Progetto di Eccellenza
Informatica per Industria 4.0

An holistic approach to Computer Engineering for Industry 4.0

Project Status

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Agenda

- Project summary
- 2018 activities:
  - Organization
    - chart
    - international advisory board
    - industrial advisory board
  - New positions
    - professors, researchers
    - research assistants
    - Ph.D. students
  - Research activities
    - actual project description
  - Industrial Computer Engineering (ICE) Laboratory
    - lab. Structure
    - Siemens agreement
  - Degrees
    - Master Degree in Mathematics
    - Master Degree in Computer Engineering for Industry 4.0
  - Dissemination
    - web pages
    - presentations
    - meeting and seminars
    - research contacts
- Roadmap 2019

PROJECT SUMMARY

Dipartimento di Eccellenza

- DI won the competition “Dipartimenti di Eccellenza 2018-2022” of the Ministry of Education, Universities and Research (MIUR)
  - research on a holistic approach to Computer Engineering for Industry 4.0
  - 8M€ funding
  - 15 new people
  - laboratories
  - new master degree

Industry 4.0: Enabling Technologies

1. **Advanced Manufact. Solutions** — • Interconnected & reprogrammable collaborative robots
2. **Additive Manufacturing** — • 3D Printers connected to Cad software
3. **Augmented Reality** — • Augmented reality to support manufacturing processes
4. **Simulation** — • Simulation of the factory for analysis and prediction
5. **Horizontal/ Vertical Integration** — • Integration of new informations among the production line
6. **Industrial Internet** — • Communication betweens different manufacturing processes and products
7. **Cloud** — • Manage big amount of data in open systems
8. **Cyber-security** — • Security during network operation
9. **Big Data and Analytics** — • Analysis of big amount of data to optimize manufacturing processes

Research Areas

- Discrete and computational mathematics
- Mathematics - applications and modeling
- Theory of computation
- Software Engineering and Security
- Bioinformatics and Medical Informatics
- Information systems
- Machine intelligence
- Cyber-physical systems
- Experimental applied physics

- Mathematics
- Computer science
- Computer engineering
- Physics

Enabling Technologies and DI Research Areas

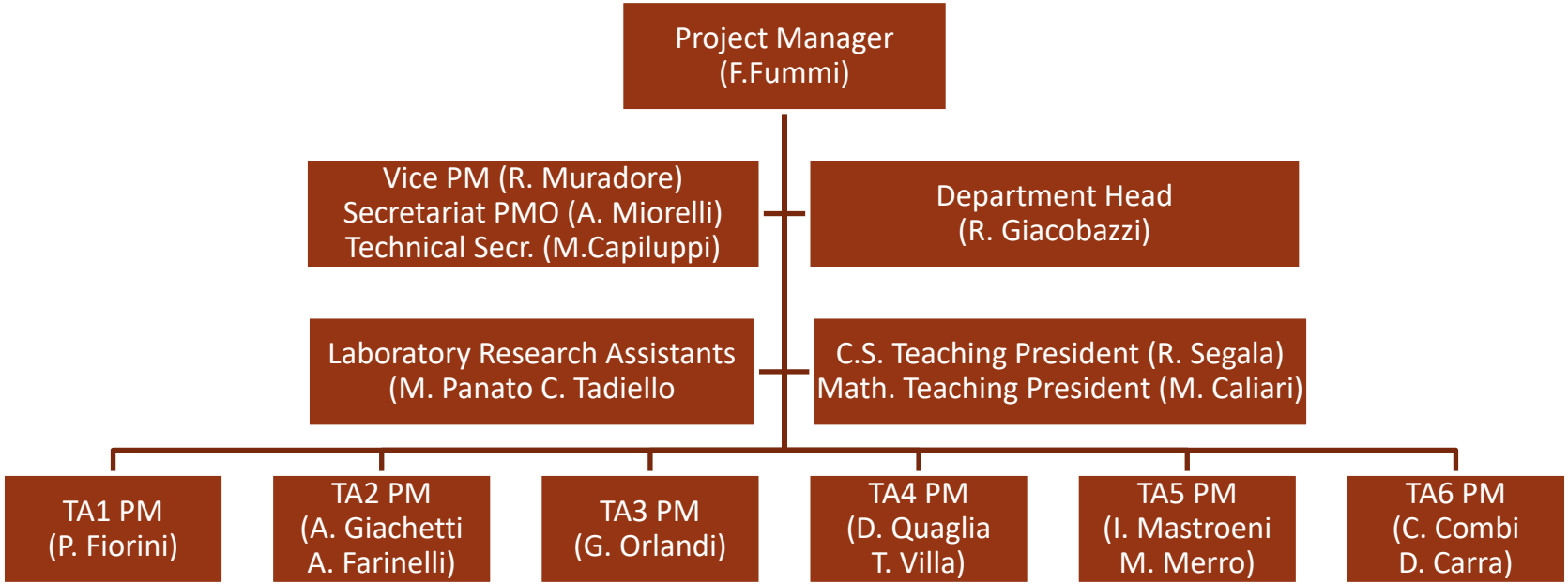
- TA1: Advanced manufacturing solutions
  - Cyber-physical systems
- TA2: Augmented reality & Additive manufacturing
  - Machine intelligence
- TA3: Simulation
  - Mathematics – applications and modeling
- TA4: Industrial internet
  - Cyber-physical systems
- TA5: Cloud Cyber-security
  - Software Engineering and Security
- TA6: Big-data and analytics
  - Information systems

Objectives and Methodologies

- Objectives:
  - A. Safety and security
  - B. Automatic design
  - C. Diagnosis and maintenance
- Methodologies:
  - M1. **High level specifications** of a production line using formal methods (TA1)
  - M2. **Design of the line** to compose verified basic elements (TA1, TA2, TA3)
  - M3. Modeling of the system and of **workflows** using common description languages (TA2, TA4)
  - M4. **Integration of data flows** and operation flows in one common representation environment (TA5, TA6)
  - M5. **Optimization of the process** with typical techniques from operation research (TA3, TA4)
  - M6. Verification of the line realization and of the process with (semi)formal methods based on **efficient simulation of the line and process**, and probabilistic identification methods (TA3, TA4)
  - M7. **Security and privacy** analysis to compose assessed modules with application of uniform techniques on the data flow from IoT sensors to cloud (TA4, TA5)
  - M8. **Protection guarantee**, with algorithms of interaction control with operators and users, and real-time estimation of the work environment (TA1, TA4)
  - M9. Realization of **remote assistance with telecontrol**, network security protocols, quality of service analysis, and visualization methods based on augmented reality (TA2, TA5, TA6)

2018 ACTIVITIES: ORGANIZATION

Organization Chart



- Periodic meetings to check the project evolution
- Periodic reports to Department Committee (8 reports Jan-Sep 2018):
  - sharing information
  - taking decisions

