chist-era

Report on Deliverable D10.5

Strategic Analysis of the Supported Topics 2022

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<tr><td>Publishable abstract</td><td colspan="3">The report presents the analysis of the outcome of the funded projects in the Call 2017 topics:
• Object recognition and manipulation by robots: Data sharing and experiment reproducibility (ORMR);
• Big data and process modelling for smart industry (BDSI)
It also gives insight into the evolution of those topics.</td></tr>
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1. Introduction

The task 10.2 related to the deliverable 10.5 covers the strategic analysis for the topics funded by CHIST-ERA calls. This task entails an analysis of the results obtained by on-going projects and aims at the definition of suitable criteria for the identification of emerging research communities and their maturity. In addition, an analysis of the needs and opportunities of research projects for specifically identified topics is conducted to determine their compatibility with possible future European programmes. Deliverables of this task will be made available to the community of the Pathfinder programme of the European Innovation Council and other fora.

2. Analysis of CHIST-ERA Call 2017 Topics

a. Scope of Deliverable 10.5

In order to allow for maturation of both funded projects and topic, deliverable 10.5 focuses on the topics of the Call 2017:

- Object recognition and manipulation by robots: Data sharing and experiment reproducibility (ORMR);
- Big data and process modelling for smart industry (BDSI).

Projects of the Call 2017 are planned to be finished in 2022 but some project extensions are possible due to the sanitary crisis. During their lifetime, the corresponding research communities could form, exchange and present their vision of the future of their topics thanks to three editions of the CHIST-ERA yearly projects seminar.

This deliverable draws on the work performed in task 4.1 'Call 2017 projects follow-up and monitoring' and in task 10.1 'Projects Seminar organisation'.

b. Analysis of the topic *Object recognition and manipulation by robots: Data sharing and experiment reproducibility (ORMR)*

i. Evolution of the Funded Projects: From Project Goals to Project Outcomes

The CHIST-ERA consortium funded seven projects in the ORMR topic. Together, those projects address the following issue: Amelioration of robotic grasping and manipulation. The table below details the specific scope of each project.

Name	Project goals
BURG	***Benchmarks for UndeRstanding Grasping*** • Trajectory generator to create and move the robot actuator to different viewpoints; • Recording program to obtain sensor data and position from different sensors; • Tools for obtaining data annotations for vision methods relevant to grasping.
CORSMAL	***Collaborative object recognition, shared manipulation and learning***

	• Develop a framework for recognition and manipulation of objects via cooperation with humans by mimicking human capability of learning and adapting across a set of different manipulators, tasks, sensing configurations and environments; • Define learning architectures for multimodal sensory data and for aggregated data from different environments; • Improve the adaptability and robustness of the learned models, and to generalise capabilities across tasks and sites.
Heap	***Human-Guided Learning and Benchmarking of Robotic Heap Sorting*** • Sorting a complex, unstructured heap of unknown objects –resembling nuclear waste consisting of a set of broken deformed bodies– as an instance of an extremely complex manipulation task; • Develop new perception algorithms and investigate interactive perception in order to improve the robot's understanding of the scene in terms of object instances, categories and properties; • Building an end-to-end benchmarking framework for application in realistic scenarios.
InDex	***Robot In-hand Dexterous manipulation by extracting data from human manipulation of objects to improve robotic autonomy and dexterity*** • Build a multi-modal artificial perception architecture that extracts data of object manipulation by humans; • Create a multimodal dataset of in-hand manipulation tasks such as regrasping, reorienting and finely repositioning; • Develop an advanced object modelling and recognition system, including the characterisation of object affordances and grasping properties, in order to encapsulate both explicit information and possible implicit object usages • Autonomously learn and precisely imitate human strategies in handling tasks; • Build a bridge between observation and execution, allowing deployment that is independent of the robot architecture.
IPALM	***Interactive Perception-Action-Learning for Modelling Objects*** • Develop a methodology able to provide an initial estimate of the physical properties of target objects using vision and language; • Developing a methodology to measure the physical properties of the objects based on an automated interactive perception and learning loop, thus it will involve robotics manipulation experiments; • Create a database of models of diverse types of objects (including articulated and deformable ones); • Develop robust manipulation skills by exploiting the dynamics properties of objects; • Develop a benchmark, with protocols and tasks to perform, as well as the metrics to evaluate the manipulation methods; • Construction of a website to present the IPALM project and host the software and data resources.
LEARN-REAL	***Improving reproducibility in LEARNing physical manipulation skills with simulators using REAListic variations*** • Learn manipulation skills through simulation for object, environment and robot, with an innovative toolset; • Develop a simulator with realistic rendering of variations allowing the creation of datasets and the evaluation of algorithms in new situations;

