Expert cooperative robots for highly skilled operations for the factory of the future

Grant Agreement No	**:**	**314355**
Project Acronym	**:**	**X-act**
Project Start Date	**:**	**1st October, 2012**
Consortium	**:**	**UNIVERSITY OF PATRAS (LMS) - Project Coordinator**
		COMAU SPA (COMAU)
		SIEMENS INDUSTRY SOFTWARE SAS (SIEMENS-PLM)
		FUNDACION TEKNIKER (TEKNIKER)
		FRAUNHOFER-GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG E.V (F-IPK)
		TOFAS TURK OTOMOBIL FABRIKASI ANONIM SIRKETI (TOFAS)
		ALFA HOGAR S.L. (ALFA)
		PILZ INDUSTRIEELEKTRONIK SL (PILZ)
		SIEMENS INDUSTRY SOFTWARE LTD (SIEMENS-IND)

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Circulation	**:**	**Consortium**

Summary:

This document is the final version of the report D6.1-Dissemination report (M36).

Table of Contents

1. EXECUTIVE SUMMARY

The purpose of this document is to present all the activities of the X-act consortium towards the dissemination of the X-act project result in European and international level. The following activities are included:

- X-act Project brochures
- X-act Project newsletters
- X-act Project posters
- X-act Project participation in public events
- Publications

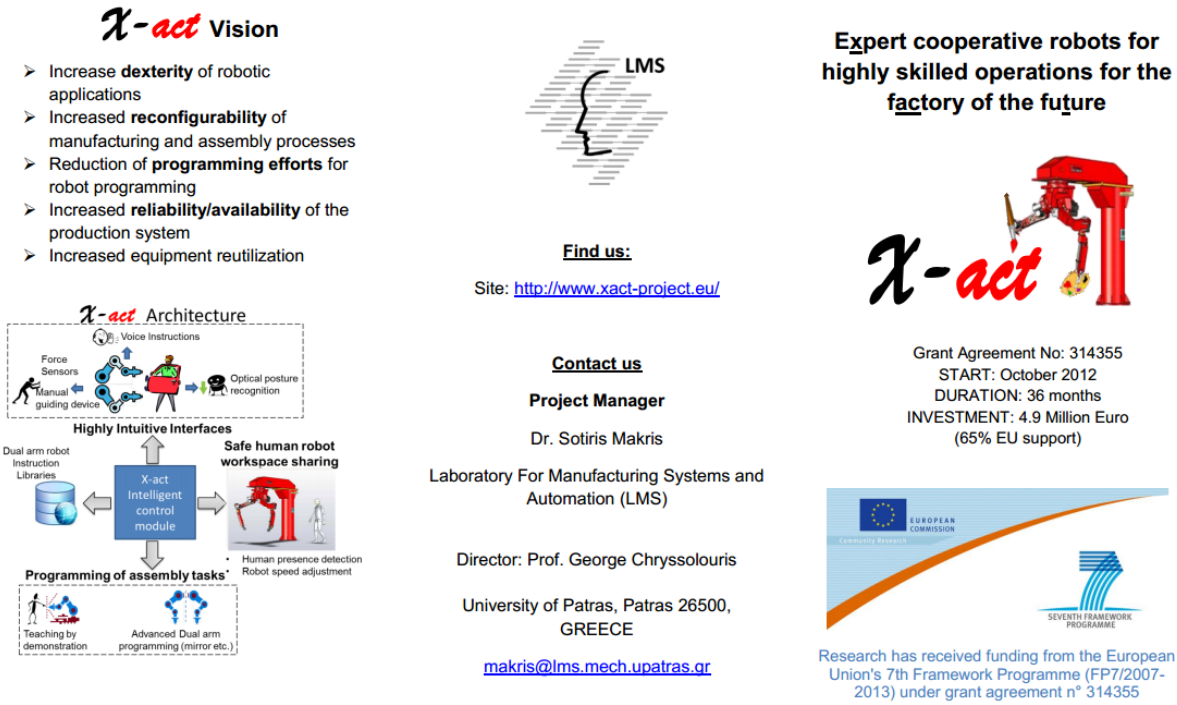
Furthermore the links with other projects were the consortium is involved is described and a list of future activities is given.

2. DISSEMINATION ACTIVITIES

2.1. Project brochure

This sections includes all the brochures of X-act project. Three different brochures has been prepared and demonstrated in different events. The first one is the overall project brochure, the second one is the brochure focused on safety related issues and the last one regards the Dual arm robot.

2.1.1. Overall project brochure



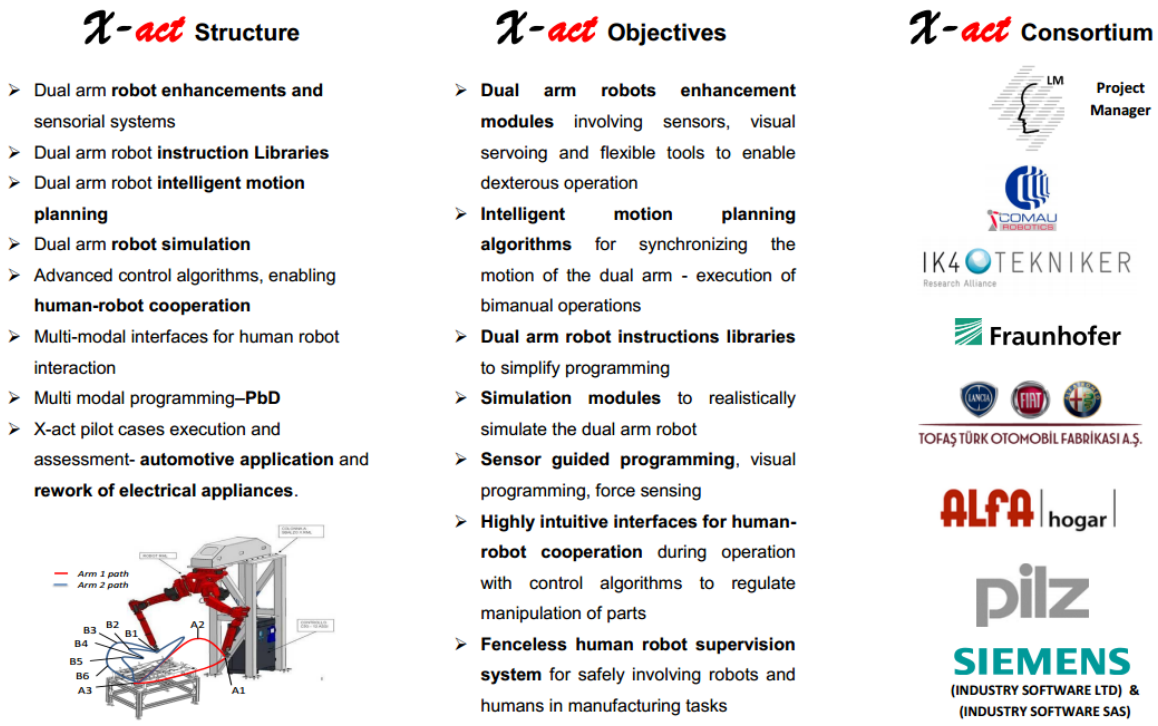


Figure 1: X-act overall brochure from LMS

2.1.2. Safety related issues- brochure

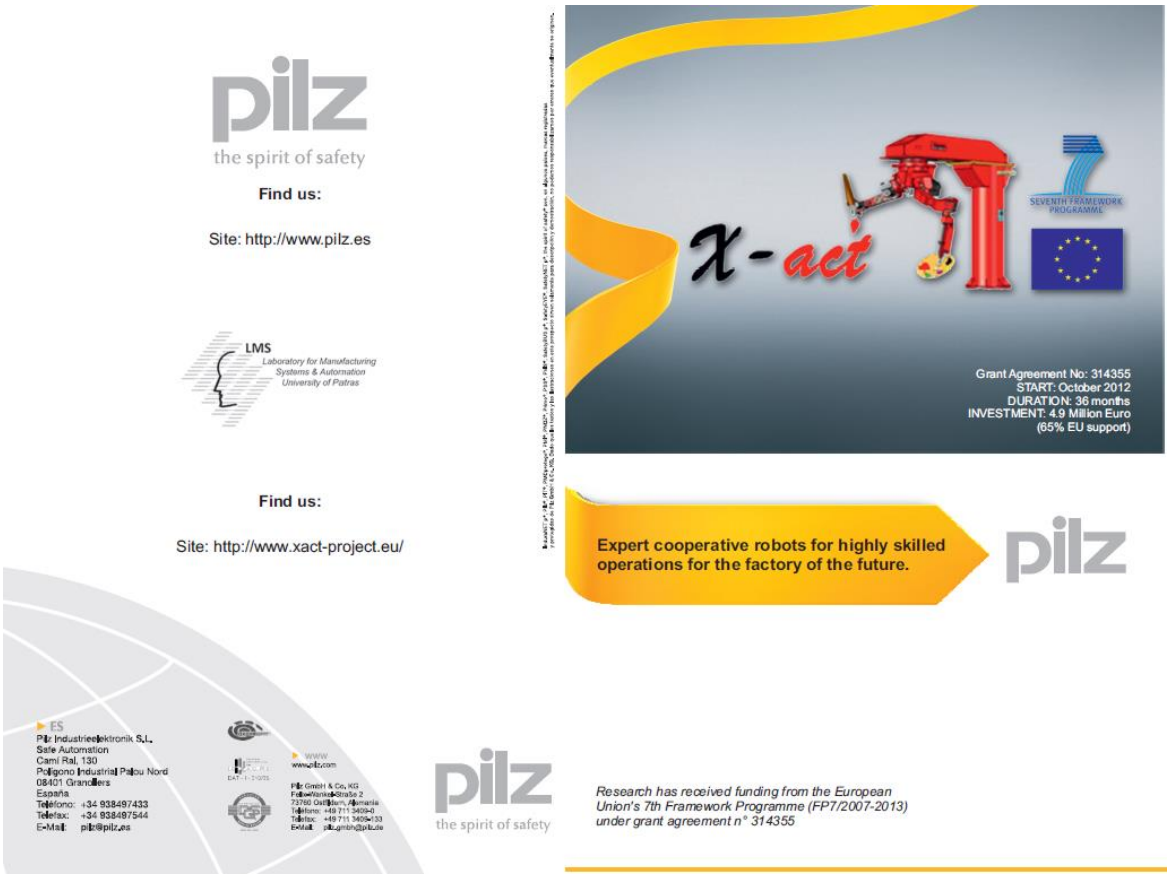
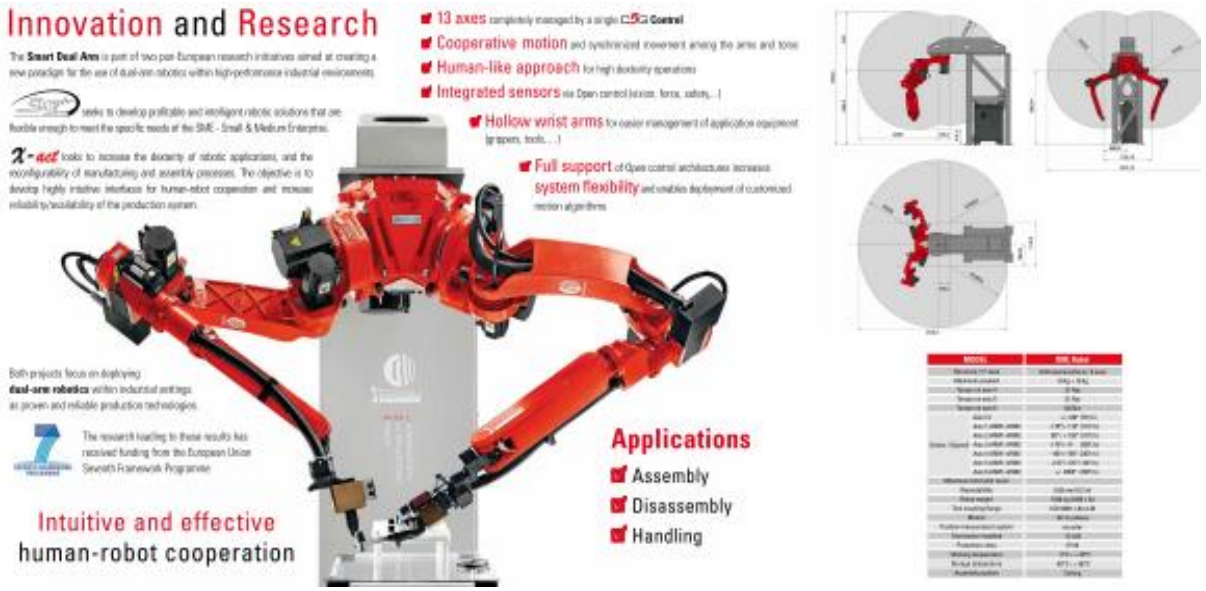