International Advisory Board

- Alberto Luigi Sangiovanni Vincentelli
  - University of California at Berkeley - USA
  - cyber-physical systems design
    - google scholar: cit. 60000 H 111
- Sukhan Lee
  - Sungkyunkwan University - South Korea
  - robotics
- Samarjit Chakraborty
  - Technical University of Munich - Germany
  - automotive and Industry 4.0
- They will periodically review the project:
  - report at beginning of Dec. 2018
  - feedback received by Feb. 2019
    - to be included in the first report for MIUR

Industrial Advisory Board (IAB)

- ACCIAIERIE DI VERONA S.p.A. - Gruppo Pittini
- ASEM s.p.a.
- ATTUA S.r.l.
- Ball Beverage Packaging Italia S.r.l.
- Brevetti C.E.A. S.p.A.
- CAD.IT S.p.A.
- CLX Europe
- Derga Consulting
- Dgroove S.r.l.
- Exor International
- Ferretto Group S.p.A.
- Fiamm Energy Technology S.p.A.
- Gizero Energie s.r.l.
- Gruppo Italiano Vini
- Hdemy Group
- ICI Caldaie S.p.A.
- IDEA S.p.A. - Gruppo Giordano
- Inerti S. Valentino S.r.l.
- KIRATECH S.p.A.
- Manni Group S.p.A.
- Maxfone S.r.l.
- OLIP Italia S.p.A.
- Plumake S.r.l. FabLab
- Qualitas Informatica S.p.A.
- Safilo S.p.A.
- Simem S.p.A.
- Sordato S.r.l.
- The Edge Company S.r.l
- Veronafiere S.p.A.
- Veronesi Holding S.p.A.
- Vetrerie Riunite S.p.A.
- Xilinx GmbH
- To Be Completed

- Selected through a call
  - Periodic meetings
  - Documentation to be reviewed
  - Technical contacts for research projects

2018 ACTIVITIES: NEW POSITIONS

Professors - Researchers

- Associate Professor (ING-INF/05)
  - *Big-data and cloud computing*
  - Elisa Quintarelli
    - previous position: associate professor at Politecnico di Milano
    - approved by the last July CdA meeting
    - starting activity: October 1 2018
- Associate Professor (INF/01)
  - *Internet of Things privacy*
  - Federica Paci
    - previous position: assistant professor at Southampton University
    - to be approved at the next CdA meeting
    - planned starting activity: October 1 2018
- Researcher (RTDa INF/01)
  - *Analysis and elaboration of large-scale data*
  - Alberto Castellini
    - co-funded by the Regional (RIR) project PREMANI on digital manufacturing
    - to be approved at the next CdA meeting
    - planned starting activity: October 1 2018

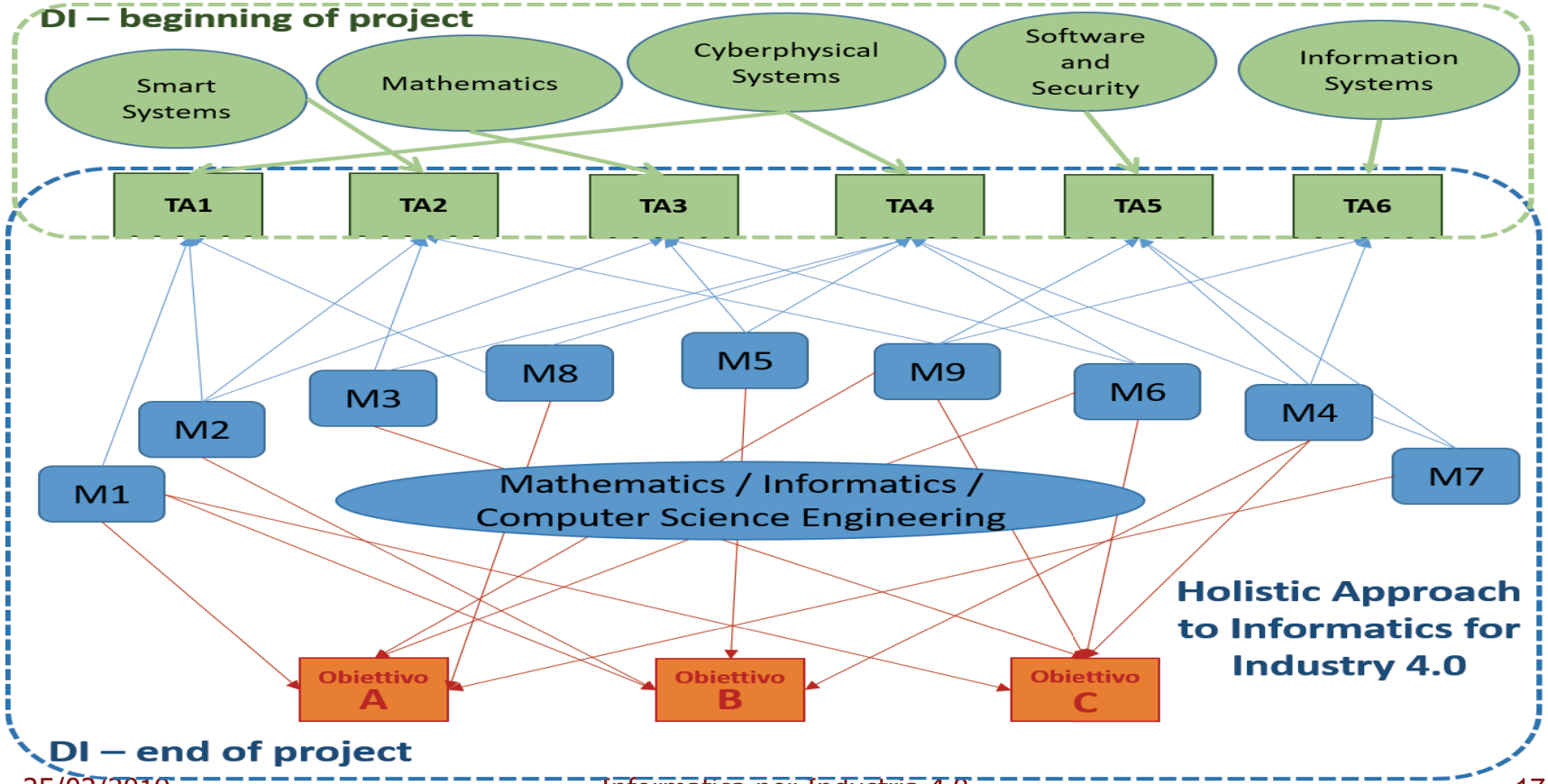
- 2019 - 2020
- Researcher (RTDb INF/01)
  - *Internet of Things security*
  - identified candidates with national habilitation for associate professors
  - planned starting activity: October 2019
- Researcher (RTDb MAT/07)
  - *Modeling, simulation, optimization of CPS*
  - identified candidates with national habilitation for associate professors
  - planned starting activity: October 2019
- Researcher (RTDb ING-INF/04)
  - *Automation of CPS*
  - identified candidates with national habilitation for associate professors
  - planned starting activity: October 2019 – March 2020