	- Develop a virtual-reality interface to interact with the robots within their virtual environments, to teach robots object manipulation skills in multiple configurations of the environment; - Develop a web-based infrastructure for principled, reproducible and transparent benchmarking of learning algorithms for object recognition and manipulation by robots.
PeGRoGaM	***Perception-guided robust and reproducible robotic grasping and manipulation*** - Ameliorate autonomous robotic grasping of objects in challenging scenes; - Develop perception algorithms that are robust in challenging environments; - Develop autonomous grasp planners using visual features perceived by algorithms developed in the first point.

From the progress reports submitted by the participating teams and the review reports by the scientific experts appointed by CHIST-ERA, we can conclude that in general the projects progressed according to the initial plan and generated relevant results, as detailed in the table below:

Name	Major project outcomes
BURG	***Benchmarks for UndeRstanding Grasping*** - Novel method for grasping objects from a partial point cloud based on a single-view depth image; - Development of a BURG Toolkit: a publicly available Python package for Benchmarking and Understanding Robotic Grasping; - Publicly available SetupTool which enables the creation of reproducible startup configurations for grasping experiments of table-top scenes; - Publicly available Grasp Evaluator for evaluating the grasps provided by different methods for estimating grasps; - Publicly available Grasp simulation; - Publicly available evaluation tools used for benchmarking the task of placing flat cloths. These tools provide simple but continuous metrics to quantify the percentage of error in a flat cloth.
CORSMAL	***Collaborative object recognition, shared manipulation and learning*** - Collection of a CORSMAL Containers Manipulation dataset of users manipulating containers; - Collection of a Crop-CORSMAL Container Manipulation (C-CCM) dataset of containers for which the pouring process has been finalized, and automatically sampled, followed by manual verification, from the CORSMAL Container Manipulation dataset; - Collection of a dataset human-to-human interactions involving pairs; - Creation of a benchmark protocol for human-to-robot handovers of unseen containers with unknown filling; - Distribution of an open source CORSMAL baseline, developed to perform human-to-robot handover of unseen cups with an unknown filling.
Heap	***Human-Guided Learning and Benchmarking of Robotic Heap Sorting*** - Set-up of a reproducible object dataset; - Benchmarking of the grasping pipeline; - Object class detection and pose; - Development of an Efficient Image-to-Image Translation HourGlass-based Architecture for Object Pushing Policy Learning; - Development of an interactive instance segmentation model;

	• Development of a probabilistic part-based scene segmentation; • Development of a Framework for Assisted Teleoperation.
InDex	***Robot In-hand Dexterous manipulation by extracting data from human manipulation of objects to improve robotic autonomy and dexterity*** • Development and test of a data glove and refinement of the sensing setup; • Development of new methods for object detection and pose estimation for object manipulation; • Development of new methods and technologies for integration of new robotic capabilities in the HRI context; • Development of new methods for biological data augmentation and datasets augmentation, useful for our project strategies; • Development of new methodology using transfer learning, data features extraction and fusion for gesture recognition and other biological data to learn motions and control robot hand;
IPALM	***Interactive Perception-Action-Learning for Modelling Objects*** • Development of D-NeRF, a method that extends neural radiance fields to a dynamic domain; • Development of a method for detecting and segmenting objects, even when these objects are unknown; • Development of a method that can recognize new objects and estimate their 3D pose in RGB images even under partial occlusions; • Development of a method for estimating the 6D motion of unknown objects; • Development of a Conditional-Flow NeRF (CF-NeRF) method, a novel probabilistic framework to incorporate uncertainty quantification into NeRF-based approaches; • Development of a learning-based approach to predict the dynamics of deformable clothes given 3D skeleton motion sequences of humans wearing these clothes; • Development of a novel soft robotic hand design with human inspired soft palm.
LEARN-REAL	***Improving reproducibility in LEARNing physical manipulation skills with simulators using REAListic variations*** • Production of a survey paper about knowledge transfer in vision recognition tasks; • Development of a Discriminative and Geometry-Aware Domain Adaptation (DGA-DA); • Development of a Discriminative Noise Robust Sparse Orthogonal Label Regression-based Domain Adaptation (DOLL-DA); • Development of a novel method using a multi-cameral design composed of subtask-specific lightweight decoder and encoder–decoder units.
PeGRoGaM	***Perception-guided robust and reproducible robotic grasping and manipulation*** • Development of a pinching-grasp models for unknown objects; • Development of a scooping-grasp model for unknown objects; • Development of novel grippers for intelligent grasping; • Development of multiple cylinders extraction strategies from organized point cloud; • End-to-end deep learning approach for predicting grasping failures in soft hands; • Benchmarking of grasp planning algorithms.