Figure 2: X-act brochure from PILZ

2.1.3. Dual arm robot Brochure

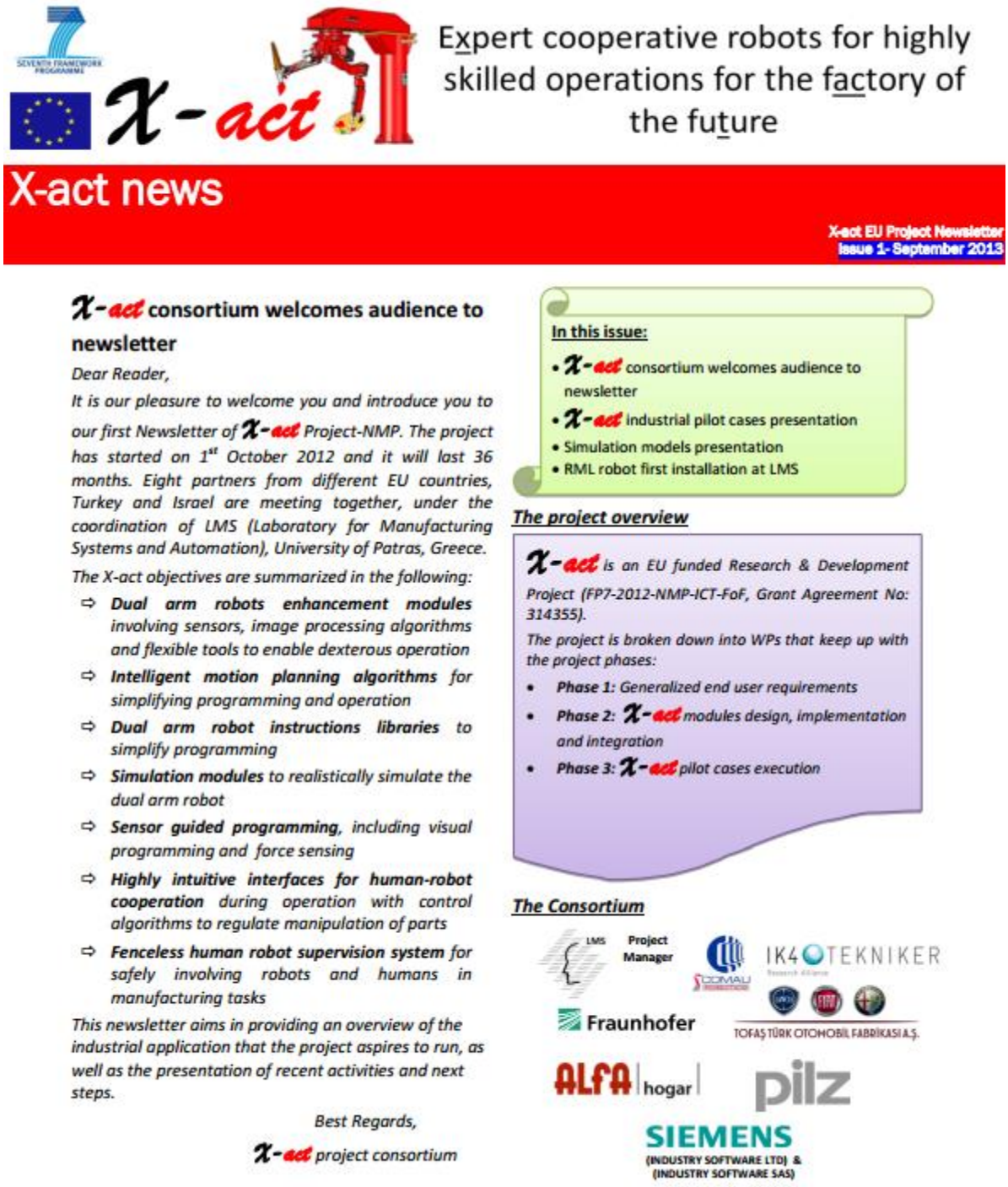
A new brochure have been made to disseminate the activity of the Dual ARM in the X-act project and was distributed to COMAU customers and potential customers.



2.2. Project Newsletters

Five newsletters have been prepared since the first year of the project. These newsletters are in the public material of the X-act portal.

2.2.1. September 2013



Expert cooperative robots for highly skilled operations for the factory of the future

X-act news

X-act EU Project Newsletter
Issue 1- September 2013

X-act consortium welcomes audience to newsletter

Dear Reader,

It is our pleasure to welcome you and introduce you to our first Newsletter of X-act Project-NMP. The project has started on 1st October 2012 and it will last 36 months. Eight partners from different EU countries, Turkey and Israel are meeting together, under the coordination of LMS (Laboratory for Manufacturing Systems and Automation), University of Patras, Greece.

The X-act objectives are summarized in the following:

- ***Dual arm robots enhancement modules** involving sensors, image processing algorithms and flexible tools to enable dexterous operation*
- ***Intelligent motion planning algorithms** for simplifying programming and operation*
- ***Dual arm robot instructions libraries** to simplify programming*
- ***Simulation modules** to realistically simulate the dual arm robot*
- ***Sensor guided programming**, including visual programming and force sensing*
- ***Highly intuitive interfaces for human-robot cooperation** during operation with control algorithms to regulate manipulation of parts*
- ***Fenceless human robot supervision system** for safely involving robots and humans in manufacturing tasks*

This newsletter aims in providing an overview of the industrial application that the project aspires to run, as well as the presentation of recent activities and next steps.

Best Regards,

X-act project consortium

In this issue:

- X-act consortium welcomes audience to newsletter
- X-act industrial pilot cases presentation
- Simulation models presentation
- RML robot first installation at LMS

The project overview

X-act is an EU funded Research & Development Project (FP7-2012-NMP-ICT-FoF, Grant Agreement No: 314355).

The project is broken down into WPs that keep up with the project phases:

- ***Phase 1:** Generalized end user requirements*
- ***Phase 2:** X-act modules design, implementation and integration*
- ***Phase 3:** X-act pilot cases execution*

The Consortium

LMS Project Manager

Figure 3: X-act Newsletter September 2013 - Page 1/2

X-act news

X-act EU Project Newsletter
Issue 1- September 2013

X-act industrial pilot case presentation

The project pilot cases involve:

✓ ***Automotive Sector***

"Dashboard pre-assembly & Hydraulic pump assembly"

Two automotive pilot cases involving flexible and large part manipulation/assembly are investigated by the project. R&D tasks give special emphasis to enhanced Human Robot Interaction (HRI) at the programming and task execution phases.

The COMAU RML (Robot Multipurpose Laboratory) dual arm robot has been selected for the development tasks thanks to its advanced manipulation and control capabilities.

✓ ***Rework of electrical appliances***

"Sewing machine disassembly"

Disassembly of sewing machines is the case of electrical appliances industry, where the main focus is at exploiting RML potential for human based tasks.

The SIEMENS Process Simulate tools are employed for simulation based validation of the pilot cases.

Next steps

- ✓ Test beds setup finalization
- ✓ Control software development on RML
- ✓ Mechatronics and software integration

X-act news and recent events

- ✓ **11 October 2012:** Kick off meeting –Athens, Greece
- ✓ **05-06 February 2013:** 2nd General Assembly meeting-TOFAS, Bursa, Turkey

- ✓ **21-22 May 2013**: 3rd General Assembly meeting-COMAU, Turin, Italy
- ✓ **09 July 2013:** RML installation in LMS Lab, Greece
- ✓ **23 July 2013:** RML installation in TEKNIKER facilities, Spain

X-act upcoming events

- ✓ **18-19 September 2013:** 4th General Assembly meeting-IPK, Berlin, Germany

X-act relevant projects

- ✓ AUTORECON, http://www.autorecon.eu/
- ✓ KNOW4CAR, http://www.know4car.eu/

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Figure 4: X-act Newsletter September 2013 - Page 2/2

2.2.2. February 2014

Expert cooperative robots for highly skilled operations for the factory of the future

X-act news

X-act EU Project Newsletter
Issue 2- February 2014

X-act Smart Dual Arm Robot cells setup in COMAU, LMS, TEKNIKER

a) Automotive industry- Hydraulic pump

Customized grippers, fingers, screw driver and vision systems were already installed in hydraulic pump cell. SafetyEye, depth sensor, MGD are being evaluated in this case.

b) Automotive industry- Dashboard pre-assembly

A modular software architecture, integrating Human, Robot, and sensors has been setup. ROS is used as an integration platform. A relational database is used for managing the high amount of data. Grippers manipulating a lengthy and heavy traverse and smaller parts are designed, built and installed.

Microphones, Kinect sensor and MGD are used for interacting with the robot.

c) Rework of electrical appliances Sewing machine disassembly

The Smart dual arm is equipped with vacuum caps &screw driver, able of changing tool through the tool exchange station. Additionally, eye-in-hand camera is used for objects pose recognition.

SafetyEye, laser range-finders and other sensors are being integrated.

In this issue:

- X-act Smart Dual Arm Robot cells setup in COMAU, LMS, TEKNIKER
- X-act service oriented architecture
- X-act C5G Open installation
- X-act Process Simulate Integration
- X-act Intuitive Interfaces for programming

X-act *Service Oriented Architecture (SOA)*

- ✓ *Integration in ROS & ROSJAVA platform.*
- ✓ *Enables both robot programming and execution.*
- ✓ *Utilises Kinect, Manual guidance and Voice based interaction.*
- ✓ *Custom motion planners for dual arm robot motion.*

The Consortium

LMS Project Manager

COMAU

IK4 TEKNIKER

Fraunhofer

TOFAŞ TÜRK OTOMOBİL FABRİKASI A.Ş.

ALFA hogar

pilz

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(INDUSTRY SOFTWARE LTD) &
(INDUSTRY SOFTWARE SAS)

Figure 5: X-act Newsletter February 2014 - Page 1/2

X-act news

X-act EU Project Newsletter
Issue 2-February 2014

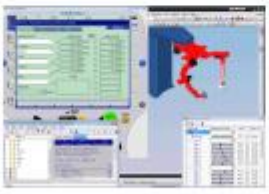
X-act C5G Open controller

Open concept allows:

a) the development of new innovative motion strategies
b) the integration of external sensors in order to simplify the implementation of complex manufacturing applications

X-act Process simulate integration

- ✓ PSR connected to Comau C5G Virtual Controller
- ✓ Monitor dual arm position
- ✓ Execute programs & Record positions in VRC



X-act Intuitive Interfaces for programming

The integration of sensors (depth sensor, microphone) for HRI is utilizing a ROS based architecture for user friendly robot programming & execution. It allows to program using simple voice commands and gestures.

X-act publications

- ✓ Makris S., Tsarouchi P., Surdilovic D., Krüger J., Intuitive Dual arm robot programming for assembly operations, to appear in CIRP Annals – Manufacturing Technology, Vol. 63, Issue 1, (2014).