Research Assistants – PhD Students

- 2 two-year research assistants (AdR)
  - design of the ICE laboratory, research support, definition of practical laboratory classes
    - identified candidates
    - activities started: October 1 2018
- Ph.D. students:
  - 4 specific positions in the Computer Science Ph.D. course
  - 2 specific positions in the Mathematics Ph.D. course
    - all positively covered
    - activities started: October 1 2018
  - 4 specific positions in the Computer Science Ph.D. course
    - planed starting activities: October 1 2019

2018 ACTIVITIES: RESEARCH ACTIVITIES

The Holistic Approach



Project structure concretization

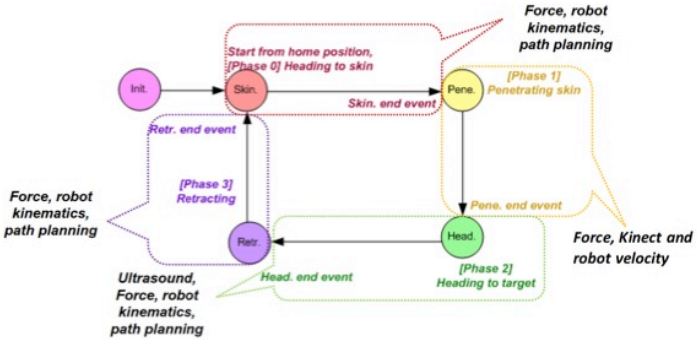
- Starting from the project description approved by MIUR:
  - complete English translation
  - for each enabling technology
    - extension of the state of the art
    - definition of 2018 and 2019 provisional milestones
      - to extend methodologies
      - for reaching project objectives
      - by measuring project indicators
- Actual project description documentation

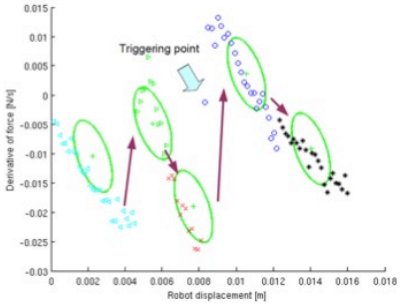
TA1: Advanced manufacturing solutions (Cyber-physical systems)

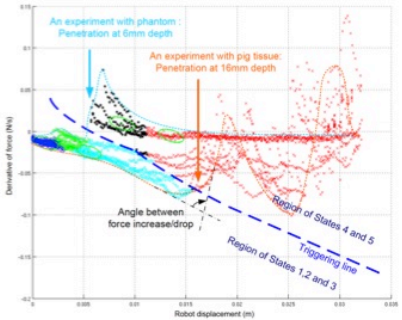
- Develop new control and interaction methods for traditional and new cyber-physical devices:
  - Traditional machine tools and industrial robots
  - Cooperative robots
- Traditional devices:
  - Identify best sensor type, configuration and data processing algorithms to identify faults, measure performance and predict maintenance needs.
- Cooperative devices:
  - Develop training, applications and technologies for new low cost robots.

TA1: Advanced manufacturing solutions (Cyber-physical systems)

- New sensors and algorithms will permit to give high level decision capabilities to cyber-physical systems through extensive data collection, process modeling, machine reasoning and new Human-Robot-Interfaces
- We aim to achieve full integration of machine accuracy and human experience in the design, production and maintenance processes.



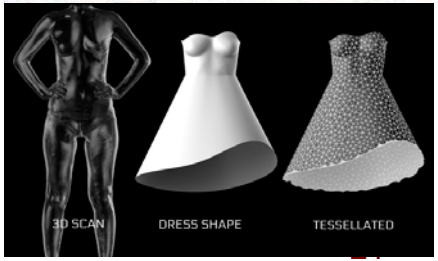




TA2: Augmented reality & Additive manufacturing

(Machine intelligence)

- Novel paradigms for user interaction
  - Mixed reality, scene augmentation, virtual reality training
  - Activity monitoring with tracking, multimodal data capture
  - System and user activity prediction with machine learning
- 3D modelling
  - Computer graphics, geometry processing for digital manufacturing, virtual/mixed world content creation

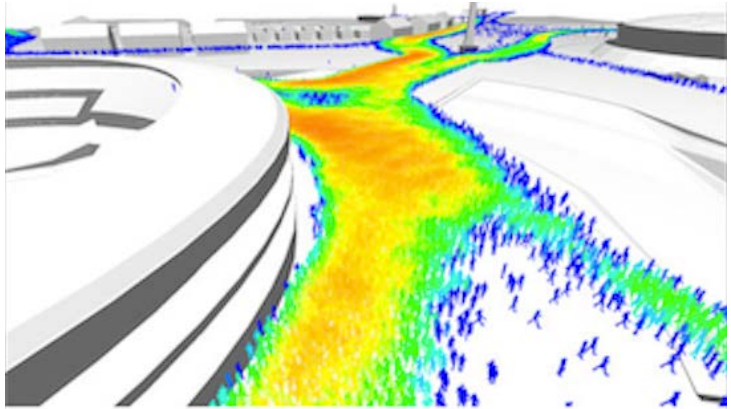


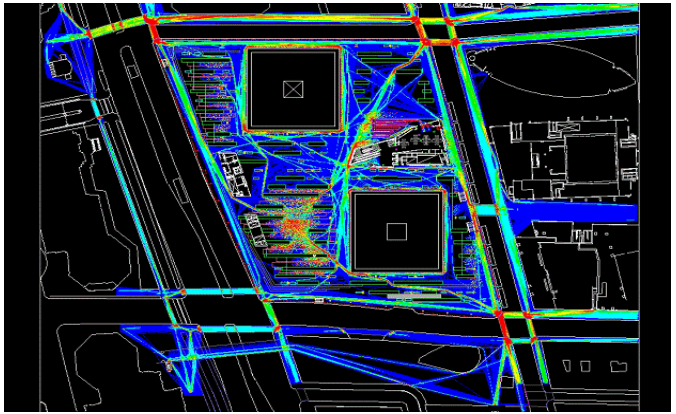
TA2: Augmented reality & Additive manufacturing
(Machine intelligence)

