CPSwarm Newsletter

December 2019, Issue 2

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Model-centric design and predictive engineering for swarm of Cyber-Physical Systems

CPSwarm Recap

The CPSwarm project positions itself in the domain of CPS system design and engineering. It aims at providing tools and methodologies that pave the way towards well-established, model-based and predictive engineering design methodologies and toolchains for next generation of CPS systems. CPSwarm aims to establish a science of system integration in the domain of swarms of CPS, i.e., of complex herds of heterogeneous CPS that interact and collaborate based on local policies and that collectively exhibit a behavior capable of solving complex, industrial-driven, and real-world problems.

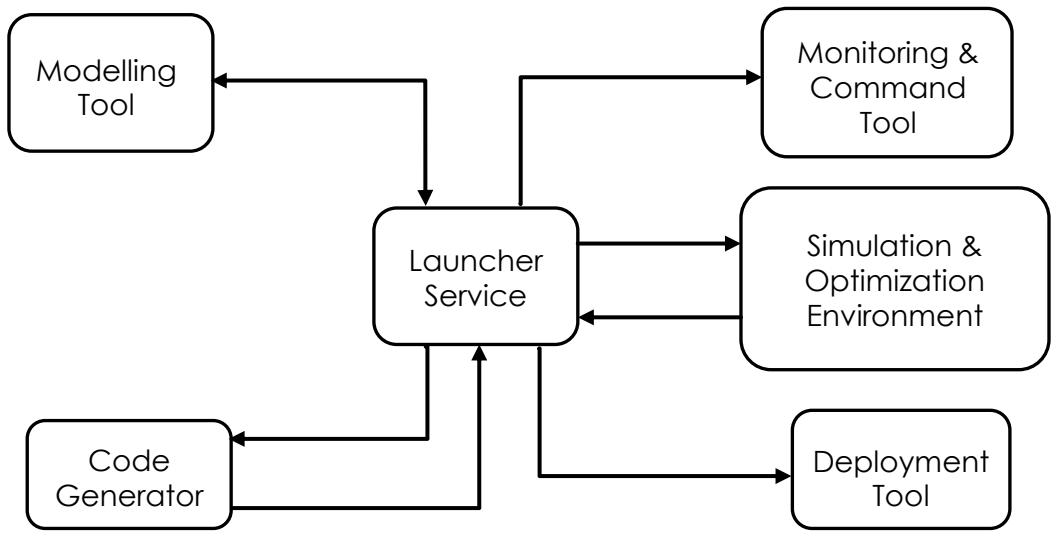
The current issue of newsletter includes the latest CPSwarm results that have been achieved during the period of three years of project. The developed CPSwarm tools that support the vision to deal with the aforementioned challenges are introduced as well.

The CPSwarm Workbench

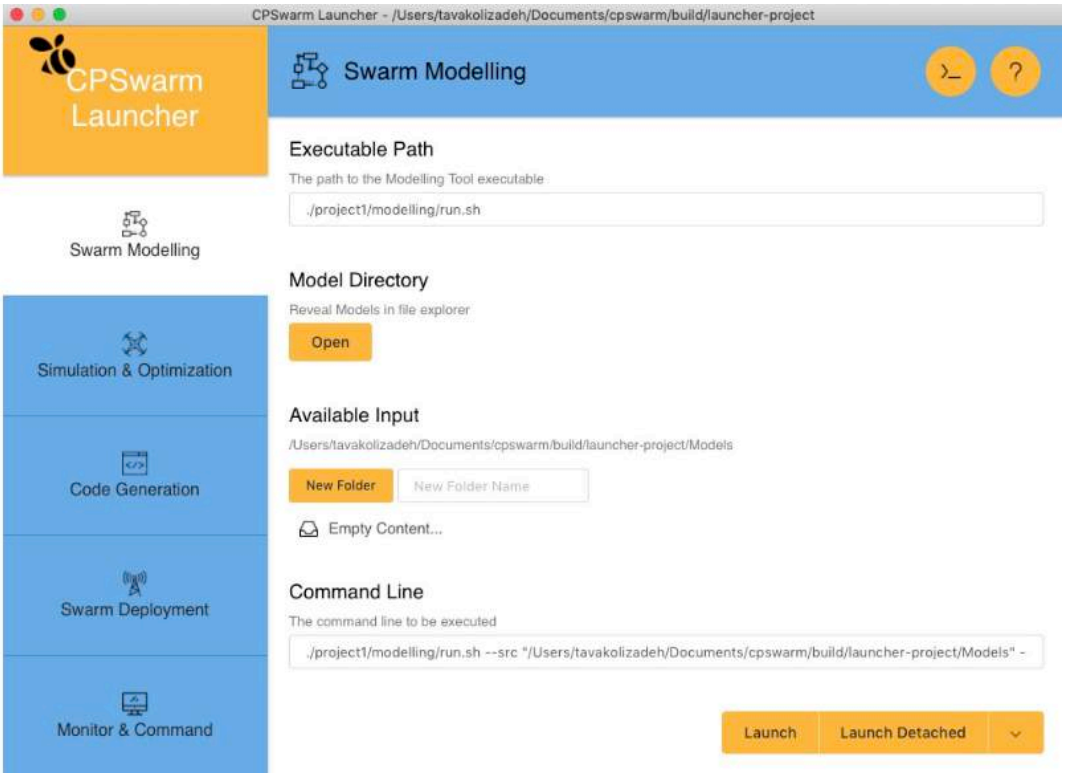
The CPSwarm Workbench is a toolset which includes the Modelling Tool, Simulation and Optimization Environment, Code Generator, as well as Deployment Tool. This system provides better integration of individual components with high potential of interoperability among them along with interaction between external users and CPSwarm system.