X-act news and recent events

- ✓ **18-19 September 2013:** 4th General Assembly meeting-IPK, Berlin, Germany

- ✓ **03-04 December 2013:** 1st Review meeting, Turin, Italy
- ✓ **BIENAL fair,** Bilbao, 2-7 June 2014

X-act upcoming events

- ✓ **March 2014:** Dual arm robots for skilled manufacturing operations-ERF 2014 workshop
- ✓ **Industrial Technologies Conference,** 9-11 April 2014, Athens

Next steps

- ✔ Test beds enhancement & mechatronics installation
- ✔ Safety strategy means implementation
- ✔ HRI strategy implementation

X-act relevant projects

- ✓ AUTORECON, http://www.autorecon.eu/
- ✓ ROBO-PARTNER, http://www.robo-partner.eu/

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Figure 6: X-act Newsletter February 2014 - Page 2/2

2.2.3. Newsletter October 2014

Expert cooperative robots for highly skilled operations for the factory of the future

X-act news

X-act EU Project Newsletter
Issue 3- October 2014

X-act Smart Dual Arm Robot cells Progress

a) Automotive industry- Hydraulic pump

Vision system for hydraulic pump parts identification has been integrated in robot cell. Force sensors have been evaluated also in this case for screwing tasks.

b) Automotive industry- Dashboard pre-assembly

Interaction mechanisms integration based on Service oriented architecture has been completed. This allows close interaction with robot, when safety mechanisms are under installation. Noise cancelling microphones, Kinect, leap motion and MGD are evaluated.

c) Rework of electrical appliances Sewing machine disassembly

Integration of tool changer, vacuum grippers and fixtures have been completed. Safety mechanisms integration and test of UCD methodology has brought the first results.

The Consortium

LMS Project Manager, IK4 TEKNIKER, Fraunhofer, TOFAŞ TÜRK OTOMOBİL FABRİKASI A.Ş., ALFA hogar, pilz, SIEMENS (INDUSTRY SOFTWARE LTD) & (INDUSTRY SOFTWARE SAS)

In this issue:

X-act *Fenceless supervision system*

- Safety Eye
- Distance and velocity monitoring system
- Signalling mechanisms

- People detection using Kinect
- Interlock system

X-act offline programming tools

Process simulate tool for exporting data in X-act Service oriented framework has been developed. Three level tree including in different classification the robot positions.

X-act news

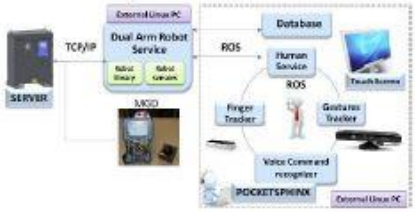
X-act EU Project Newsletter
Issue 3- October 2014

X-act motion planning tools

An intelligent search algorithm is proposed to define the path that leads to the desired position. Multiple criteria are used during alternatives evaluation

X-act Intuitive Interfaces for programming

The integration of sensors (depth sensor, microphone) for HRI is utilizing a ROS based architecture for user friendly robot programming & execution. It allows to program using simple voice commands and gestures.



X-act publications

- S.Makris, P. Tsarouchi, D. Surdilovic, J. Krüger, Intuitive Dual arm robot programming for assembly operations, to appear in CIRP Annals – Manufacturing Technology, Vol. 63, Issue 1, (2014).
- P.Tsarouchi, S.Makris, G.Michalos, M.Stefos, K.Fourtakas, K.Kaltsoukalas, D.Kontovrakis, G.Chryssolouris, Robotized assembly process using Dual arm robot, to be presented in 5th CATS 2014 - CIRP Conference on Assembly Systems and Technologies
- K. Kaltsoukalas, S. Makris, G. Chryssolouris, On generating the motion of industrial robot manipulators, Robotics and Computer-Integrated Manufacturing, Volume 32, April 2015, Pages 65-71, ISSN 0736-5845, http://dx.doi.org/10.1016/j.rcim.2014.10.002.
- A.Ibarguren, I.Maurtua, M.A.Perez, B. Sierra, Multiple Target Tracking based on Particle Filtering for Safety in Industrial Robotic Cells

X-act news and recent events

- **13 March 2014**: Dual arm robots for skilled manufacturing operations-ERF 2014 workshop, Rovereto, Italy
- **05-06 May 2014:** 5th General Assembly meeting-TEKNIKER, Eibar, Spain

- **BIENAL fair,** Bilbao, 2-7 June 2014
- **16-17 September 2014:** 6th General Assembly meeting-SIEMENS, Paris

X-act upcoming events

- Participation in **ERF 2015**, Vienna
- Participation in **CIRP General assembly 2015**

Next steps

- Test beds finalization and cases quantification
- Programming tools integration in X-act framework
- Safety strategy means implementation in dashboard case
- HRI tools integration and finalize versions

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2.2.4. Newsletter February 2015

Expert cooperative robots for highly skilled operations for the factory of the future

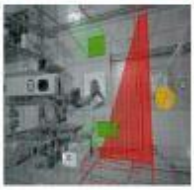
X-act news

X-act EU Project Newsletter
Issue 4- February 2015

X-act Smart Dual Arm Robot cells- final enhancements before demonstrators

a) Automotive industry- Hydraulic pump assembly

Integration of fenceless supervision system for safety, as well as force sensor and control schema or the screw tasks.



b) Automotive industry- Dashboard assembly

In this stage the fenceless supervision system is integrated in LMS premises. Minor adaptations in the cell will take place until the final demonstrator (September 2015).

c) Rework of electrical appliances- Sewing machine disassembly

Final experiments and tests before the final demonstrator at TEKNIKER. An initial prototype of the cell was recently presented in review meeting.

The Consortium

Project Manager

IK4 TEKNIKER

Fraunhofer

ALFA hogar

pilz

SIEMENS

In this issue:

- X-act Smart Dual Arm Robot cells- final enhancements before demonstrators
- X-act dual arm simulation modules
- X-act dual arm robotics library
- X-act Human Robot Interaction mechanisms
- X-act Intuitive Interfaces for programming
- X-act validation of User centered design process for interactive systems

X-act *dual arm simulation modules*

Current status: Tecnomatix 12.0 [20th November 2014]

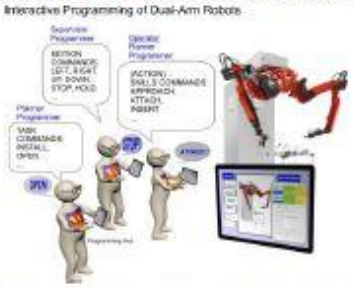
Siemens PLM presented new capabilities for modelling dual arm robot during the 2nd review meeting. Concurrent operations modelling is possible now allowing synchronized and cooperation motions.

X-act news

X-act EU Project Newsletter
Issue 4- February 2015

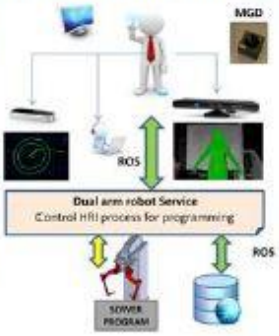
X-act dual arm robotics library

An interactive programming framework for bi-manual operations is the focus of IPK in X-act, based on the development of a dual arm robotics library called CURL++.



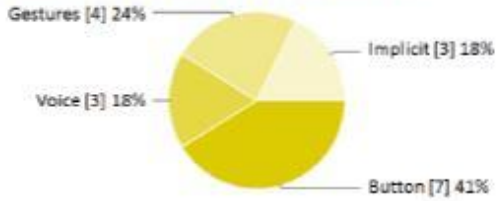
X-act Human Robot Interaction mechanisms

Different interaction mechanisms (depth sensors, finger trackers, microphones, MGD etc.) are used for X-act collaborative tasks execution, as well as for programming. LMS integrates these mechanisms under a ROS based architecture for communication.



X-act validation of User centered design process for interactive systems

Experiments were designed and performed in TEKNIKER premises in order to study human perception/attitude and identify the most acceptable robot behavior in terms of safety and selection of interaction mechanisms.



X-act news and recent events

✓ **20 November 2014**: 2nd review meeting, TEKNIKER, Eibar, Spain

X-act upcoming events

- ✓ **Participation in ERF 2015, Vienna**
- ✓ **7th General assembly- May 2015**
- ✓ **Final review meeting- September 2015**

Next steps

- ✓ Test beds finalization and cases evaluation
- ✓ Safety strategy implementation in dashboard case
- ✓ HRI tools integration and test in the demonstrators

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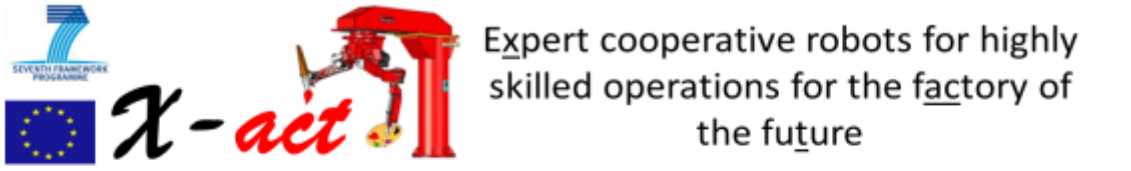
2.2.5. Newsletter October 2015



X-act news

X-act EU Project Newsletter
Issue 5- September 2015

X-act Findings and Conclusions

X-act project has finalized the developments and demonstrators. It is worth saying that the following results were achieved:

- ✓ Dual arm robot were integrated in different industrial scenarios for assembly and disassembly of small and big parts, as well as plastic and delicate parts
- ✓ Different gripping technologies were used in these scenarios, as well as tool changer systems
- ✓ HRC coordination was also achieved based on ROS platform
- ✓ Fenceless supervision system was successfully integrated in the three cases and allowed safe Human robot coexistence, interaction during programming and collaboration
- ✓ Simulation of dual arm robots was achieved and successfully demonstrated for single, synchronized and cooperative motions execution

The main benefits that Dual arm robots integration brings are summarized here:

- ✓ The complexity of gripping devices is reduced compared with the grippers that are used in single arm robots
- ✓ Significant Reduction in the number of fixtures in the final layout
- ✓ Possibility to handle big and small parts event with the same grippers
- ✓ Significant reduction in the number and the complexity of tools/grippers
- ✓ Space saving in the shop floor is also a main using dual arm robots

The Consortium

In this issue:

Message from Coordinator

Dear Reader,

The X-act Project has ended this month. I would like to thank the consortium for their excellent work and collaboration in this project, but also for great opportunity in this scientific experience. Additionally, I would like to thank the Research community that helped with their interest, questions in presentations and workshops to improve the X-act project developments and offer helpful solutions for Dual Arm Robot and Human Robot Collaboration in Industrial environments.

I will call you to enjoy our last newsletter and the dissemination staff that will be available in the public the next months.

Best Regards,

Sotiris Makris

X-act news

X-act EU Project Newsletter
Issue 5- September 2015

X-act Participation in ERF 2015

X-act Booth in IROS 2015

X-act EFFRA portal

X-act Exploitable results

Exploitation package 1: Enhanced Process Simulate:

1. Simulation of Dual arm robots
2. OLP Programming Suite
3. Virtual Teach Pendant
4. OLP XML Exporter
5. Multi-criteria motion planner

Exploitation package 2: Enhanced Dual Arm Robot Platform:

6. On site programming tool
7. Dual arm robot platform & mechatronics
8. Fenceless supervision system
9. H-R station controller
10. Intuitive HMI
11. Robot Programming Language- CURL ++

X-act publications

- Papacharalampopoulos, S. Makris, A. Bitzios, and G. Chryssolouris, "Prediction of cabling shape during robotic manipulation," *Int. J. Adv. Manuf. Technol.*, vol. 32, pp. 1–8, Jun. 2015.
- Ibarguren, I. Maurtua, M. A. Pérez, and B. Sierra, "Multiple target tracking based on particle filtering for safety in industrial robotic cells," *Rob. Auton. Syst.*, vol. 72, pp. 105–113, Oct. 2015.
- P.Tsarouchi, S.Makris and G.Chryssolouris, "Human-Robot Interaction-Review and challenges on Task planning and Programming", International Journal of Computer Integrated Manufacturing (Under Publications), 2015.
- Panagiota Tsarouchi, et al., ROS based coordination of human robot cooperative assembly tasks-an industrial case study, Cirp-e 2015 (available presentation on https://vimeo.com/141575008), October 2015 (Published).
- G. Michalos, S. Makris, P. Tsarouchi, Toni Guasch, D. Kontovrakis, G. Chryssolouris, Design considerations for safe human robot collaborative workplaces, Cirp-e 2015 (available presentation on https://vimeo.com/141575393), October 2015 (Published).