- Objectives/evaluation
  - Validation of AR/VR interaction, gestural interaction prediction end monitoring on specific benchmarks
  - Tests of solutions for human body modelling and shape/appearance modelling and retrieval
  - Demos and scientific publications and presentations

TA3: Simulation (Mathematics – applications and modeling)

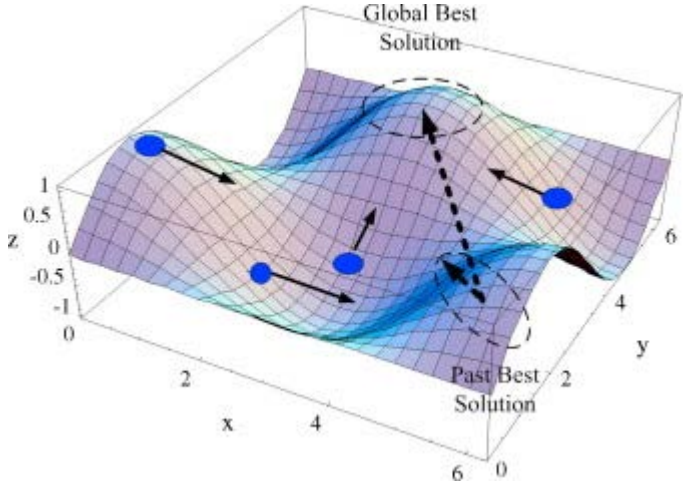
- Advanced mathematical tools for the modelling of complex processes in modern applications: unmanned vehicles design, data-driven forecast, smart cities, logistics, cryptography, biomedical applications.
- Data-model comparison, analytics and numerical simulation of models (HPC knowledge, optimization, …).

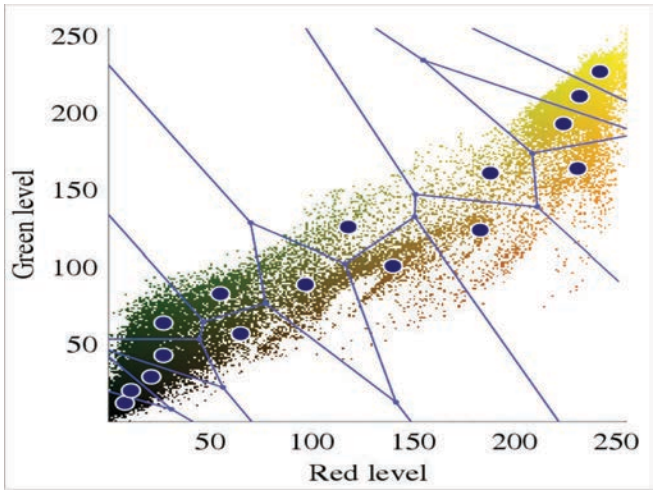




TA3: Simulation (Mathematics – applications and modeling)

- Development of efficient numerical schemes for control and simulation, HPC implementation and open-software platform with downloadable material.
- Scientific publications in peer-review journals, report and communications in international conference, and media press.





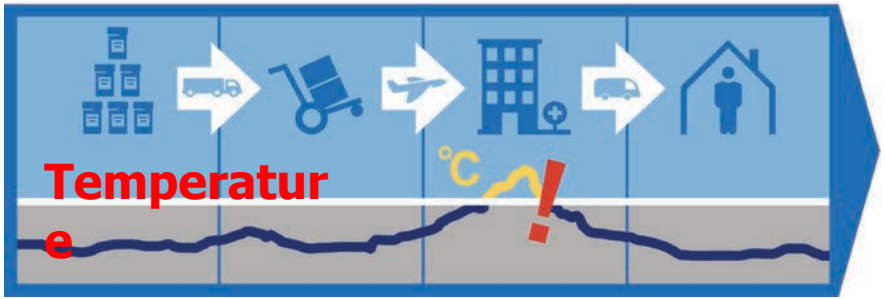
TA4: Industrial internet (Cyber-physical systems)

- Starting point
  - **Asset identification and tracking** through barcode and RFID
  - **Wireless** networks
  - Environmental **sensors** (e.g., temperature)

- Proposition: **Industrial Internet of Everything**
  - Global **integration** of produced objects, production machines and environmental sensors
  - **Formalization** of the manufacturing process to trap errors

TA4: Industrial internet (Cyber-physical systems)

- Objectives
  - Real-time **identification and fixing** of errors and failures in the production chain to save time and money
- Performance indexes
  - % coverage of various manufacturing processes
  - % of trapped errors
  - saved time
  - saved money



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TA5: Cloud Cyber-security (Sw Engineering and Security)

Description

Cloud computing is becoming more and more integrated to the IoT paradigm and Cyber-Physical Systems (CPSs), adding an extra layer of vulnerability in already highly vulnerable systems.

Challenges:

- IoT devices are highly vulnerable due to weak authentication/authorization mechanisms
- Physical consequences of cyber-physical attacks put CPS security apart from IT security

Methodologies

- Authentication/authorization mechanisms for IoT security and privacy
- Static analysis and runtime analysis for CPS security
- Formal metrics to estimate the impact of cyber-physical attacks
- Integration of data flow and operation flows for web security
- Statistical methods and Artificial Intelligence techniques cyber-threat intelligence

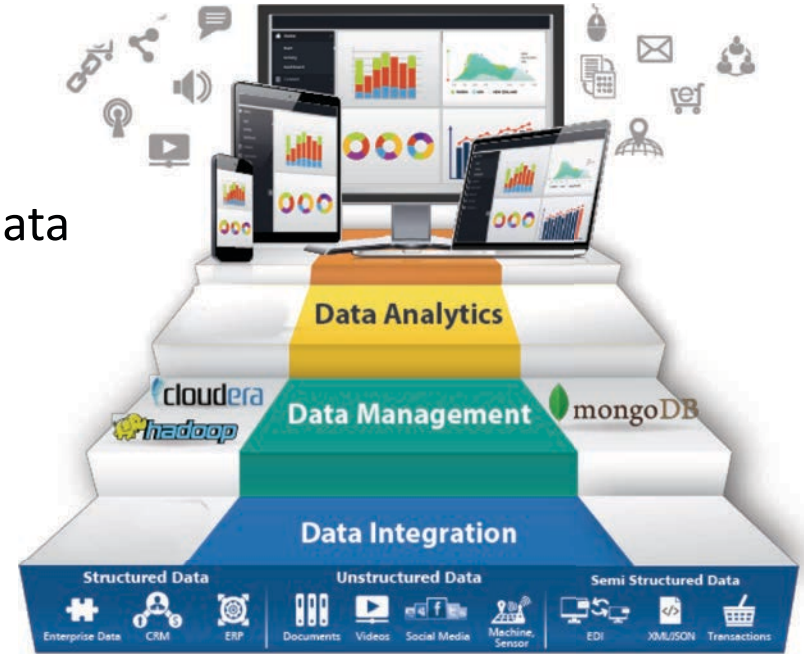
TA5: Cloud Cyber-security (Sw Engineering and Security)