ii. Evolution of the Topic

As part of the projects seminar's format, the projects in the same topic were invited each year to reflect jointly on their progress and on the key challenges that still need to be tackled in their field. They produced one joint topic presentation per year that are made public and available from the CHIST-ERA website (http://www.chistera.eu/funded-topics). The following challenges were identified during the Projects Seminar 2022:

- Standardization of representations and interfaces:
  - Reproducible setups and dataset integration: documentation and maintenance beyond the projects;
  - Combining learning modalities (orchestrating learning by interaction and self-refinement);
  - Integration and engineering effort not available in academia.
- Increase robustness to uncertain conditions.
- Fusion of audio, visual and tactile sensing.
- Benchmarks accounting for different types of variations and involvement of humans: adaptation of the pre-trained models across labs and conditions.
- Engagement with the community after the projects end.
- Uptake by industry.

As one can notice, there are still of lot of challenges that remain to be tackled with, both technical and societal.

c. Analysis of the topic *Big data and process modelling for smart industry (BDSI)*

i. Evolution of the Funded Projects

The CHIST-ERA consortium funded seven projects in the BDSI topic. The table below details the specific scope of each project.

Name	Major project outcomes
ABIDI	***Context-aware and Veracious Big Data Analytics for Industrial IoT*** • Build reliable industrial IoT networks; • Automate the processing of big variety, volume, and velocity industrial IoT data streams, and offering big data insights with centralized or distributed solutions; • Develop adaptive models-based decision support and recommendation tools that enable the automated control of the system with processing big industrial data.
BIG-SMART-LOG	***The Use of Big Data Analytics for Process Modelling in Smart Logistics Operations*** • Design and development of a semantic-enhanced self-learning processing model which captures the rhythm of existing infrastructure by analyzing operational data in real-time, uses learned data to positively influence the utilization of existing infrastructure and resources, increase system resiliency and service quality, and reduce greenhouse gas emissions, fuel consumption, idle times, traffic congestion, revenue losses, late deliveries, customer complaints through the use of big data technologies.
FIREMAN	***Framework for the Identification of Rare Events via MAchine learning and IoT Networks***

	• Large data acquisition / dissemination: A physical process is monitored by sensors that pre-process the (assumed large) collected data and send the pre-processed information to an intelligent node (e.g. aggregator, central controller); • Big data fusion: The intelligent node uses machine learning techniques (e.g. data clustering, pattern recognition, neural networks) to convert the received ("big") data to useful information to guide short-term operational decisions related to the physical process; • Big data analytics: The physical process together with the acquisition and fusion steps can be virtualized, building then a cyber-physical process, whose dynamic performance can be analysed and optimized through visualization (if human intervention is available) or artificial intelligence (if the decisions are automatic) or a combination thereof.
PACMEL	***Process-aware Analytics Support based on Conceptual Models for Event Logs*** • Develop a process-aware analytics framework for analyzing data from sensors and devices to enable the use of this data for process modeling and analysis, with the aim of improving the business processes considered in the industry on the high-level.
RadioSense	***Wireless Big Data Augmented Smart Industry*** • Develop an adaptive workspace sharing system for dynamic smart industrial environments; • Device-free Gesture-based Control: human-robot interaction by in-air gesture recognition from heterogeneous multi-antenna CSI streams and machine-attached sensors; • Device-free Localization: develop new radio sensing theory for multi-subject tracking and utilize multiantenna massive MIMO, beamforming and high-frequency devices (1-5GHz up to sub-THz bands) to track activities of multiple moving subjects in dynamic scenarios; • Device-free Safety Guarantee: identify behavior and motion that compromises worker safety in dynamic workspaces; develop adaptive learning, to address environmental and human behaviour changes and to isolate irrelevant interference sources; aggregate CSI data with other sensors; propose a cloud-IoT platform; • Proof-of-concept cloud-IoT Platform: showcase the RadioSense concept, verify/validate the major functionalities and enabling technologies for future device-free human activity monitoring in the CNR Re/De-Manufacturing pilot plant.
SOON	***Social Network of Machines*** • Investigate the impact of the social autonomous agents in the industrial manufacturing processes optimization; • Maintain the processes parameters at their nominal values and minimising or avoid the production flow disruption or outage through a set of adequate interventions such as predictive maintenance measures; • Identification and early anticipation of the malfunctions or faults occurrence, their nature and localisation.
SPuMONI	***Smart Pharmaceutical MaNufacturIng*** • Deliver innovative scientific approaches to establish and assure constant proof of the authenticity of pharmaceutical manufacturing data to support dynamic data quality, compliance, and auditability.