Basic building blocks

The CPSwarm workbench integrates the components in the following manner.



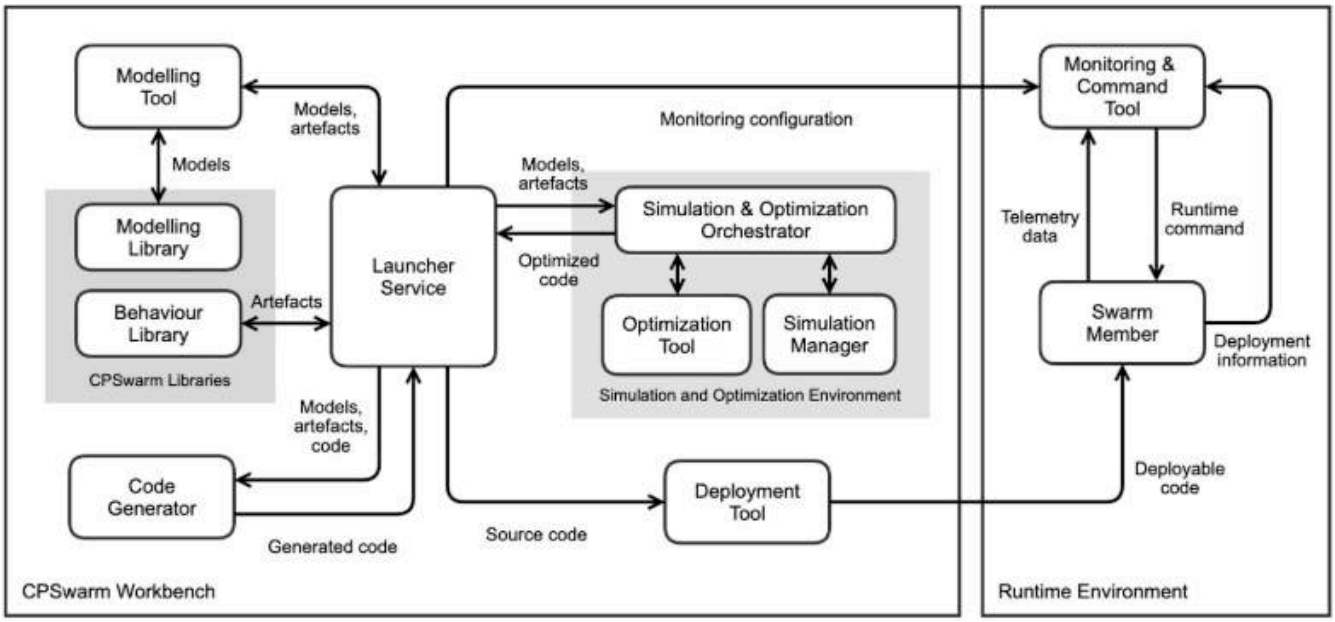
The CPSwarm Launcher



The launcher service is a central component that acts as a portal and starting point of interaction with the other components of the system. The launcher service manages inputs and outputs of the components and offers a minimalistic user interface to guide the user towards different design steps and to set components configurations for launching different components. For more information, please check the [the Launcher on GitHub].