Objectives

Formal and (semi-)formal methodologies to formalize, statically detect and mitigate vulnerabilities in CPSs and IoT devices and applications

TA6: Big-data and analytics (Information systems)

- Characterization of the **data**
  - Heterogeneous sources must be harmonized
  - Data **exploration**: find relevant data
  - Knowledge filtering / **mining**
- Methodologies
  - **Integration** of data flows
  - Data **visualization**



TA6: Big-data and analytics (Information systems)

- Objectives
  - **Automatic** design
    - Guided by the information extracted from the data
  - **Diagnosis** and maintenance

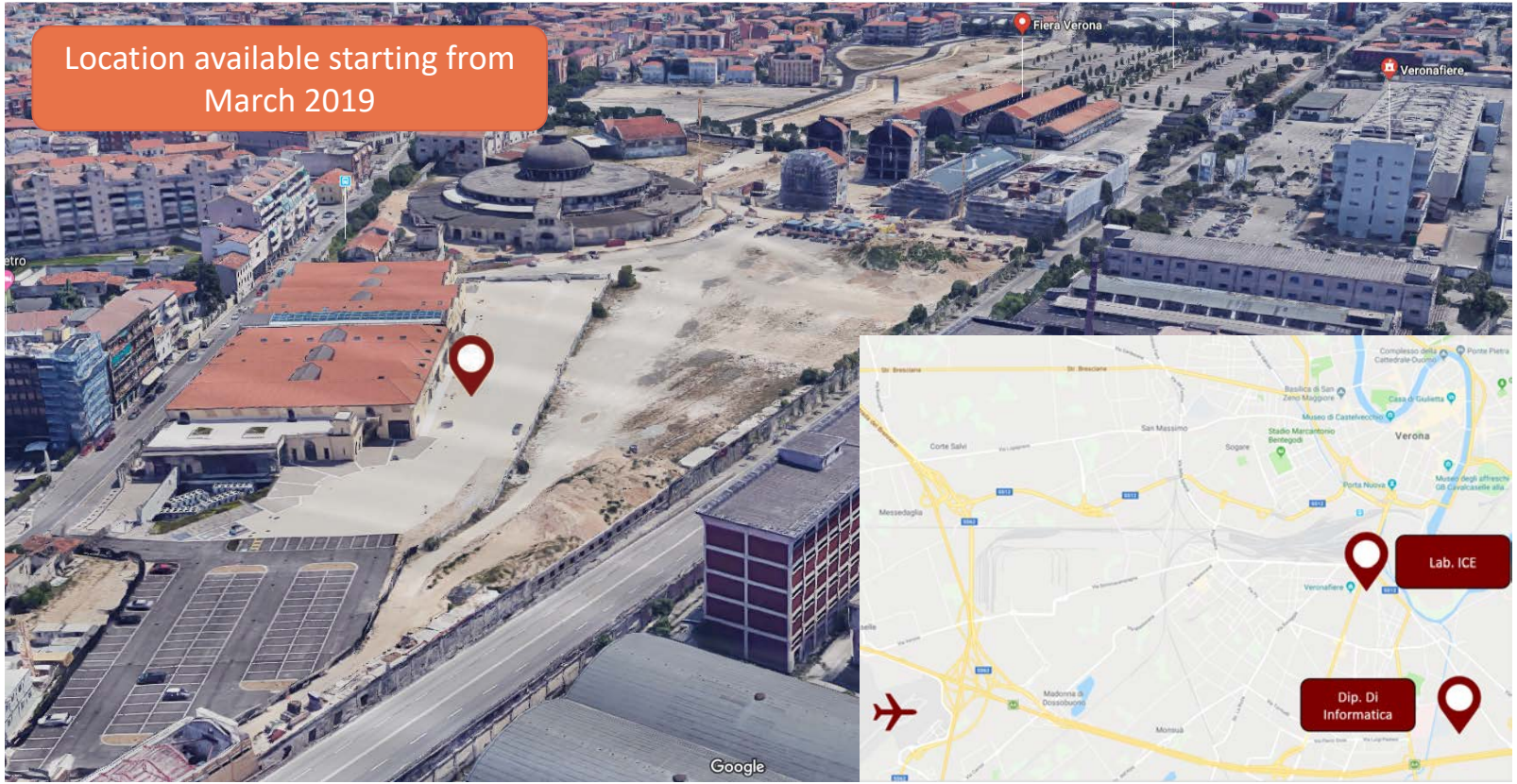
- Performance indexes
  - Successful application of new methodologies to enabling technologies

2018-2019 Activities: Industrial Computer Engineering (ICE) Laboratory

Laboratory for Industry 4.0

- Modular infrastructure to develop, integrate and validate, commercial and custom solutions
- The laboratory will be based on a commercial backbone, specifications to be decided, on which various components will be integrated
- Many open questions:
  - Most relevant sw/hw architecture
  - Degree of modularity
  - Type of manufacturing process
  - Relevance of devices (sensors, robots…) used
  - Open vs custom solutions, i.e. academic vs commercial
  - IP protection and interaction among laboratory users
  - Training and support

ICE Laboratory - Where



ICE Laboratory - System Architecture - I

Enterprise Resource Planning (**ERP**)

Cloud Application

UniVR Comp. Platform

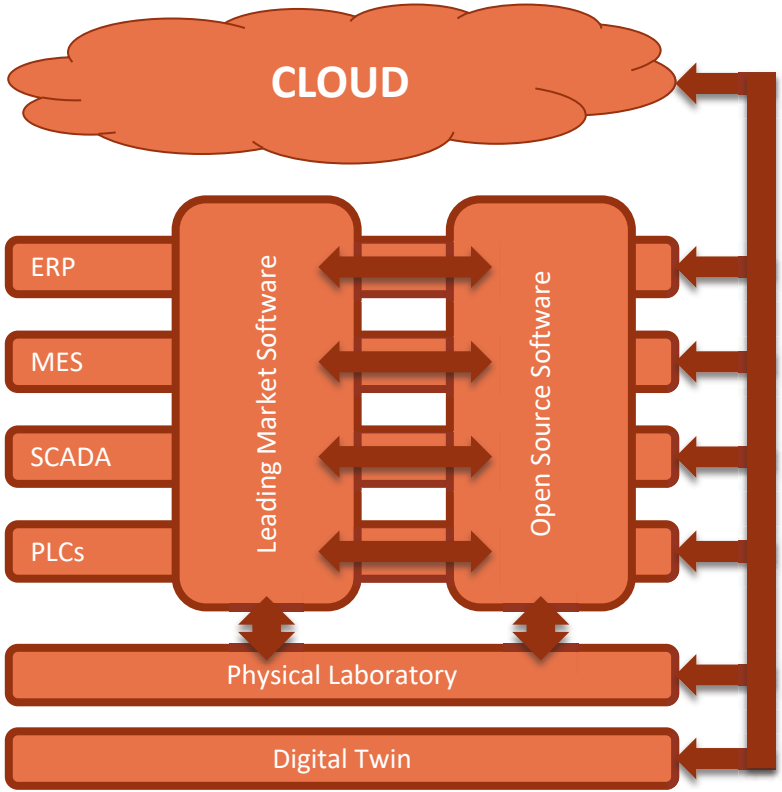
Manufacturing Execution System (**MES**)