From the progress reports by the participating teams and the review reports by the scientific experts appointed by CHIST-ERA, we can conclude that projects progressed generally according to the initial plan and generated relevant results, as detailed in the table below:

Name	Major project outcomes
ABIDI	***Context-aware and Veracious Big Data Analytics for Industrial IoT*** • Development of a benchmarking infrastructure for Kafka and ElasticSearch; • Implementation of a Python package for API for task/data offloading in an edge infrastructure; • Implementation of a first version of a tool for real-time demand response decision support between Oulun Energia and City of Oulu; • Improvement of the setup for measuring the reliability of IoT network technologies, adding new communication protocols such as 4G or NB-IoT; • Optimization of the setup to experimentally measure the energy consumption related to the transmission process; • Improvement of the convergence speed and accuracy of the architecture for decentralized learning.
BIG-SMART-LOG	***The Use of Big Data Analytics for Process Modelling in Smart Logistics Operations*** • Literature overview Enterprise Ontology, Business Process Modelling, Enterprise Architecture and Semantic Modelling and Processing to deliver a Semantically Enhanced Process Modelling Framework to enable smart logistics; • Development of the data visualization framework; • Development of a semantically Enhanced Reference Model Generator; • Development of process and Models Repository Manager; • Development of meta-data Model Generator.
FIREMAN	***Framework for the Identification of Rare Events via MAchine learning and IoT Networks*** • Set up of a general framework to define the boundary conditions of the specific problem to be solved based on the proposed 3-layer model utilizing six guiding questions; • Proposal of event-driven data acquisition methods to be employed in combination with fault detection and classification methods aiming to improve their effectiveness; • Study of different large-scale transmission techniques focused on machine-type communications, including traffic modeling, power wide area networks, non-orthogonal multiple access, network slicing, waveform design, antenna polarization, intelligent reflecting surfaces, and massive multi-antenna systems; • Analysis of data aggregation for distributed networks and clustering formation; • Extensive analysis of Quantitative Association Rule Mining Algorithm (QARMA) as a tool for fault detection and classification (including rare events); • Definition and initial studies of the testbeds.
PACMEL	***Process-aware Analytics Support based on Conceptual Models for Event Logs*** • Implementation of new advanced scientific methodologies; • Development of innovative software ; • New ideas, new knowledge, new interpretative models of complex phenomena.
RadioSense	***Wireless Big Data Augmented Smart Industry*** • Development of a cloud platform and consensus-driven Federated Learning technology; • Exploration of LoRa for Long-range Through-wall Sensing;

	• Lightweight gesture recognition from mmWave Radar Point clouds via message passing graph CNNs.
SOON	***Social Network of Machines*** • Novel predictive maintenance algorithms based on social multi-agents approach; • Open datasets with manufacturing data to share with the scientific community; • An evaluation framework to ensure repeatability and validate the resilience of the proposed approach; • Metrics to assess and compare intelligence of cooperative multi-agent systems.
SPuMONI	***Smart Pharmaceutical MaNufacturIng*** • Data quality controls specifically with respect to hinder data falsifiability; • Traceability assurances that security, privacy, compliance and ownership concerns have been properly met; • Intelligent control, coordinated data gathering, and processing within a number of contexts and environments.

