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Producing IDEAS

Offering an insight into their project which is developing multi-agent systems for industrial purposes, **Professor Mauro Onori** and **Andreas Hofmann** describe how they are delivering an adaptable, effective and affordable alternative to conventional factory assembly systems



Firstly, what is the background to the Instantly Deployable Evolvable Assembly Systems (IDEAS) project?

MO: IDEAS emerged from a previous project – Evolvable Ultra-Precision Assembly Systems (EUPASS) – and was formed as a result of the precise objectives derived from the Assembly-Net roadmap. The project addresses the necessity for self-adaptive and flexible production systems for assembly automation in order to better manage either programmed process changes or unforeseen events. Basically, these assembly systems are characterised by modular and distributed systems-based architectures.

Do you hope to address specific needs through your work?

AH: Production requires systems that can be deployed quicker, with less programming and with the option to reuse equipment that is already in place. In the past, the focus was on developing hardware that was adaptable. As a result of this, software and architecture were a bit neglected. IDEAS is seeking solutions that are based on the agent concept: modules, substations, stations or any part of an assembly line can be autonomously run by a piece of software that enables the controller to negotiate processes and the sequence of steps in a production line. This allows the user to design systems that can adapt or be adapted rapidly to new production requirements, avoiding long ramp-up times. It also allows the option of reusing existing hardware or quickly inserting new technology.

IDEAS introduces a fundamentally novel way of conceiving mechatronic systems, with great emphasis on creating a 'plug and produce' modular environment. It is the first step towards dramatically improving the management of resources on a production floor, since it opens the door to offer mechatronic agents as services that can be consumed to tackle a volatile and specific business opportunity.

Could you elaborate on how EUPASS has influenced and benefited IDEAS?

MO: EUPASS was a large project involving over 20 partners from both industry and academia. Although too large to achieve consensus on the final objectives, it did point out who the most dedicated actors were, as well as providing results that could be improved upon. It took the first step on the road to modular and distributed systems. Based on its results, it was possible to conceive a project that focused more on industrial applications. EUPASS laid the foundations for selfcontained mechatronic entities as basic building blocks for assembly systems, having a significant impact in generating the main terminology and forming the basis for modelling agent-based systems. It also provided the groundwork for experimenting and understanding how agents should be applied when considering mechatronic systems with a fine granularity level.

IDEAS was highlighted by the EC as a 'Success Story'. Why do you think the programme was chosen and what has this award meant?

AH: The project was chosen because it has demonstrated real shop-floor pluggability for the very first time. The project deals with concrete industrial needs and represents a technology breakthrough towards the 'factory of the future'. It has also demonstrated otherwise elusive concepts and technologies and has done so through the work of a credible and wellbalanced consortium with key experts in core areas. The award recognised the effort of daring to succeed in a new approach to tackle pressing industrial challenges.

To what extent will the project help to improve the competitiveness of European SMEs?

MO: If and when the technology is standardised, IDEAS could provide an immense competitive advantage over other countries: low-cost automation becomes viable; product design and production become intertwined; production volumes can be raised/lowered stepwise, etc. IDEAS traces an important line on the road to distributed systems. SMEs as system integrators could experience great return from IDEAS results, especially from the possibility of building the assembly systems of the future in a modular way and with zero-reprogramming efforts.

The advantages for SMEs are obvious. It enables them to build new assembly equipment with less effort and investment than in the past. Another advantage is the scalability of the solution. It is easy to develop a system from manual to semiautomatic and then to fully automatic without having to redesign the whole line again and again. Most SMEs cannot afford a full-featured production system to tackle a temporary business opportunity. The fact that IDEAS processorientated modules can be reused means that clustered SMEs can rent and share modules, dramatically reducing installation and operational costs. It also opens up new business opportunities for system integrators who do not develop systems from scratch, but rather follow a more mechatronic LEGO[™]-orientated approach.

What would you highlight as the most significant achievement of IDEAS thus far?

AH: This project has proven for the first time that devices at shop-floor level can be used as plug and produce modules, without any pre-programming or human intervention. It is a very industrial production line managed with agents. One of the major successes has been to confirm that a mechatronic agent can indeed be realised and is not just a research dream. I am particularly proud



IDEAS



IDEAS INDUSTRIAL DEMONSTRATOR PLATFORM BASED ON IDEAS MECHATRONIC AGENTS AT MASMEC SPA (ITALY)

of the simple architecture that resulted from this work. IDEAS has been very successful in demonstrating concepts that, for a considerable amount of time, have previously only been talked about in academic and industrial forums.