SCADA

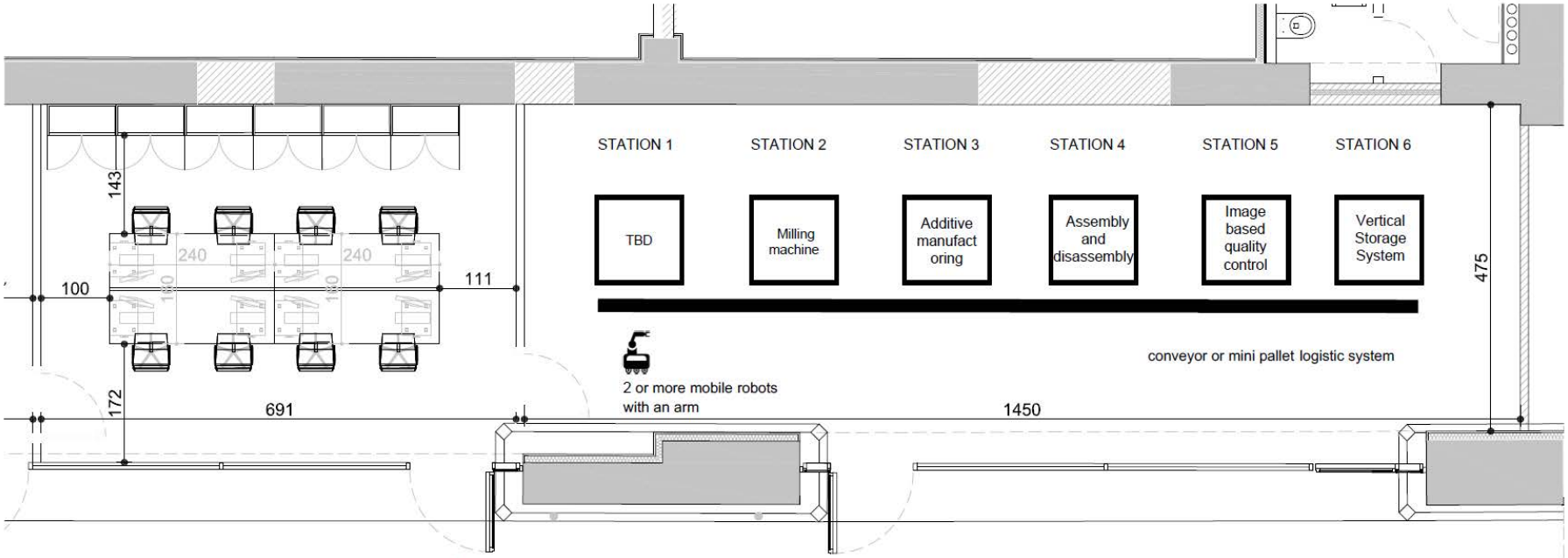
Digital Twin

Physical Laboratory

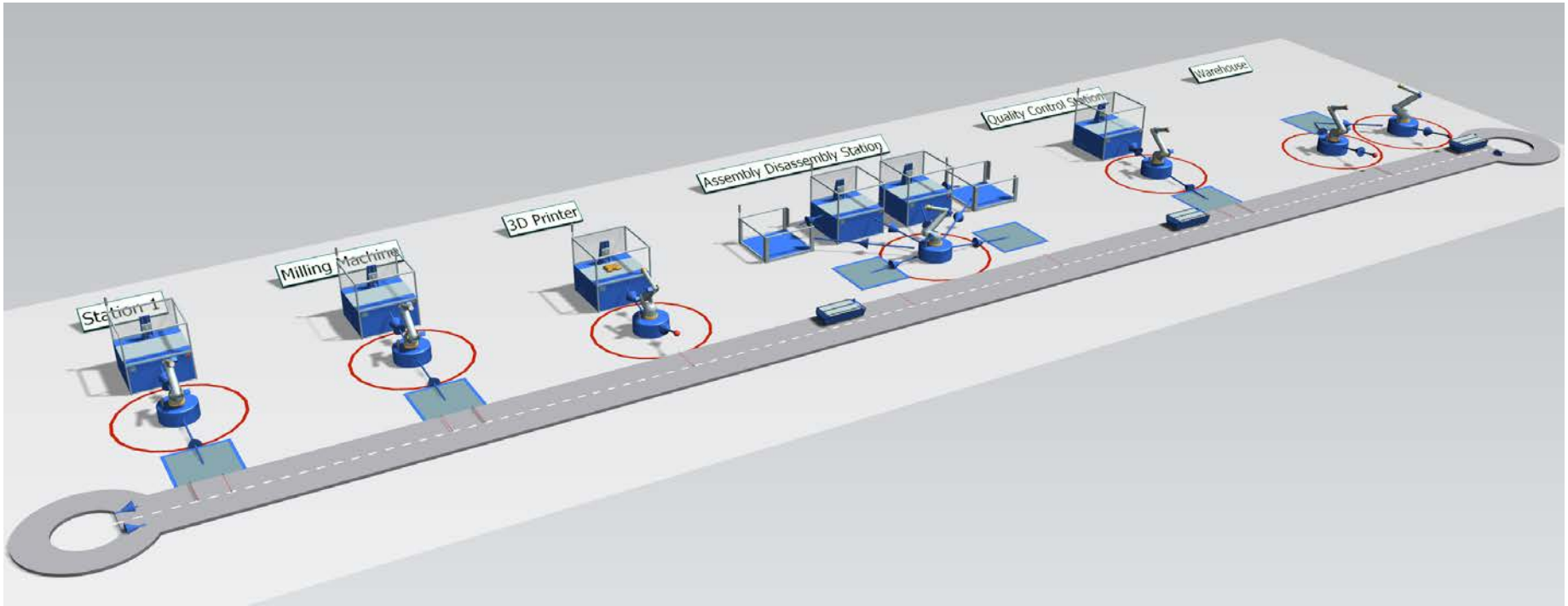
ICE Laboratory - System Architecture - II