X-act upcoming events

✓ **Final review meeting- November 2015**

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2.3. Poster

Two posters have been prepared during X-act project. The first one was the overall project poster and the second one was focused on safety related issues. Both posters were demonstrated in multiple events.

2.3.1. Overall project poster

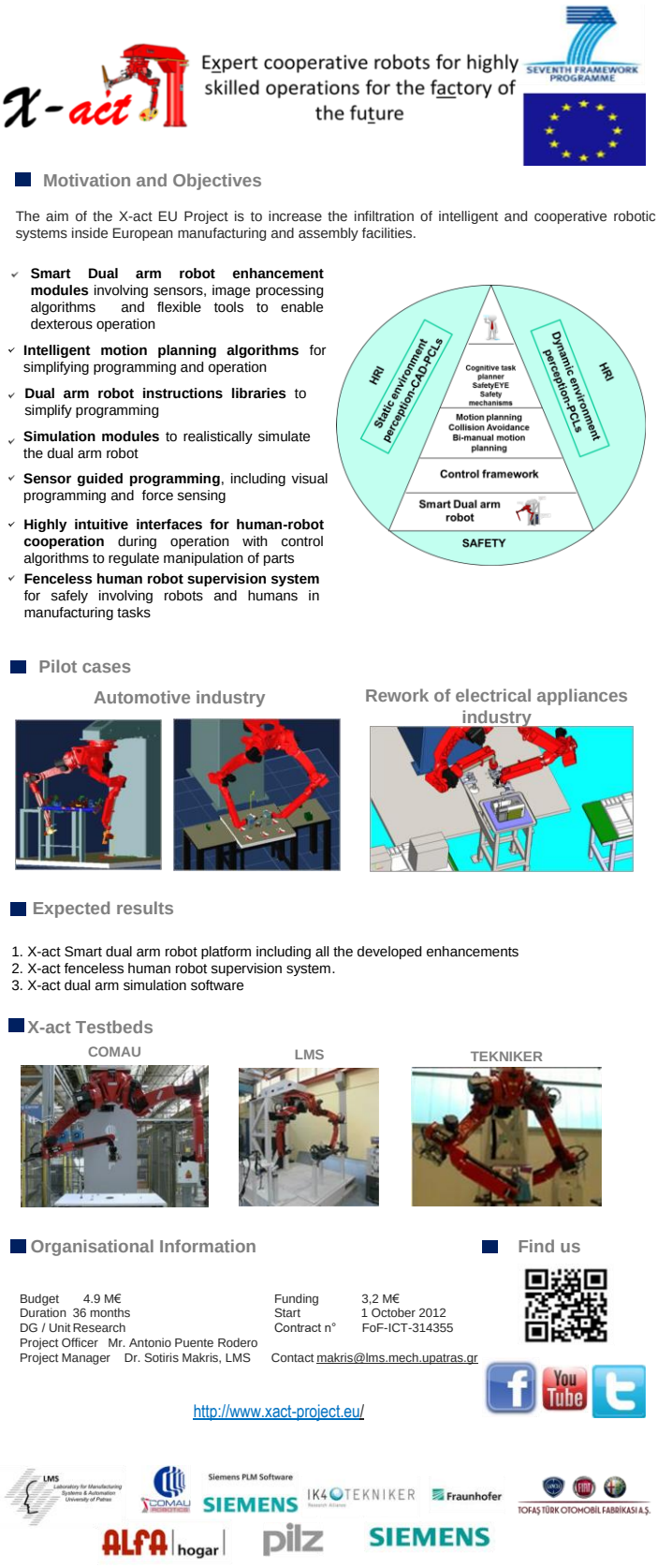


Figure 7: X-act overall poster

2.3.2. Safety issues related Poster

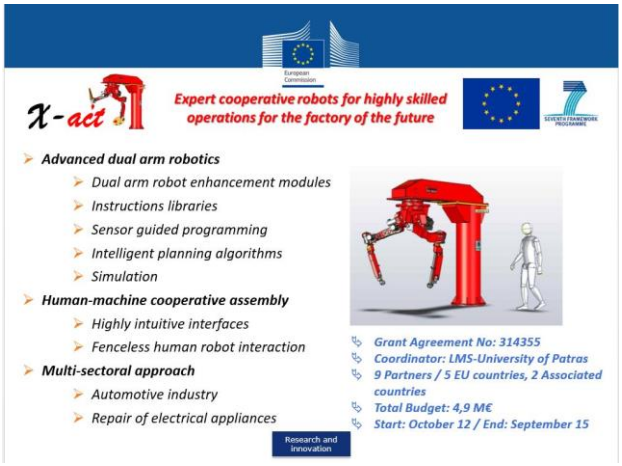
Figure 8: X-act Poster from PILZ

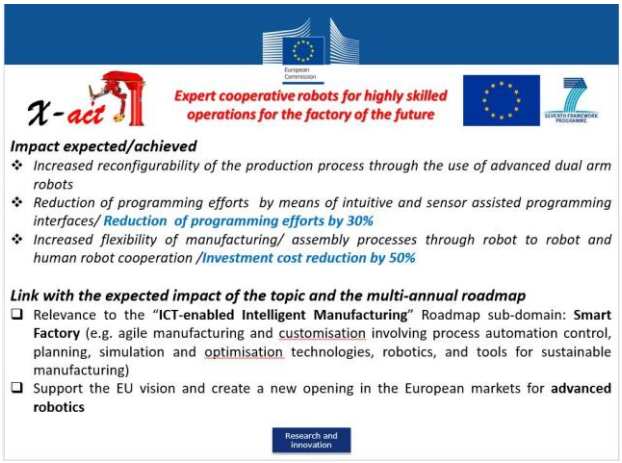
2.4. Events participation

The following section summarizes all the relevant events that X-act consortium participated on.

2.4.1. FoF Impact workshop 2013

Presentation in Impact workshop (March 2013)- Session ICT for Manufacturing



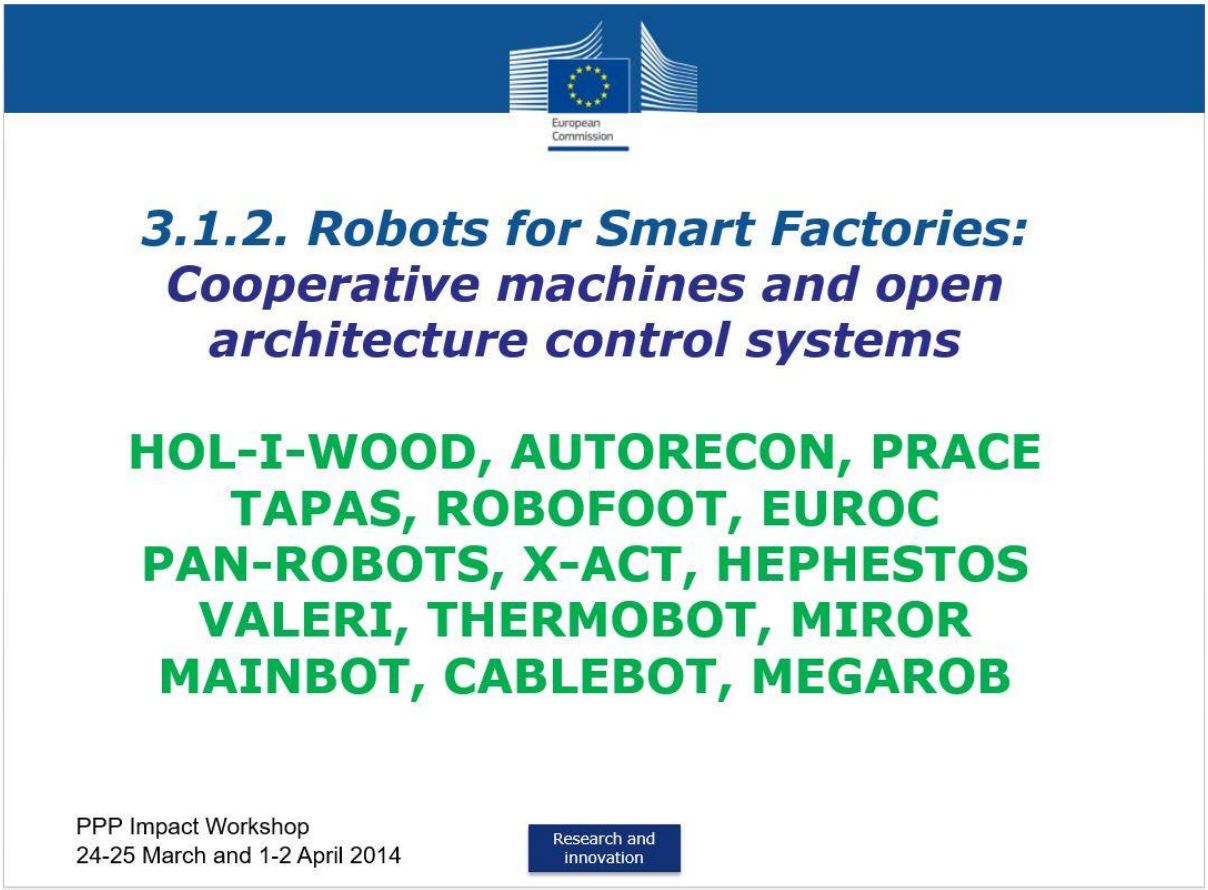


2.4.2. ICRA 2013

X-act leaflets and a video was presented in ICRA 2013.

2.4.3. FoF Impact workshop 2014

Presentation in Impact workshop (March 2014)



2.4.4. FoF Impact workshop 2015

Presentation in Impact workshop (March 2015). LMS led the presentation with IPK and gathered all the material from the other project coordinators.

2.4.5. ERF 2014

- European Robotics forum (http://www.erf2014.eu/)
  Rovereto, Italy from the 12th to the 14th of March 2014

2.4.6. ERF 2015

2.4.7. Industrial technologies conference, Athens 2014, LMS

A poster was prepared for this conference in the LMS booth.

http://www.industrialtechnologies2014.eu/exhibition/

2.4.8. Robobusiness Billund 2014, LMS, COMAU, TEKNIKER, IPK

http://www.robobusiness.eu/?page_id=2966/#production

PRODUCTION TRACK

Sensor controlled industrial robots

May 27, 10.00 a.m. – 13.00 p.m.

