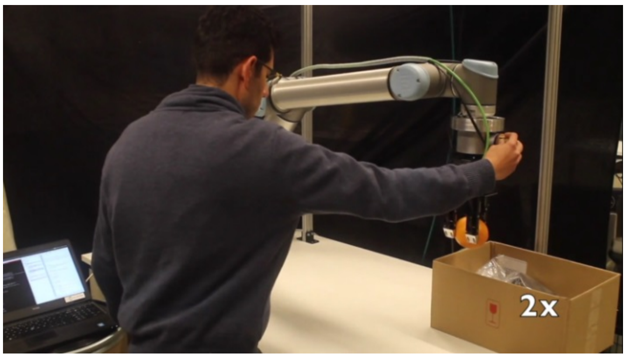
In another demonstration (for deliverable 5.4 see picture on the right), the demonstration of motion segments is further improved by increasing the interactivity of the demonstration process. By using a combination of motion models (extracted from demonstrations), geometric constraints, camera constraints and force admittance constraints, the operator is assisted while demonstrating. If available, this assistance uses also information of previous demonstrations. In this way, an incremental teaching process is started and the lines are blurred between the teaching/demonstration phase and the execution. By using a force-torque sensor as input for the kinesthetic teaching, this demonstration also shows our ability to deal with other input modalities besides the skin. These demonstrations (and other) can be seen on the Factory-in-a-day YouTube Channel. With these demonstrations, we showed that our presented framework enables a standard industrial robotic system to be flexible, modular and adaptable to different production requirements.

<u>Publications:</u>

- E. Dean, K. Ramirez-Amaro, F. Bergner, I. Dianov, P. Lanillos, and G. Cheng: Robotic technologies for fast deployment of industrial robot systems. IEEE Industrial Electronics Conference (IEEE IECON2016), 2016.

- Erwin Aertbelien and Joris De Schutter, eTaSL/eTC: A constraint-based Task Specification Language and Robot Controller using Expression Graphs, IEEE/RSJ International Conference on Intelligent Robots and Systems, 2014.

- Aertbeliën, Erwin, and Joris De Schutter. "Learning a predictive model of human gait for the control of a lower-limb exoskeleton." 5th IEEE RAS/EMBS International Conference on Biomedical Robotics and Biomechatronics. 2014.

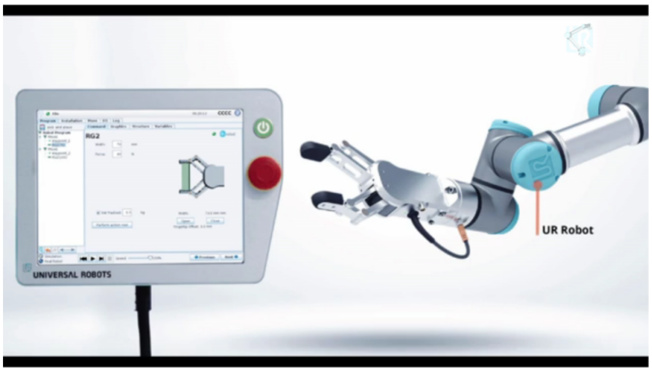


Incremental programming-by-demonstration using eTaSL, see https://www.youtube.com/watch?v=NhBbLwEzQ9I

Universal Robots' UR Caps

In Deliverable 5.4, partner Universal Robots has delivered URCaps, an open system in which any vendor can add components for easy and quick integration. We are proud to say that the research prototype URCaps has even already resulted in a commercial roll-out as the "Universal Robots+" developer program.
There are also videos on our website: http://www.factory-in-a-day.eu/media/videos/

The URCaps (UR Capabilities) are hardware and/or software extensions for the [Universal Robot](#) system. The purpose of the URCaps is to seamlessly extend any Universal Robot with customized functionality. Using the URCap software platform, third parties can define graphical user interfaces that seamlessly integrate with the UR workflow and provide device drivers for their hardware.
The research done in Factory-in-a-day project has contributed to the following features in the URCaps software platform:
Workflow integration – Third party developers can provide custom installation extensions and custom program nodes. The installation stores information and provides an interface for a specific hardware setup, i.e. settings that are valid for any program made with this hardware configuration. Custom program nodes can be used to hide complicated behaviour and provide a convenient graphical user interface for the end-customer.
Device drivers – Many hardware extensions require device drivers for the robot program to communicate with the hardware extension or an extension might require a daemon process to run on the robot. The URCaps software platform provides a generic way to install and run a daemon process.
Real-Time Data Exchange (RTDE) – Reliably exchange data between UR robot controller and third party process to implement hierarchical control loops or monitoring software. Request specific robot state data (incl. registers) to be output at a specified rate. Input custom data (e.g. setpoints) through registers and use it in your program. Streaming setup is on a per connection basis and watchdogs are available to guard the input connection status.



Screen shot from one of the videos explaining UR Caps.

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Factory in a Day

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Short news and events

- At the European Robotics Forum 2017, we will participate in the Workshop on Hybrid Production Systems on March .22-24, 2017. More details at: www.erf2017.eu/

- Visit us at the **RoboBusiness 2017!** We are exhibiting our results in a demonstrator. April 19-21, 2017 in The Hague in the Netherlands.
  More at: http://robobusinesseurope.com/

Questionnaire for SMEs:

We are trying to develop a suitable business plan for our project, therefore, we would like to ask fo your help! If you are working or owning a SME company we would be happy if you would fill in our questionnare, which is online available at:
http://ww3.unipark.de/uc/robotics

Factory in a day project meeting

At the end of October, Factory-in-a-day had its second project meeting in this year in Barcelona, at our partner PAL Robotics. The focus of this meeting was to set the plan for the final year of the project. Even though we progressed towards the project's goal of reducing the time for integrating robotic solutions in an assembly chain in a short period of time, there was still a lot to discuss and talk about.

The Factory-in-a-day team at the meeting in October.
The Factory-in-a-day team at the meeting in October.

New videos

We put a number of videos from our recent deliverables online see on our YouTube channel.
There are also a number of new publications from different conferences available on our website.

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Follow us!

www.factory-in-a-day.eu

SEVENTH FRAMEWORK PROGRAMME