ICE Laboratory – LAB Focus



ICE Laboratory – Digital Twin Focus



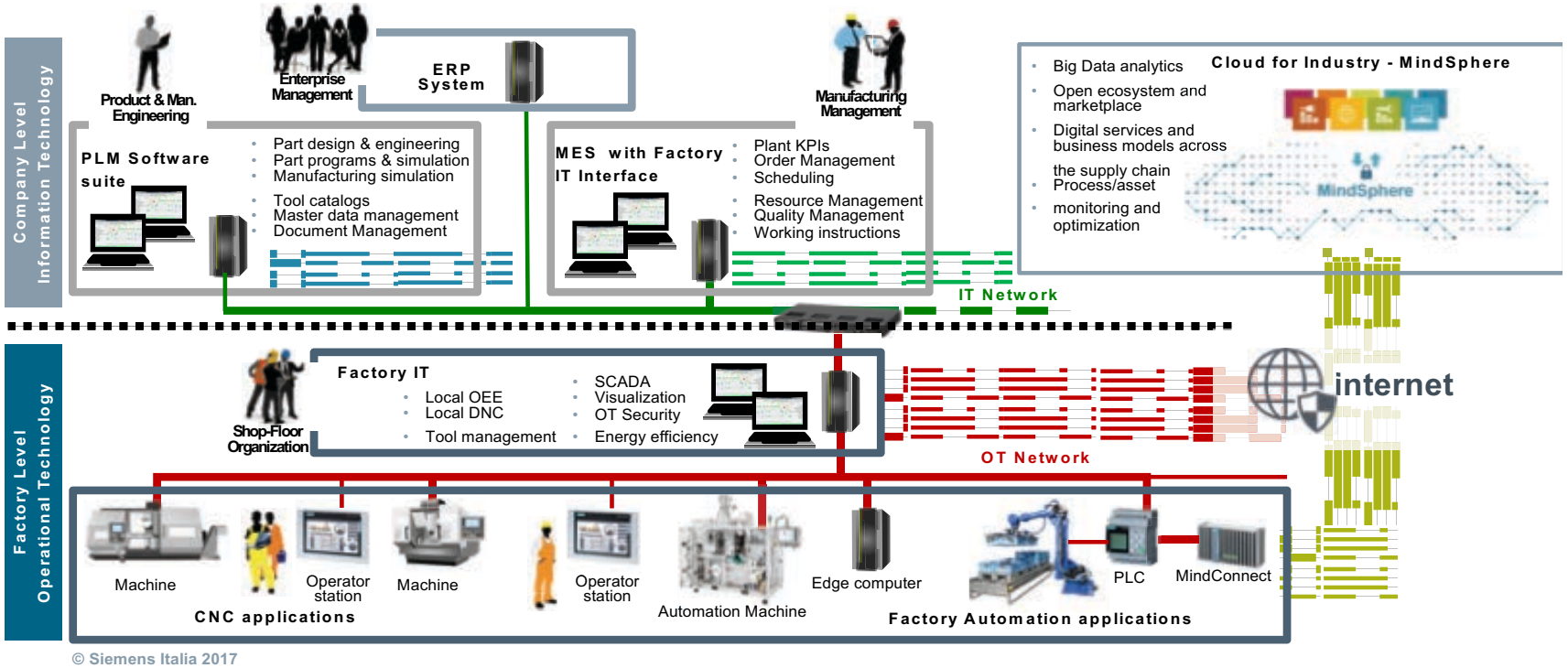
Siemens / CS Department Agreement

- Signed on Nov. 2018 for:
  - co-designing of the ICE lab.
  - sharing of methodologies and knowledge
  - joining use of the lab. facilities
  - contacting with technology providers
  - accessing to software and tools
    - ICE as a show-room to attract industrial research interests

Computer Engineering for Industry 4.0

Siemens Digital Factory outlook
Integration from shop floor to top floor

SIEMENS
Ingegno per la vita



ACTIVITIES 2018-2019: DEGREES

Roadmap

- Mathematics for Industry 4.0:
  - addition of specific competences to the master degree in Mathematics
    - proposed by the Computer Science Department
    - formalized by the Mathematics Teaching Committee
    - approved by the School of Science and Engineering
      - activation: 2019-2020
- Computer engineering for Industry 4.0:
  - extension of the degree in Informatica to cover the basic competences for this master course
    - definition through the industrial advisory board
    - proposed by the Computer Science Department
    - formalized by the CS Teaching Committee
    - approved by the School of Science and Engineering
      - activation: 2019-2020
  - master degree in Computer engineering for Industry 4.0
    - working team defined by the Computer Science Department
    - definition of the proposal by March 2019
      - activation: 2020-2021

Master Degree in Mathematics

- Enriched with courses in:
  - Foundations of data analysis (6cfu - MAT/08)
  - Statistical learning (3cfu - MAT/06 + 3cfu INF/01)
  - Laboratory classes in:
    - Computational geometry (MAT/03),
    - Numerical methods for partial diff. eq. (MAT/08),
    - Numerical modelling and optimization (MAT/07-MAT/08)
- Educational program status:
  - Approved by the Department of Computer Science
  - Approved by the School of Science and Engineering
  - Approved by the Academic Senate

Computer Engineering for Industry 4.0

optimization
simulation
data analysis
security / privacy
big data
cloud computing
architecture cloud
embedded software
middleware
operating systems
embedded systems
Field bus / wireless networks
sensors /actuators

TA3. Simulation

TA2. Augmented Reality,

TA5. Cloud, Cyber-Security

TA6. Big-Data and Analytics

TA4. Industrial Internet

TA1. Advanced Manufacturing Solutions

- Students trained in:
  - Industrial computer engineer
- Main skills:
  - Knowledge of the entire computing hierarchy from sensors to cloud
  - Experience with the 3C paradigm (computing, control, communication) and mechatronic engineering
  - Focus on solid computer science basis applied to the fields of robotics, cyber-physical systems, artificial intelligence, and big data analytics.