Chairman: Gian Paolo Gerio, Performance Engineering Manager, Comau Robotics, Italy

Speakers

Soeren Boeving-Andersen, CEO, Scape Technologies, Odense, Denmark

'Standardized Bin-picker in a skeptical market'

Dragoljub Surdilovic, Dr.Sc., Principal Investigator, The Robotics Department, IPK Berlin, Germany

'Impedance/Force Robot Applications in Industry – Perspectives of Open Robot Control'

Sotiris Makris, Dr., Project Manager, Department of Mechanical Engineering and Aeronautics, University of Patras, Greece

'Industrial applications of cooperating robots for flexible assembly'

Nicola Pedrocchi, PhD, Researcher, The Institute of Industrial Technology and Automation, National Council of Research, Italy

'Roughing of the Uppers of fashion shoes: a successful case study for sensor based (open)

control solutions'

Iñaki Maurtua, IK4-TEKNIKER, Head of Autonomous and Intelligent Systems, Spain

'Dual-arm robot in cooperation with humans for assembly and disassembly operations'

2.4.9. ETFA'2014

- 19th IEEE International Conference on Emerging Technologies and Factory Automation (ETFA'2014), Barcelona (Spain) from 16 to 19 September 2014.
- http://www.etfa2014.org/
- TEKNIKER: Presentation of the paper: 6DOF pose estimation of objects for robotic manipulation. A review of different options

2.4.10. Industria 4.0

- Event in Bilbao (900 attendants) about this new paradigm of manufacturing
- http://www.spri.eus/basqueindustry_4_0/es/
- TEKNIKER: Participation on the Collaborative Robot workshop, using X-ACT as an example

2.4.11. BIEMH'14

- Bienal de la Máquina Herramienta 2014, Bilbao, 2-7 June
- Exhibition link:

  http://www.biemh.com/en/biemh-2014-highlights-machine-tool-sector-recovery-onset/#.VD9lf-lxljo

Figure 9: X-act Poster & brochures presented by PILZ in the event

- TEKNIKER: presentation in a booth, including real demos with the dual arm robot

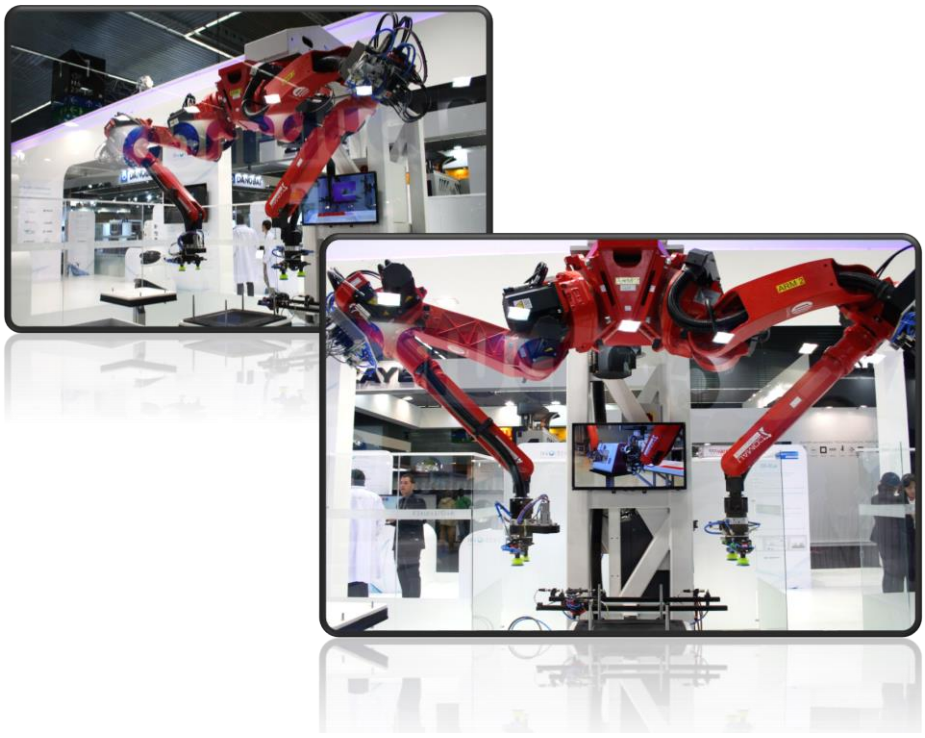


Figure 10: TEKNIKER booth with the Dual arm robot

2.4.12. IQ Patras 2015, Greece

LMS participated in the IQ event in Patras Greece with X-act poster, as it is visualized below.

2.4.13. World manufacturing forum Milan, 2014, LMS

X-act poster was present in this event.

2.4.14. AUTOMATICA 2014

A booth in AUTOMATICA 2014 was demonstrating the hydraulic pump assembly scenario.

2.4.15. Fiat journal 'ILLUSTRATO FIAT', 2014

Dual arm robot and X-act project was presented in the Fiat Journal in Europe.

2.4.16. EFFRA Innovation portal

X-act consortium updated the EFFRA Innovation portal.

RESEARCH & INNOVATION PROJECT | edit general information

Acronym	X-ACT
Title	Expert cooperative robots for highly skilled operations for the factory of the future
Website address	http://www.xact-project.eu/
Project duration	36 months (2012-10-01 until 2015-09-30)
Number of participants	9 participants
Total budget - EC contribution	4,845,590 Euro - 3,212,991 Euro
Description	X-act aims to increase the infiltration of intelligent and cooperative robotic systems in European, "robot resistant" production facilities. The penetration of such systems has poorly advanced due to a) the lack of user friendly programming in real industrial environments, b) the complexity in managing robot to robot and human to robot cooperation c) the combined need for production and robotics experts for achieving dexterous operations d) the high safety requirements for human-robot interaction. X-act proposes the enhancement of dual arm robots for cooperative use with human operators, by means of: - Dual arm robots enhancement modules involving sensors, visual servoing and flexible tools to enable dexterous operation - Intelligent motion planning algorithms for synchronizing the motion of the dual arms combined with the enablement of the execution of bimanual operations - Dual arm robot instructions libraries to simplify programming, allowing the robot program to be incrementally and automatically created - Simulation modules capable of representing realistically the behaviour of the dual arm robot - Sensor guided programming involving voice recognition, visual programming, force sensing - Highly intuitive interfaces for human-robot cooperation during assembly by means of control algorithms to regulate the manipulation of the parts - Fenceless human robot supervision system to adjust the speed of the robots upon the detection of humans and automatically re-plan robot trajectory The project will be based on industrial applications, bringing dual arm robots to a maturity level that allows the introduction in industry, not as experimental equipment but as well proven and reliable production technologies. A demonstration in automotive will involve the dexterous assembly of flexible parts by dual arm robots in cooperation with humans. A second demonstration will focus on rework of electrical appliances to disassemble, rework and reassemble electrical devices.
Summary of most striking achievements	Overall summary of project achievements. https://www.youtube.com/watch?v=_MVruSKhpHA - Advanced control of dual arm robot system - Advanced simulation technology for dual arm robot systems - Increased flexibility in assembly and disassembly operation sin manufacturing
Clustering - cooperation with other projects	Cooperation with other projects has been reported. X-act has participated in a number of clustering activities with relevant projects. European Robotics Forum in 2014 Projects X-act, HEPHESTOS, ROSETTA. European Robotics Forum 2015 Workshop Flexibility and Dexterity in industrial robots: Demonstrators of new frontiers in industrial applications

2.4.17. ROBOBUSINESS 2015

- TEKNIKER gave the talk “Human and robot collaboration: technologies to achieve human trust” during ADVANCED MANUFACTURING track on March 29th, during the ROBOBUSINESS 2015 event that took place in Milano.
- The agenda is available here: http://www.robobusiness.eu/rb/program-overview/

2.4.18. ETFA'2015

- 20th IEEE International Conference on Emerging Technologies and Factory Automation ETFA 2015 held in Luxembourg City.
- http://www.etfa2015.org/
- TEKNIKER: Presentation of the paper: “Human Robot interaction in industrial robotics. Examples from research centers to industry” in the workshop: Int. International Workshop on Robotics Technology Transfer: Innovation from Academia to Industry (RTT2015).
- The project officer was present in the workshop and the agenda is available in http://www.etfa2015.org/index.php?page=1-int-workshop-rtt

2.4.19. Martes de Innobasque “Robótica e innovación”

- Talk of TEKNIKER “Fabricación avanzada mediante la colaboración persona-robot: claves tecnológicas”
- June 26th, San Sebastian
- http://www.innobasque.com/home.aspx?tabid=665&idEvento=212

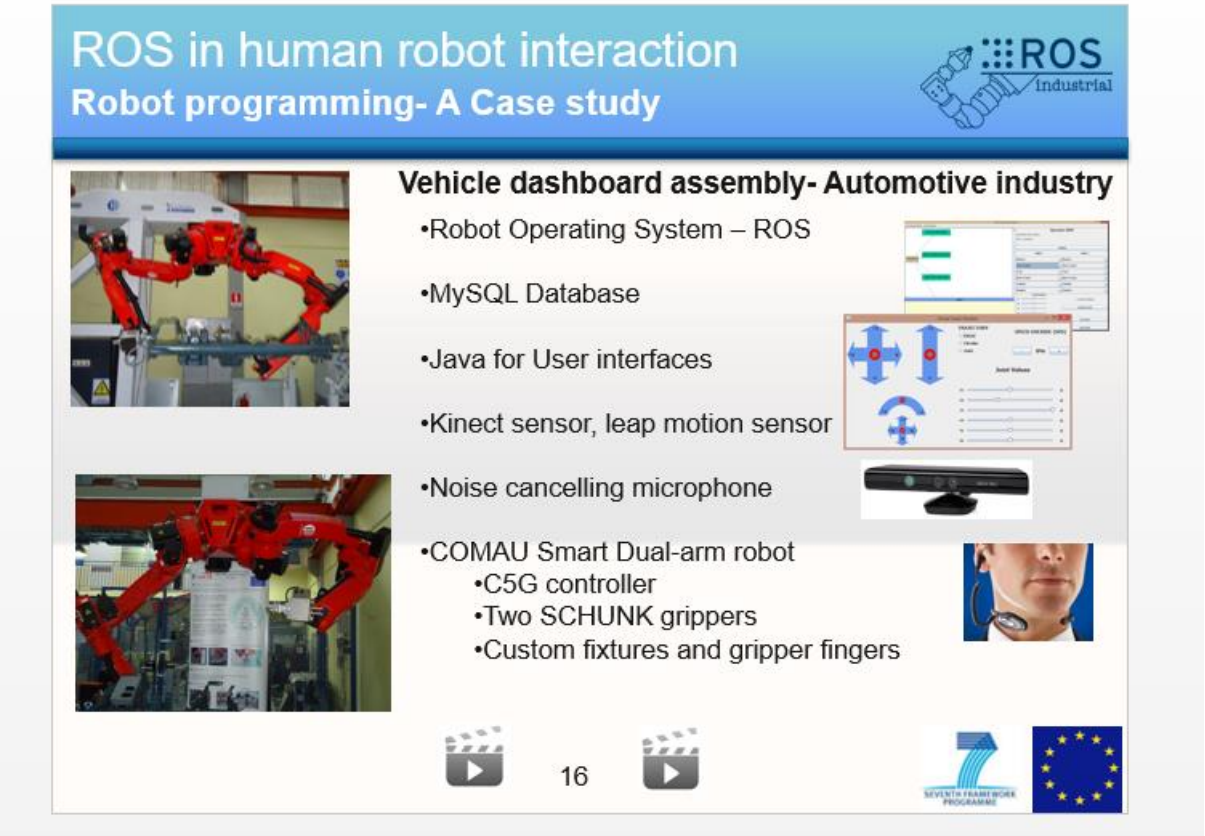
2.4.20. Basque Industry 4.0 2015

Bilbao on 14th October.

http://www.spri.eus/es/eventos/basque-industry-4-0-fabricacion-avanzada-2015

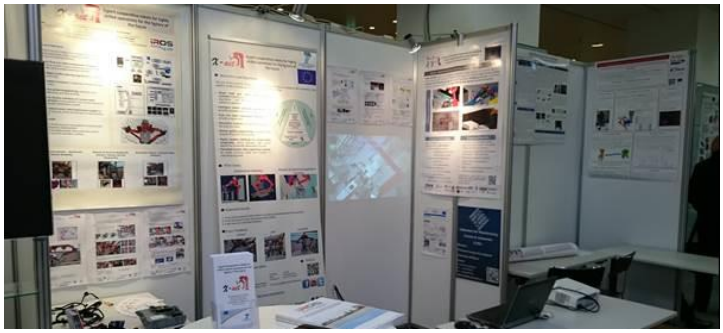
2.4.21. ROS industrial conference 2015

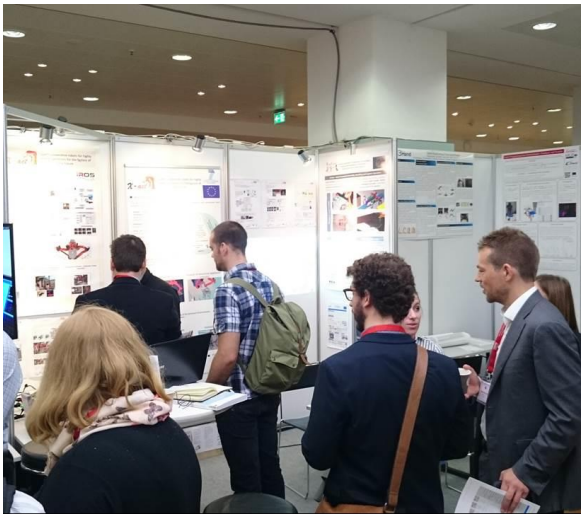
Presentation with title: “ROS Based Scheduling of Cooperating Robots- Industrial case study”



2.4.22. IROS Conference 2015-Hamburg

X-act project participated in IROS 2015 Hamburg with a booth. Videos, posters of the project and exploitable results poster books were available in the booth. The interest of the audience was impressive for the project developments but as well as the real world demonstrators.