The project benefits from a wide range of partners. How have the partners helped the investigation to evolve?

AH: Partners were selected from the core teams of previous projects. We all knew each other before and we all had specific knowledge to bring into the project. A European collaborative project such as IDEAS puts together different competences from different research areas. In the case of a large company such as ELECTROLUX, for example, the collaboration with academia and other companies not belonging to its supply-chain is essential to investigate those topics not completely aligned with its daily research activities, especially when they involve the factory environment.

Collaborating with a variety of partners allows a well-rounded knowledge base to develop, encouraging the coming together of a range of technical backgrounds in order to develop a rigorous system that covers many areas that would otherwise be forgotten were the correct expertise not involved. Each partner brings their own experiences and abilities to the table to help move the project forward and develop areas in different ways. IDEAS would never have succeeded without such a carefully balanced consortium. Each partner has unique knowledge of a core dimension of the project, but with just the right degree of overlap to make things work as a whole without major complications.

There are a number of related FP7funded manufacturing programmes. Is there a mechanism by which they will be synergised to improve manufacturing in Europe?

MO: What is missing is a form by which successful projects may be granted a two- to five-year extension. Three or four years only allow one to create a basis from which further work can be finalised, so the end of projects terminates the work far too prematurely when successful. IDEAS

Tackling industrial challenges

Highlighted by the EC as a 'Success Story', the IDEAS programme is working at the cutting edge of industrial production by developing evolvable assembly systems



THE MANUFACTURING WORLD is increasingly competitive, so being able to retain automation and production within Europe's borders means that European industry can be far more cost-effective and innovative. Evermore outsourcing of equipment and production workers – the assembly production system – to non-EU countries is having a major impact on the wide range of sectors that require automated assembly production.

The Instantly Deployable Evolvable Assembly Systems (IDEAS) project, funded by the EU Seventh Framework Programme (FP7), is addressing this challenge. Led by Professor Mauro Onori from the Royal Institute of Technology (KTH; see p18) in Stockholm, Sweden, IDEAS is a collaboration between academia and industry working towards the development of a flexible approach to automated production in order to retain assembly in-house, particularly for Europe's new products and markets.

GOOD IDEAS

The basic premise of IDEAS is that it provides a new paradigm for creating production systems focused on highly automated modules that can be mixed and matched as needed. Many of today's assembly systems are built for a known product and then dismantled or destroyed after the product goes off the market, which results in major costs, waste and therefore outsourcing of production.

However, evolvable assembly systems (EASs) may buck this trend because they save on ramp-up and installation times, reusing or adapting existing equipment, utilising multivendor suppliers and reducing the time it takes for a new product to get to market: "In other words, the EAS challenges the traditional way of conceiving systems by introducing the notions of self-organisation and emergence as a means to support evolution," Onori elucidates.

CREATING REUSEABLE MACHINES

Outsourcing of production is not a short-term decision for many companies; it is a midto long-term strategy that involves a wide consideration of issues. One of the main reasons for making such a decision can be considerable cost reductions. From a political perspective, manufacturing is one of Europe's main income generators and so there is much interest in slowing down the outflow of work from the EU's borders. "Outsourcing often means loss of know-how and intellectual property," notes Onori. "Any temporary cost reduction can come at a greater price with respect to quality of the manufactured goods and potentially introduces a global sustainability problem." In response to this, IDEAS has demonstrated how new technologies are able to create reusable equipment, meaning that companies both large and small can automate their production lines in a cost-effective way. The assembly systems they have designed are self-adaptive and flexible, meaning that there are cost benefits resulting from reductions in try-out and ramp-up times; zero downtime, meaning no production loss; and the solutions are affordable and reliable.

The systems consist of simple, dedicated machine modules with embedded controllers. The modules communicate with one another to establish what functionality is required each time a new module is added, activating a preprogrammed code accordingly. A key advantage in this regard is that companies will not have to train personnel to program and run the automation equipment, saving time and costs.

SKILLED SOFTWARE

One of the most important elements of IDEAS is the software tools it provides, which target the different stages of a given system. The MASCOT tool designs the physical system and equipment module specification, essentially providing a module's capability. This information is crucial for the creation of the mechatronic agents which are able to control the equipment modules, and in turn the whole system. The Agent Configuration tool is responsible for processing this information, deploying Agents which are able to execute defined skills. The Process Configuration tool provides the means to specify the manufacturing workflow which enables the system to produce products. The Product Agent tool contains a sequence of required skills for the system to execute and also checks what skills are already present in the system. Finally, the System Visualization tool monitors the operation of the system, the multiple products or equipment modules. This information can be used to verify the existence of bottlenecks, so that the system can be reconfigured accordingly.