Assumptions and View

- Students will enter the Master degree with solid Computer Science knowledge and basic engineering skills, with respect to standard Computer Science bachelor students
- In particular, they will have knowledge about:
  - automatic control
  - signals analysis
- Global view:
  - Industry 4.0 is based on a set of enabling technologies that require high-level and widespread computer engineer skills
  - Industrial computer engineering is becoming the unified knowledge to design, integrate and manage industry 4.0 production plants
    - this produces he so-called digital manufacturing
  - Robotics technologies exploiting advanced cyber-physical systems have a crucial role to enable digital manufacturing
    - focusing industrial computer engineering to robotics and digital manufacturing is the main strategy for training engineers able to design, integrate and manage industry 4.0 production plants

Two-level Degree Structure

- Laurea (bachelor) degree in Computer Science
  - Enriched with courses in:
    - system and control and signals analysis
  - Approved
  - Activation expected by October 2019
- Master Degree in Industrial Computer Engineering:
  - Curricula will include courses in:
    - robotics,
    - cyber-physical systems design
    - artificial intelligence
    - cloud – big-data - security
    - industrial internet
    - advanced control strategies
  - Activation expected by October 2020

Industrial Computer Engineering vs. Computer Engineering

- During the Master degree, students will acquire knowledge in industrial engineering, such as:
  - Industrial Plant main characteristics
  - Computer Numerical Control (CNC) manufacturing
  - Computer Aided Design (CAD) techniques
  - Human Computer Interface (HMI) technologies
  - Industrial Electronics
- This knowledge differentiates the specific specializations of the Industrial Computer Engineering degree from a typical Computer Engineering Master degree
- Possible specializations will be:
  - Industrial robotic system designer
  - Industrial system integrator
  - Production programmer and analyst
- Possible master degree title:
  - Robotics & Smart Systems Engineering

Industrial Robotic System Designer

- Target professional figure:
  - Designer of robotic systems with advanced cyber-physical features

- Main knowledge to be acquired:
  - Modeling, specification and verification of Robotic systems
  - Specification of cyber-physical components and property analysis
  - Design of the networking infrastructure
  - Analysis and design of system controllers
  - Analysis and design of computing resources
  - Design of collaborative and cooperative robotic architectures
  - Techniques for safety and certification

Industrial Systems Integrator

- Target professional figure:
  - Integrator of robotic and cyber-physical systems into manufacturing and information management systems

- Main knowledge to be acquired:
  - Definition of machine tool properties from the point of view of data and processes
  - Identification of the most appropriate computing components
  - Definition of data sharing modes within the system architecture
  - Integration of components and processes
  - Optimization of processes and data flows
  - Integration of machine tools into the enterprise information system

Production Programmer and Analyst

- Target professional figure:
  - Production programmer and industrial data analysis expert

- Main knowledge to be acquired:
  - Analysis of production processes
  - Production program of industrial systems
  - Analysis and integration of production data
  - Analysis of data through machine learning techniques
  - Techniques for predictive maintenance
  - Techniques for quality control
  - Data security and privacy

Final Master Degrees Organization

Sicurezza dei Sistemi Informatici	Ingegneria del Software	Sistemi Informativi e A.I.

- Linguaggi e Intelligenza Artificiale
- Algoritmi e Complessità
- Basi di dati e Verifica
- TBD

Ingegneria *e* Scienze Informatiche

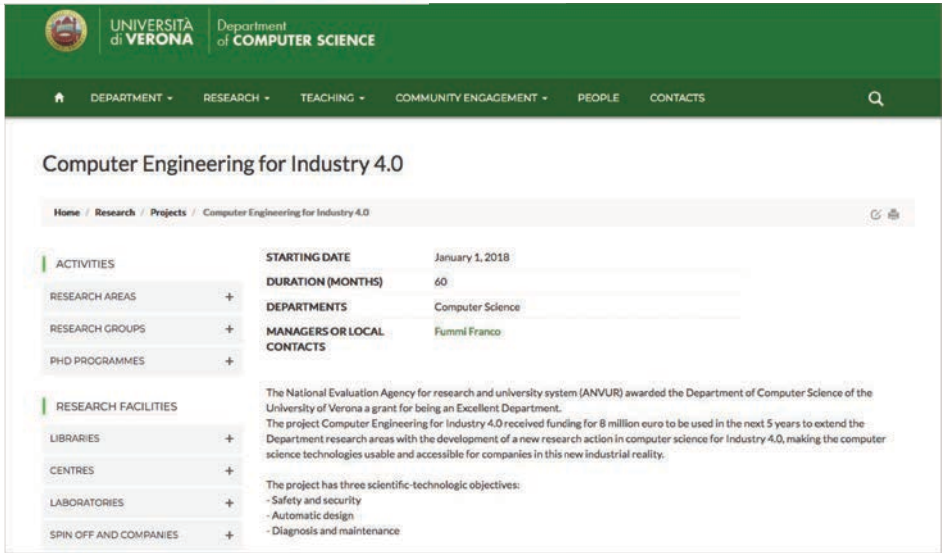
Industrial Robotic System Designer	Industrial Systems Integrator	Production Programmer and Analyst
Embedded Systems & IoT	Robotics & Cyber-Physical Systems	Smart Systems & Data Analytics

- Industrial plants & Production mgt.
- Dynamic systems (lab)
- Machine learning & Artificial intel.
- Discrete events systems (lab)

Robotics & Smart Systems Engineering

ACTIVITIES 2018: DISSEMINATION

Web Page and Presentation



- Press release:
  - Univr Magazine - Marc 1 2018
  - VeronaSera - Marc 1 2018
  - La Cronaca di Verona e del Veneto - Marc 1 2018
  - TGR Veneto - Marc 2 2018

Seminars and Meetings

- Seminars:
  - *La sicurezza informatica ai tempi dell'Industria 4.0*
    - Marc 26 2018
  - *Industry 4.0: Participatory Design as a process to share the benefits of automation*
    - April 24 2018
  - *Industrial Advisory Board Constitution*
    - May 10 2018
  - *Industrial research day*
    - June 13 2018

Research Contacts

- Regional Innovation Network (**RIR**):
  - IMPROVENET (ICT for Smart Manufacturing Processes Veneto Network),
  - M3 Net (Precision mechanics, microtechnologies, additive manufacturing),
  - Veneto Clima ed Energia (companies specialized in thermo-mechanics),
  - ICT4SSL (ICT for Smart and Sustainable Living)
    - projects funded in for all RIRs
- **SMACD** Competence Center
  - ICE lab. In the set of dissemination laboratories

- Companies:
  - Ferretto Group
  - Siemem
  - Veronesi Holding
  - Gruppo Italiano Vini
    - explored research activities
    - contracts to be defined

ROADMAP 2018-2019

2018 2019-Q1/Q2 Roadmap

- Distribution of the project proposal to each member of the IAB, completion of the Web page
  - end of May 2018 (DONE)
- Industrial research day (presentation to current students)
  - June (DONE)
- Definition of specification for the ICE laboratory
  - July (DONE)
- Computer Science Degree transformation proposal
  - July (DONE)
- First research report
  - December (DONE)
- Seminar on Industry 4.0 (Speedhub Joint Activity)
  - Mar. / Apr. / May 2019 (on-going)
- International procurement of the ICE lab.
  - Feb. / Mar. (on-going)
- Master degree draft proposal
  - Feb. / Mar. (on-going)
- ICE lab. first opening
  - Jul. (on-going)