2.5. Other activities

In this section other activities that were undertaken from X-act consortium are presented.

2.5.1. Teknopolis program, TV, TEKNIKER

The X-act project was presented in Spain, in the Teknopolis TV program.

http://teknopolis.elhuyar.org/reportajes/sobre-robotica-con-aitzol-astigarraga/

2.5.2. Innovation program, TV, LMS

The Innovation program showed the developments of the X-act project in the Greek TV.

https://www.youtube.com/watch?v=UdMMyTRUHLE&feature=youtu.be&t=0

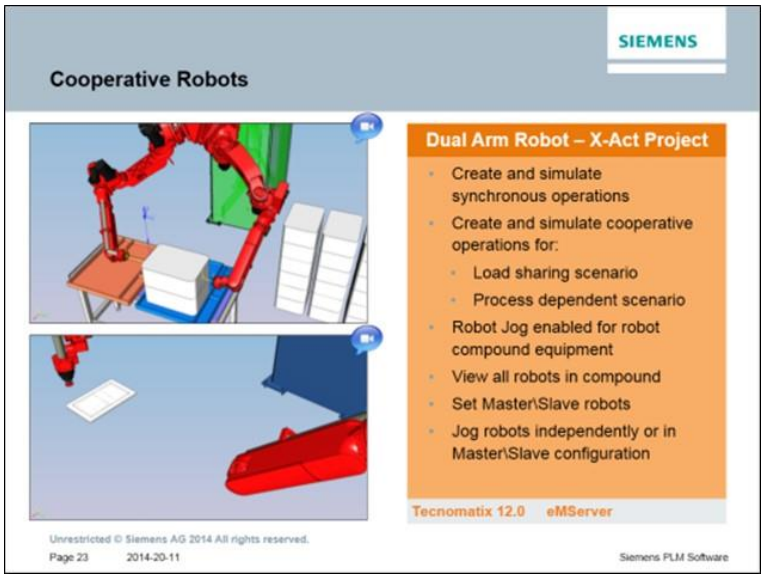
2.6. Patents and internal publications

The patents and the internal publications are reported in this section. Siemens has reported here a number of relevant activities, such as h PS v12 release notes, the new features of PS (after X-act project), the webminar etc.

2.6.1. Tecnomatix 12.0 Release Notes, SIEMENS

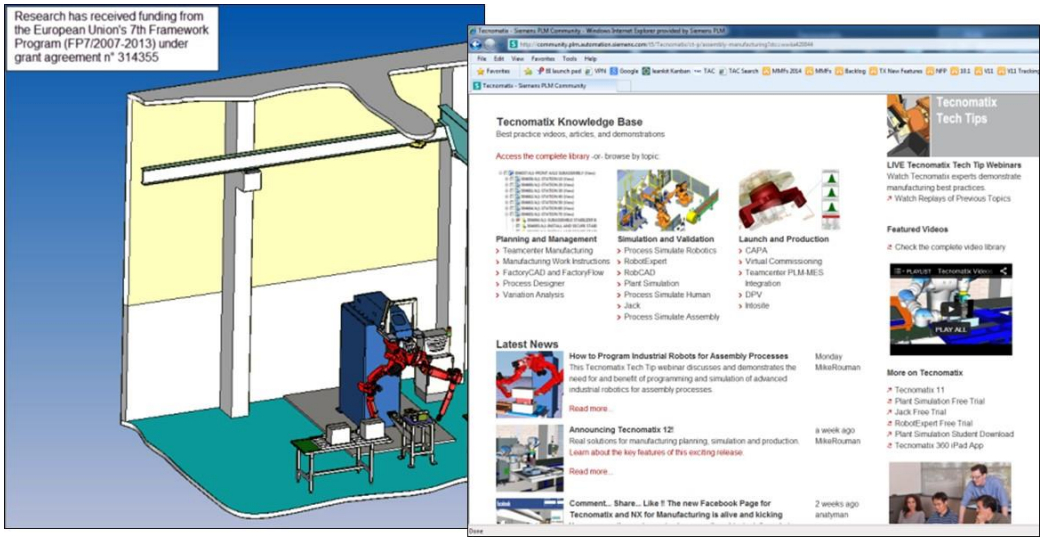
2.6.2. User meetings exposure, Siemens

- Tecnomatix 12.0 New Features Presentation
- User meetings exposure:
    - AUG (German Automotive User Group) – 5/2014, 10/2014
    - Process Simulate user conference – Tokyo
    - GM – 8/2014
    - Renault – 9/2014



2.6.3. Webinar, Siemens

Robotic Assembly Tech Tips Webinar (26 June 2014)



3. LIST OF DISSEMINATION ACTIVITIES

O.	Type of activities[1]	Main leader	Title	Date	Place	Type of audience[2]	Size of audience	Countries addressed
1.	Web	LMS	X-act Website http://www.xact-project.eu	Sept 2012	World wide web	Public	Worldwide	Worldwide
2.	Presentation	LMS	Impact of the Factories of the Future PPP, ICT for Manufacturing	March 2013	Brussels	Scientific Community, Industry	40	EU
3.	Video	LMS	International Conference on Robotics and Automation (ICRA)	May 2013	Karlsruhe, Germany	Scientific Community, Industry	Worldwide	Worldwide

[1] A drop down list allows choosing the dissemination activity: publications, conferences, workshops, web, press releases, flyers, articles published in the popular press, videos, media briefings, presentations, exhibitions, thesis, interviews, films, TV clips, posters, Other.

[2] A drop down list allows choosing the type of public: Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias ('multiple choices' is possible.

4.	Brochure	LMS	International Conference on Robotics and Automation (ICRA)	May 2013	Karlsruhe, Germany	Scientific Community, Industry	Worldwide	Worldwide
5.	Newsletter	LMS	X-act newsletter September 2013	September 2013	World wide web	Public	Worldwide	Worldwide
6.	Web	COMAU	COMAU web site http://www.comau.com/eng/news_events/news/archive/Pages/fp7.aspx	September 2013	World wide web	Public	Worldwide	Worldwide
7.	Newsletter	LMS	X-act newsletter February 2014	February 2014	World wide web	Public	Worldwide	Worldwide
8.	Presentation	LMS	Impact of the Factories of the Future PPP, ICT for Manufacturing	March 2014	Brussels	Scientific Community, Industry	40	EU
9.	Workshop	LMS, COMAU, IPK, TEKNIKER	Dual arm robots for skilled manufacturing operations European Robotics forum 2014	March 2014	Rovereto, Italy	Scientific Community, Industry	100	Worldwide

10.	User conference	Siemens IND	Process Simulate Robotic seminar	March 2014	Tokyo, Japan	Process Simulate customers	75	Japan
11.	Poster	LMS	Dual arm robots for skilled manufacturing operations European Robotics forum 2014	March 2014	Rovereto, Italy	Scientific Community, Industry	100	Worldwide

12.	Brochure	LMS	Dual arm robots for skilled manufacturing operations European Robotics forum 2014	March 2014	Rovereto, Italy	Scientific Community, Industry	100	Worldwide
13.	TV	TEKNIKER	Teknopolis program	March 2014	Basque Country	Civil Society		Spain
14.	Workshop	COMAU, LMS, IPK, TEKNIKER	Sensor controlled robots ROBOBUSINESS Europe 2014	May 2014	Billund, Denmark	Scientific Community, Industry	100	Worldwide
15.	Workshop	Siemens IND	Process Simulate hands-on workshop	May 2014	Stuttgart, Germany	Process Simulate customers	15	Germany, Austria
16.	Software release	Siemens IND	Tecnomatix 11.1TR2	May 2014	Not relevant	Industry	Not relevant	World wide
17.	Webinar	Siemens IND	Robotics Webinar	June 2014	Web	Siemens Internal	Not relevant	World wide
18.	Exhibition	TEKNIKER	Bienal de la Máquina Herramienta 2014	June 2014	Bilbao	Industry	35500	Spain

19.	Exhibition	COMAU	AUTOMATICA 2014	June 2014	Munich	Industry	Worldwide	Germany
20.	Exhibition	LMS	World manufacturing forum Milan	July 2014	Milan	Industry	Worldwide	Italy
21.	Publication	LMS, IPK	Intuitive dual arm robot programming for assembly operations	August 2014	Nantes, France CIRP General assembly 2014	Scientific Community, Industry	400	Worldwide
22.	Conference	TEKNIKER	Collaborative Robots workshop in Industria 4.0 Event	October 2014	Bilbao	Industry	900	Spain
23.	TV program	LMS	Innovation program	October 2014	Patras	Scientific Community, Industry	TV, Web	Greece
24.	Workshop participation	LMS	1st: Hybrid Production Systems 2nd: Flexibility and dexterity in industrial robots European Robotics forum 2015	March 2015	Vienna	Scientific Community	150	Austria

25.	Workshop	TEKNIKER	"Human and robot collaboration: technologies to achieve human trust" ROBOBUSINESS 2015	March 2015	Milano	Industry	100	Europe
26.	Workshop	Siemens IND	Process Simulate hands-on workshop	April 2015	Stuttgart, Germany	Process Simulate customers	15	Germany, Austria
27.	Software release	Siemens IND	Tecnomatix 12.1	April 2015	Not relevant	Industry	Not relevant	World wide
28.	Exhibition	LMS	IQ Patras	May 2015	Patras	Scientific Community, Industry		Greece
29.	Workshop	TEKNIKER	"Fabricación avanzada mediante la colaboración persona-robot: claves tecnológicas" Martes de INNOBASQUE	June 2015	San Sebastian	Industry	40	Spain
30.	Webinar	Siemens IND	Robotics Webinar	July 2015	Web	Siemens Internal	Not relevant	World wide

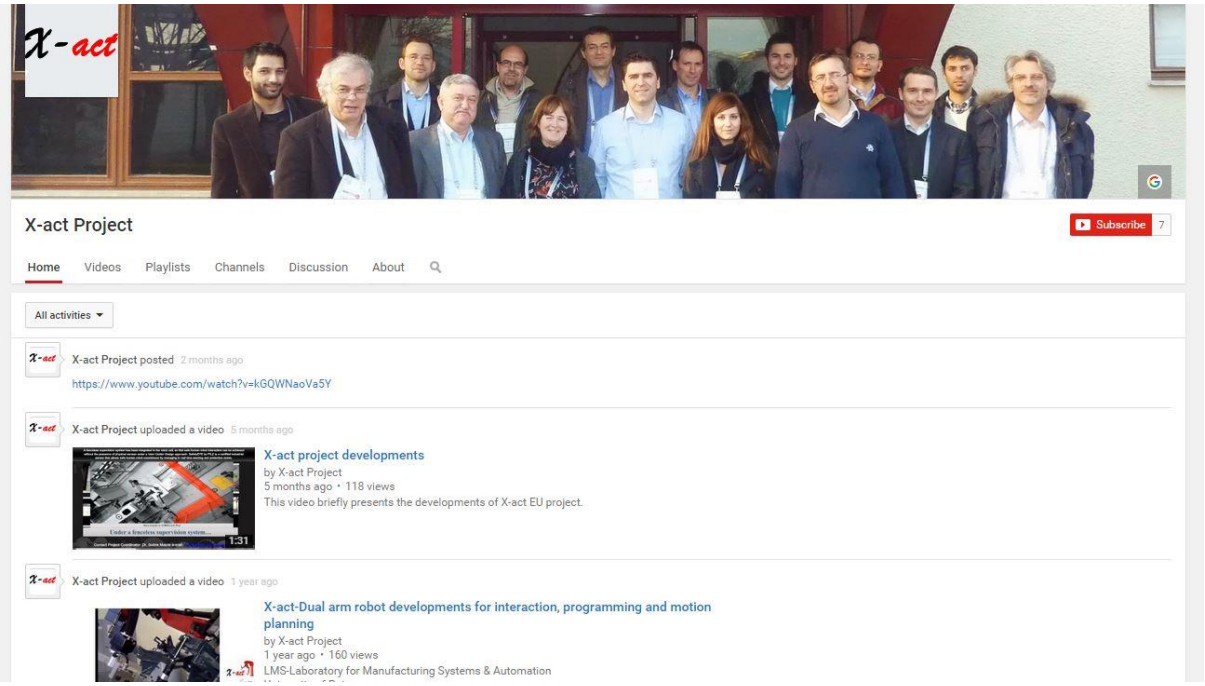
31.	Conference- 20th IEEE International Conference on Emerging Technologies and Factory Automation	TEKNIKER	"Human Robot interaction in industrial robotics. Examples from research centers to industry" ETFA 2015	September 2015	Luxembourg	Industry/academia	40	Europe
32.	X-act booth in IROS 2015	LMS	Booth	September 2015	Hamburg	Industry/academia	5000	Worldwide
33.	Workshop on IROS conference 2015	TEKNIKER	FrWS-15: Safety for Human-Robot Interaction in Industrial Settings	September 2015	Hamburg	Industry/academia	500	Worldwide
34.	Web	LMS	EFFRA Innovation portal	N/A	World wide web	Public	Worldwide	Worldwide
35.	Web	LMS	X-act Twitter https://twitter.com/XactProject	N/A	World wide web	Public	Worldwide	Worldwide
36.	Web	LMS	X-act Facebook https://www.facebook.com/pages/X-act-Project/465940116805086	N/A	World wide web	Public	Worldwide	Worldwide