IDEAS provides a new paradigm for creating production systems focused on highly automated modules that can be mixed and matched

DEMONSTRATORS

IDEAS has been able to successfully demonstrate EAS in a real-world context. The FESTO medical testing/production system pre-demonstrator implements a multi-agent system in an existing and enclosed production environment. If the system requires DNA testing, for instance, a module for that task is added. If any other testing is suddenly demanded, only the needed modules are replaced. "This was a big help in developing the overall system architecture, and as a result we showed that production system modules can be added or removed during ongoing production, without any human or computer interference," emphasises Andreas Hofmann, from Karlsruhe Institute of Technology and the person responsible for project dissemination. In fact, this was the first time at pre-industrial level that production modules with on-board control had been demonstrated, revealing a system that is both self-configurable and self-organising.

Not only remarkable for its innovative technical aspects, the FESTO pre-demonstrator also showcased the multidisciplinarity needed to complete such an ambitious proof of concept. The controller for multi-agent applications was created by Elrest; software was developed by UNINOVA and program languages by KTH and UNINOVA; the modules were made by MASMEC and FESTO and KIT; TEKS designed the simulation tools; and methodologies were planned by UNOTT.



MINIATURISED IDEAS MECHATRONIC AGENT CONTROLLER FOR DIRECT MODULE INTEGRATION

IDEAS researchers have since developed two new assembly systems; one for automotive products at MASMEC in Italy and the other for white goods at KTH in Sweden. These demonstrators clearly show how to construct EASs from the beginning, identify the engineering process needed to build the required system and how new technology should be developed to cope with limitations.

EMBEDDING THE TECHNOLOGY

A project of this scale, complexity and breadth presents a number of challenges. Hofmann elucidates that there are a number of technical and organisational problems they have had to face: "Balancing the use of off-the-shelf technology and specific IDEAS developments has probably been one of the most difficult aspects in this short project".

With IDEAS due to end in 2013, this will be a busy year for the group. They still have to build the two final assembly systems, but are very close to completing final tests. The project results also need to be arranged into a usable status and evaluated. Validation will be performed by comparing the same layout with traditional and agent-based control, with no external reference for comparison. At the same time, life-cycle analysis has to be finalised.

The team is hopeful that they will be able to continue once the programme has finished, particularly as they want to pursue the standardisation of results and embedding hardware and software components. However, there is a significant threat to the future of this work: "All proposals to date (in FP7) have failed to receive funding and we now risk losing momentum," Onori warns. "Our concern is that the results could actually be picked up by non-European groups and exploited." They expect, however, that given the multidisciplinary context of IDEAS and a number of identified challenges for the next batch of developments, they will be successful in their next application for funding, and will be able to continue with this important work for Europe's manufacturing industry.



INTELLIGENCE

IDEAS

OBJECTIVES

Developing and enabling intelligent selfconfiguring models with advanced interfaces that enable social and emergent exchanges; self-organising coalitions; evolvable systems that self-diagnose and adapt to emergent behaviour; modules developed on the basis of precise assembly process constraints; and highly distributed, dynamic control systems at both shop floor and system levels.

KEY PARTNERS

The Royal Institute of Technology (KTH) • FESTO AG & Co KG • UNINOVA – Instituto de Desenvolvimento de Novas Tecnologias • Electrolux Italia Spa • University of Nottingham (UNOTT) • MASMEC SpA • Elrest Automationssysteme Gmbh • TEKS SARL • Karlsruhe Institute of Technology (KIT) • Centro Ricerche Fiat ScpA (CRF)

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PROFESSOR MAURO ONORI obtained his

PhD in 1996, and became Full Professor in 2010. He is the Director of Scientific Studies at the department and has published over 120 articles in both conference proceedings and international journals. Onori has been a conference track organiser, guest lecturer at the École Polytechnique Fédérale de Lausanne and Universidade Nova de Lisboa, and acted as a consultant to companies and funding organisations. He is an editorial board member and reviewer of the Assembly Automation Journal. Onori also coordinated the EUPASS FP6 Integrated Project, which was the precursor to IDEAS.

ANDREAS HOFMANN has been working in the field of automated production for more than 15 years. His main research interests lie in the field of comprehensive (assembly-)process and system design for microsystems and the implementation in modular and adaptable system solutions. In numerous national and international funded projects and bilateral cooperations with industry, he has developed and realised several assembly process solutions and related machine concepts.