ii. Evolution of the topic

As part of the projects seminar's format, the projects in the same topic were invited each year to reflect on their progress and on the key challenges that still need to be tackled in their specific field. They produced presentations that are made public and available from the CHIST-ERA website (http://www.chistera.eu/funded-topics). The following challenges were identified during the Projects Seminar 2022:

- Long-term vision
  - Keep the human in the loop (HMI-HRI);
  - Advances in next-generation networks & industrial connectivity;
  - New sustainable way of manufacturing through digitization;
  - Smart manufacturing (robotic assisted) and multi-agent systems.
- Research methods
  - Address limitations of current AI methods (centralized vs. distributed);
  - Interpretable/explainable modules for actionable insights and decision-making;
  - Convergence in cyber-physical system modeling approaches;
  - Experimental validation of theoretical achievements;
  - Stream mining with industrial data;
  - Data and model-driven analysis (statistical, physical/electromagnetic modelling).

3. General comments

Based on the scope of the supported topics and the progress and analysis of the funded projects about what still needs to be investigated, certain future calls from the Horizon Europe Cluster 4 and EIC Work Programmes 2023-2024 are identified as being of interest to the CHIST-ERA Call 2017 research communities.

Topic	Relevant Horizon Europe Work programme: relevant topics of WP 2021-2022

	EIC funding schemes • **EIC Transition open – for further valorisation of the projects research results** EIC Transition funds innovation activities that go beyond the experimental proof of principle in laboratory. It supports both the maturation and validation of your novel technology in the lab and in relevant application environments (by making use of prototyping, formulation, models, user testing or other validation tests) as well as the development of a business case and business model towards the innovation's futured commercialisation. • **EIC Pathfinder open – for tackling the identified challenges of the research area** EIC Pathfinder Open involves interdisciplinary research and development. By bringing diverse areas of research together, often with different perspectives, terminologies and methodologies, within individual projects and within a portfolio of projects, really new things can be generated and entirely new areas of research can be opened up. It is up to you to compose the team that you need, that you can learn from, and that you can move forward with.
ORMR	**HORIZON-CL4-2023-DIGITAL-EMERGING-01-01: Novel paradigms and approaches, towards AI-driven autonomous robots (AI, data and robotics partnership) (RIA)** Scope: Achieve substantial "next step autonomy" in robots, undertaking non-repetitive tasks in realistic settings, including Human-Robot interactions, as well as robots acting in isolation. This next step autonomy should clearly delineate from state-of-the-art solutions and can be illustrated by the following non-exhaustive examples: • In autonomy to reach the point where the robot systems, operating in complex and dynamic working environments can autonomously select the tasks and task sequences that are needed to achieve long term mission goals over long periods of autonomous operation, relative to the current state of the art, and are able to react and adapt to changes in both the environment and to the external instructions received from unskilled or semi-skilled human users. • In human interaction to reach the point where robots are able to autonomously adapt in order to socially interact with people in an everyday working environment in order to achieve task outcomes through intuitive interaction that is multi-modal; by voice, physical, gestural etc. and to collaboratively achieve complex tasks that require multiple functional capabilities where humans and robots contribute equally to those capabilities. • In manipulation, to be able to achieve more complex manipulative tasks autonomously, requiring advanced perception and task understanding, as well as adaptive planning to anticipate possible changes in the environment during task execution. Robotic manipulation systems should target speed and dexterity with respect to a wide range of different objects and materials. **HORIZON-CL4-2024-DIGITAL-EMERGING-01-03: Novel paradigms and approaches, towards AI-powered robots– step change in functionality (AI, data and robotics partnership) (RIA)** Scope: The following major areas of functional performance need to be progressed to the next level of performance: • significant enhancement of navigation capabilities in order to enhance mobility (underwater, on the ground, in the air, in the body, in areas difficult to reach, on rough terrain, in unpredictable environments, in areas including people or other moving agents, etc.), particularly in highly dynamic and complex environments. • Extension of manipulation capabilities

	• significant enhancement of functional interaction capabilities to deliver efficient, safe and natural interaction with people, objects, with other robots, within complex and dynamic working environments, including the ability to adapt to variation in the working environment and the needs and dynamics of users, objects and structures, etc.) Each of these require significant advances in precision, force, speed, re-planning, physical perception, grasping, manipulation (including bi-manual), etc.), in order to achieve beyond human capability in manipulation and dexterity.