37.	Web	LMS	X-act YouTube channel http://www.youtube.com/user/xactproject	N/A	World wide web	Public	Worldwide	Worldwide
38.	Web	PILZ	PILZ Youtube channel https://youtu.be/qMbP-bbubEI	N/A	World wide web	Public	Worldwide	Worldwide

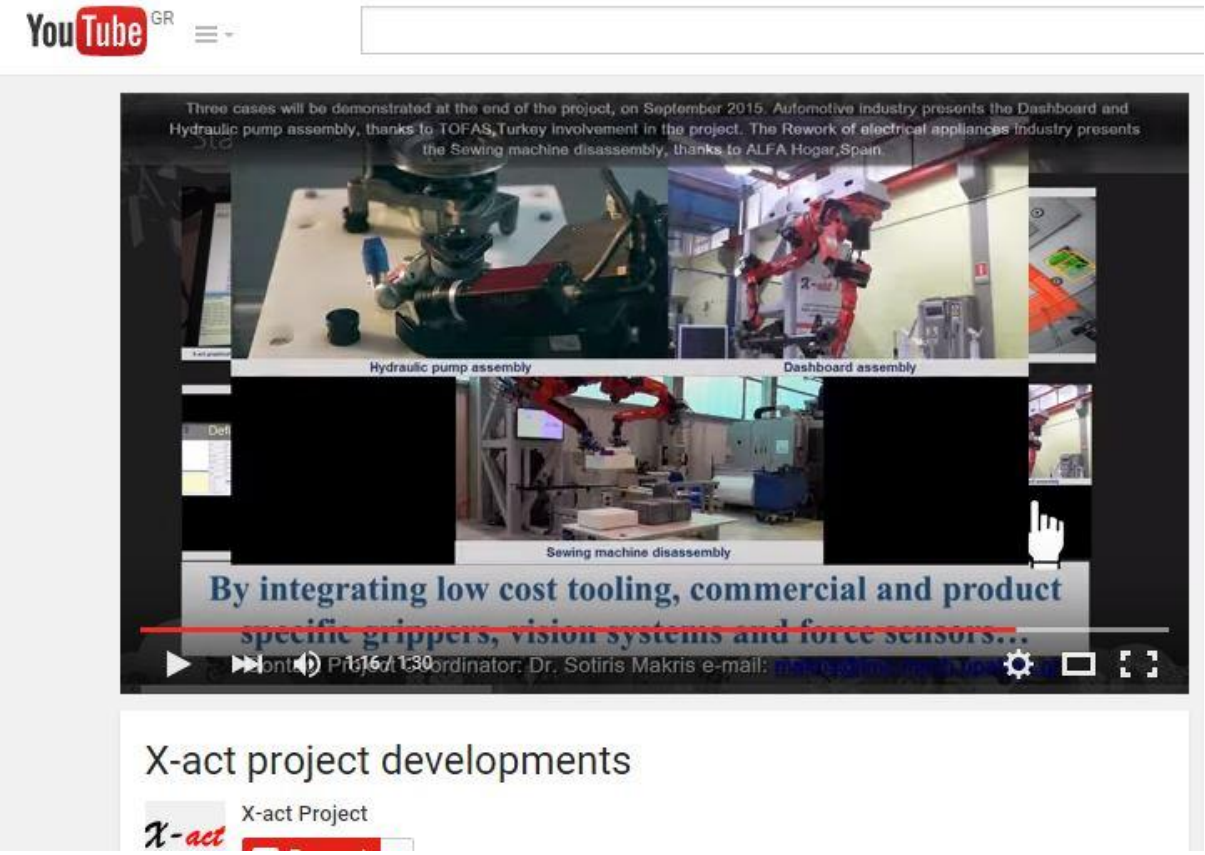
4. SOCIAL NETWORKING SERVICE

4.1. YOUTUBE channel

X-act project has created a channel in Youtube for sharing information with the public. The name of the channel is: ***X-act Project.***



A new overall video of the project developments can be found also in this channel.



4.2. Twitter

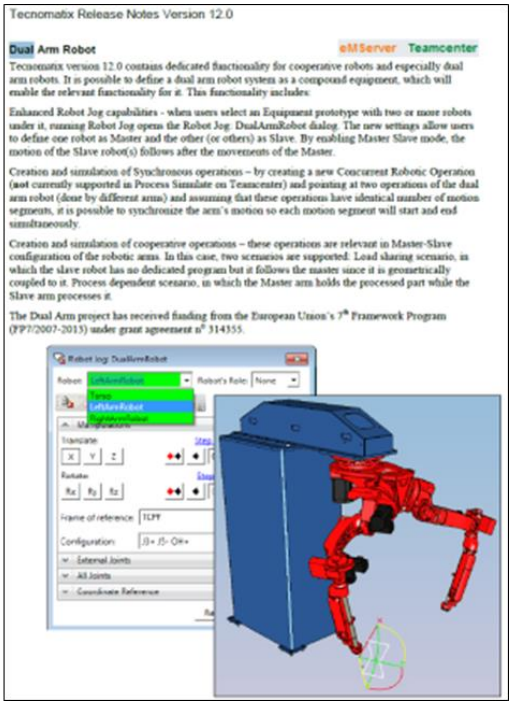

twitter
X-act
TWEETS 12
ΑΚΟΛΟΥΘΟΥΝΤΑΙ 1
ΑΚΟΛΟΥΘΟΙ 5
X-act Project
@XactProject
Joined Οκτώβριος 2012
11 Photos and videos
Tweets
Tweets & replies
Φωτογραφίες και βίντεο
X-act Project @XactProject · 1 Ιουλ
X-act was presented in Robobusiness Europe, 27 May 2014, Sensor controlled industrial robots. robobusiness.eu/?page_id=2966/...
X-act Project @XactProject · 27 Μαΐ
X-act-Dual arm robot developments for interaction, programming and motion planning: youtu.be/rZgEmA2uphI?a μέσω @YouTube
YouTube
LMS
View more photos and videos

4.3. Facebook


facebook
Expert cooperative robots for highly skilled operations for the factory of the future
X-act EU-Project
Add Friend
Message
Timeline
About
Photos
Friends
More
DO YOU KNOW X-ACT?
To see what she shares with friends, send her a friend request.
Add Friend
4 Mutual Friends
X-act EU-Project
https://www.youtube.com/watch?v=YvGGyVdlBtk
X act Smart dual arm in Hydraulic pump assembly
COMAU

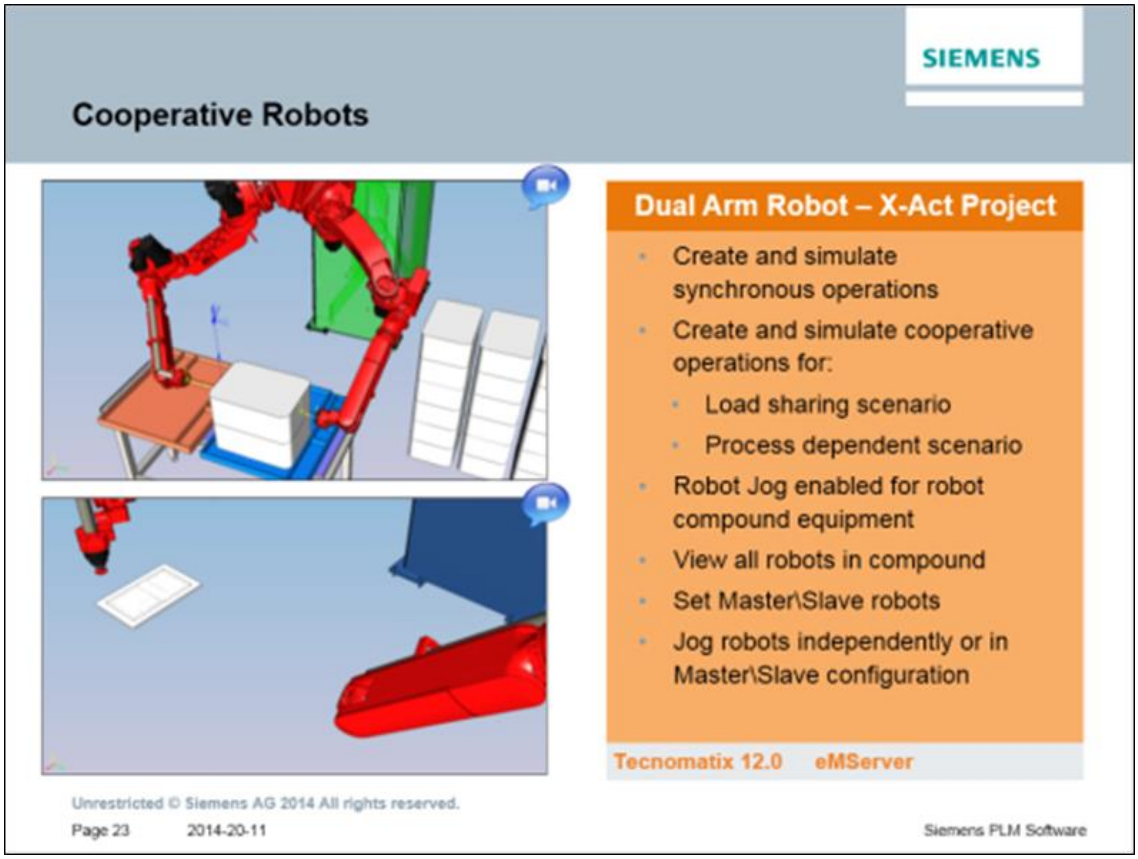
5. PATENTS AND INTERNAL PUBLICATIONS

5.1. Tecnomatix 12.0 Release Notes, SIEMENS

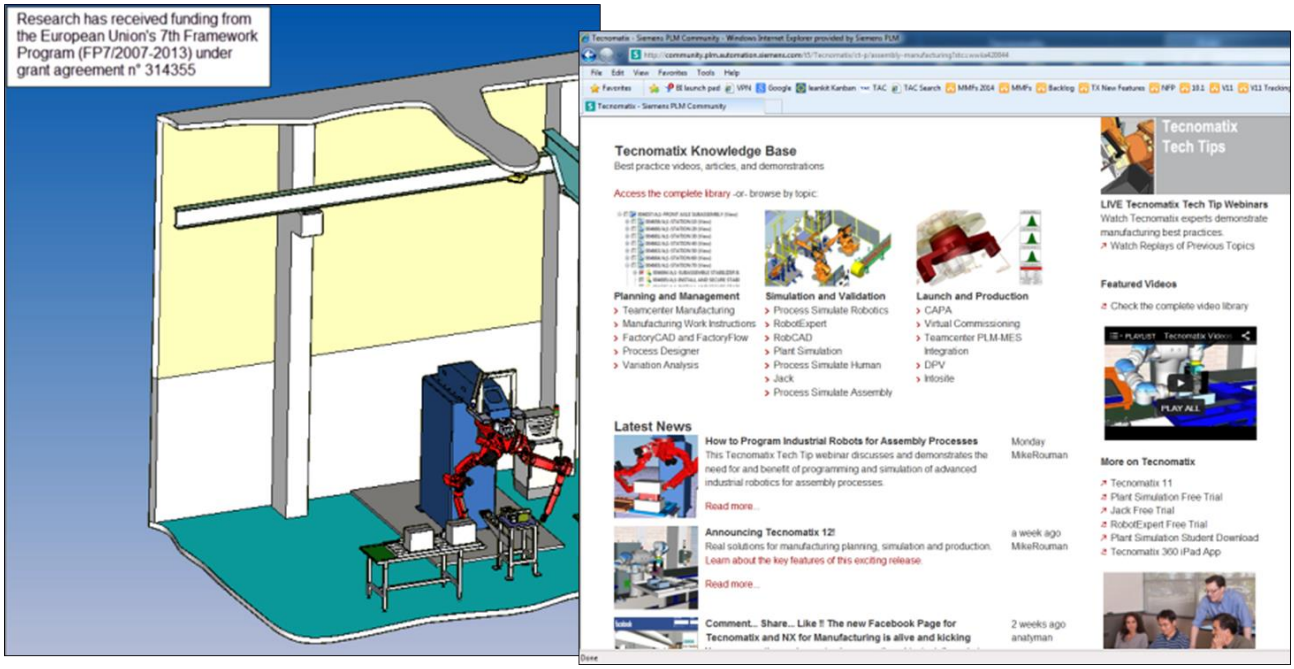


5.2. User Meetings Exposure, SIEMENS

- Tecnomatix 12.0 New Features Presentation
- User meetings exposure:
  - AUG (German Automotive User Group) – 5/2014, 10/2014
  - Process Simulate user conference – Tokyo
  - GM – 8/2014
  - Renault – 9/2014



5.3. Webinar, SIEMENS



6. LINKS WITH OTHER PROJECTS

6.1. AUTORECON

AUTORECON project has finished (September 2014). LMS, COMAU and TOFAS have worked together for the integration of ROS based modules in COMAU for robot to robot coordination and cooperation. Similar X-act, has used the ROS framework for coordinating Human to Robot cooperation.

6.2. ROBO-PARTNER

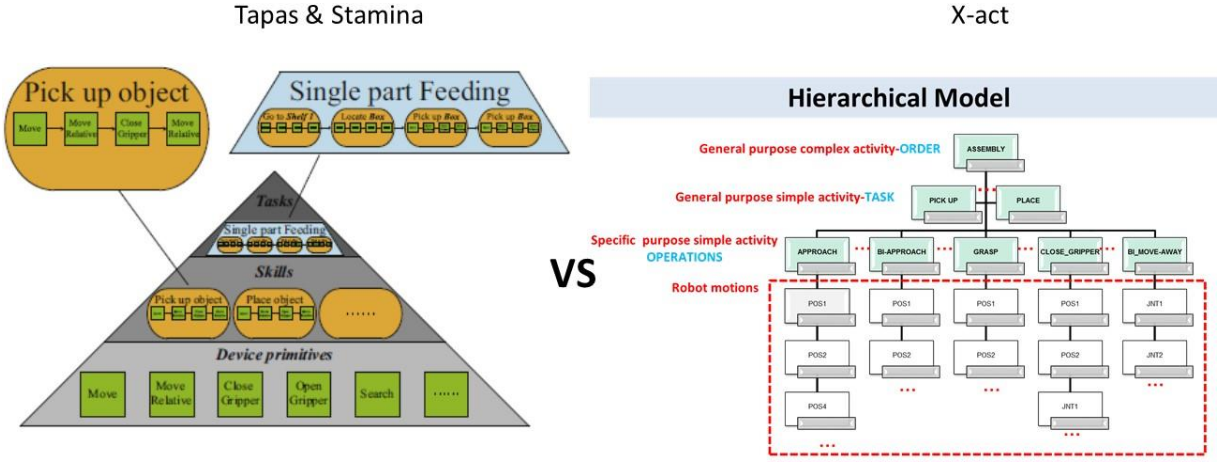
LMS, TEKNIKER, IPK, COMAU, TOFAS and PILZ participate in ROBO-PARTNER project working on Automotive and Electrical Appliances Industry demonstrators. Human robot cooperation and fenceless cells are investigated also in this project.

6.3. LIAA

LMS participates also in LIAA project working on Automotive Industry demonstrators for the assembly of mechanical parts of the car. Human robot interaction methods are investigated also in this project, as well as safety issues that allows close human robot collaboration. Universal Robots (IWA 5, 10) are used for the integration of the final demonstrators. IPA also works on the Robotic Assembly skills and primitives similar to the TAPAS and Stamina projects.

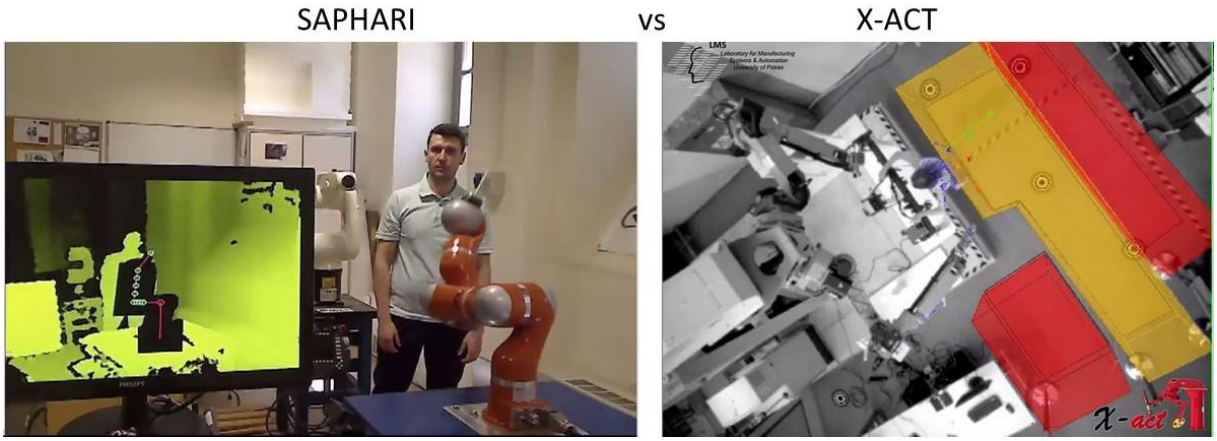
6.4. TAPAS & Stamina projects

TAPAS project has finished on November 2014 (Final review meeting), while Stamina is an ongoing project. Both sides identified the use of hierarchical models for structuring a number of tasks for programming of human and robot tasks. TAPAS and Stamina consortiums have worked on the orientation of skills, tasks and primitives, when X-act project was focused more on the Order, Task and Operation orology. The inspiration came from the production lines hierarchy.



6.5. SAPHARI

SAPHARI project has worked on Human Robot safety related issues, from real time perception to learning and interpretation of human, physical human interaction and human aware task planning. In terms of Human robot coexistence and collaboration, but with heavy industrial robots, X-act has investigated the related safety measures and safety standards that are applicable.



6.6. SMERobotics

TEKNIKER is taking part in the project developing one of the additional demonstrators: “Aeronautic components assembly using flexible dual-arms (FLEXAS)”.

The basic setup developed for the ALFA scenario in X-ACT is used in a completely new scenario the assembly of metallic parts in the aeronautic sector. A link to the demonstrator description is available here: http://www.smerobotics.org/demonstrations/d7.html

COMAU also participates in this project for Gear Box Assembly Demonstrator. A video and description can be found here: http://blog.robotiq.com/high-tech-robotic-assembly-cell .

6.7. FOF workshop- 2015

In the Impact workshop 2015, X-act project manager (LMS) and IPK coordinated and presented the presentation of the projects that are summarized in the following figures. Interaction between the Projects’ Representatives took place during the preparation of the presentation and discussion followed on the common research areas. Exchange of information and sharing of publications took also place

HEPHESTOS:
www.hephestosproject.eu
Gerhard Schreck
gerhard.schreck@ipk.fraunhofer.de

MAINBOT
www.mainbot.eu
Iñaki Maurtua
inaki.maurtua@tekniker.es

THERMOBOT
http://thermobot.eu
Emanuele Menegatti
emg@dei.unipd.it

Hol-I-Wood:
http://holiwoodpr.wordpress.com/
Christoph Steiner
Christoph.Steiner@microtec.eu

MEGAROB:
www.megarob.eu
José Antonio Dieste
joseantonio.dieste@aitiip.com

CableBOT
www.cablebot.eu
Mariola Rodríguez
mariola.rodriguez@tecnalia.com

7. PLANNING OF FUTURE ACTIVITIES

NO.	Type of activities[3]	Main leader	Title	Date	Place	Type of audience[4]	Size of audience	Countries addressed
1.	Paper submitted, waiting for acceptance	TEKNIKER	Human Robot collaboration in Industrial applications: safety, interaction and trust ICRA 2016	2016	Stockholm	Industry/Academia		Worldwide

[3] Choose the dissemination activity: publications, conferences, workshops, web, press releases, flyers, articles published in the popular press, videos, media briefings, presentations, exhibitions, thesis, interviews, films, TV clips, posters, Other.

[4] Choose the type of public: Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias ('multiple choices' is possible.

8. LIST OF PUBLICATIONS

NO.	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Is open access[5] provided to this publication?
1.	Intuitive dual arm robot programming for assembly operations	S.Makris	CIRP General assembly 2014	August 2014	CIRP Annals - Manufacturing Technology	Nantes, France	2014	Pages 13–16	Yes
2.	Robotized Assembly Process Using Dual Arm Robot	P.Tsarouchi	5th CIRP Conference on Assembly Technologies and Systems	November 2014	5th CIRP Conference on Assembly Technologies and Systems	Dresden, Germany	2014	Pages 47–52	Yes
3.	On generating the motion of industrial robot manipulators	K. Kaltsoukalas	Robotics and Computer Integrated Manufacturing	April 2015	Robotics and Computer Integrated Manufacturing	N/A	2014	Pages 65–71	Yes

[5] Open Access is defined as free of charge access for anyone via Internet. Please answer "yes" if the open access to the publication is already established and also if the embargo period for open access is not yet over but you intend to establish open access afterwards.

NO.	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Is open access[5] provided to this publication?
4.	6DOF pose estimation of objects for robotic manipulation. A review of different options	A. Tellaeche, I. Maurtua	Proceedings of Emerging Technology and Factory Automation (ETFA)	September 2014	IEEE	Barcelona	2014	1-8	No
5.	Prediction of cabling shape during robotic manipulation	A.Papacharalampopoulos	International Journal of Advanced Manufacturing Technology	June 2015	International Journal of Advanced Manufacturing Technology	N/A	2015	N/A	Yes
6.	Human-Robot Interaction-Review and challenges on Task planning and Programming	P.Tsarouchi	International Journal of Computer Integrated Manufacturing	Accepted August 2015	International Journal of Computer Integrated Manufacturing	N/A	2015	Under publication	Yes

NO.	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Is open access[5] provided to this publication?
7.	ROS based coordination of human robot cooperative assembly tasks-an industrial case study	P.Tsarouchi	Procedia CIRP Volume 37, 2015, Pages 254–259 Cirp-e 2015 https://vimeo.com/141575008	September 2015	Procedia	WEB conference	2015	Under publication	Yes
8.	Design considerations for safe human robot collaborative workplaces	G.Michalos	Procedia CIRP Volume 37, 2015, Pages 248–253 Cirp-e https://vimeo.com/141575393	September 2015	Procedia	WEB conference	2015	Under publication	Yes
9.	Multiple target tracking based on particle filtering for safety in industrial robotic cells.	A. Ibarguren, I. Maurtua, M.A. Pérez, B. Sierra	Robotics and Autonomous Systems.	October 2015, Volume 72	Elsevier	N/A	2015	Pages 105-113	No