CPSwarm architechture

The detailed architecture of CPSwarm workbench divides the system into two logical groups as presented in the figure below. The components used during designing phase are part of workbench, whereas monitoring and command tool is part of run-time environment.

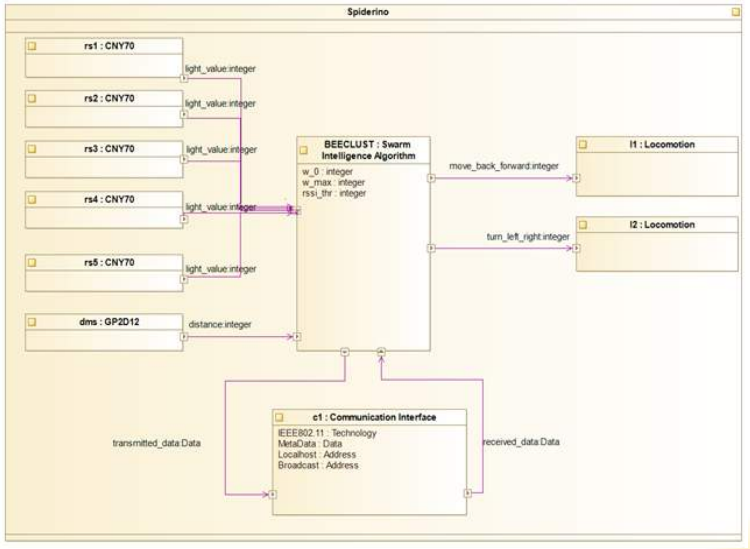


Swarm Modelling

CPSwarm Modelling Tool allows users to define

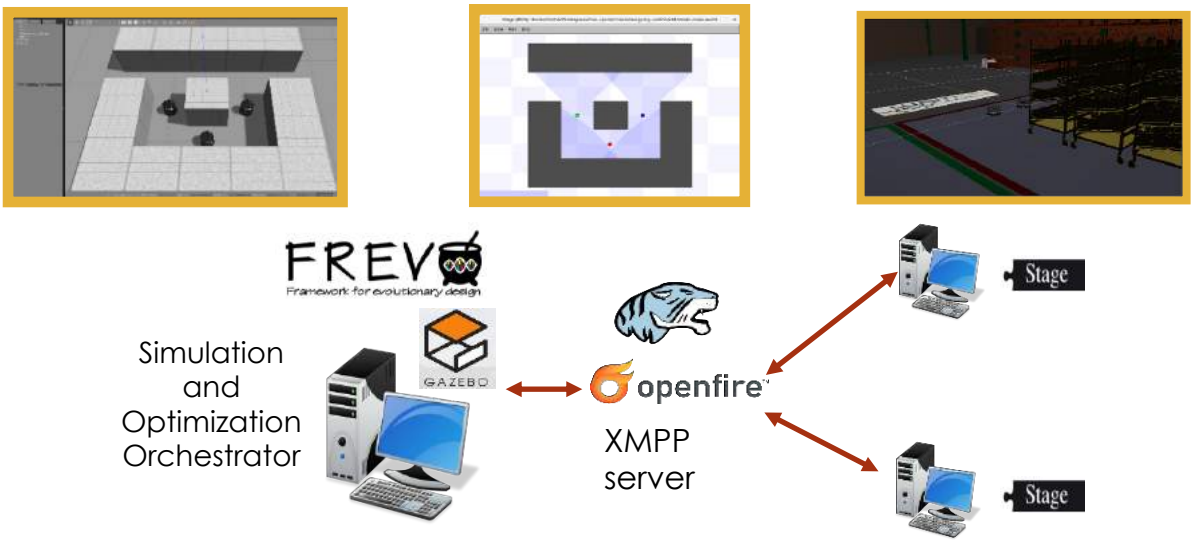
- ✓ Its architecture as a set of CPSs composed of Hardware components,
- ✓ Its behaviour as set of individual State Machine.

Based on top of SysML standard, many reusable models (CPS, sensors, behaviour) are provided inside dedicated libraries.



The CPSwarm Workbench Tools

Simulation and Optimization

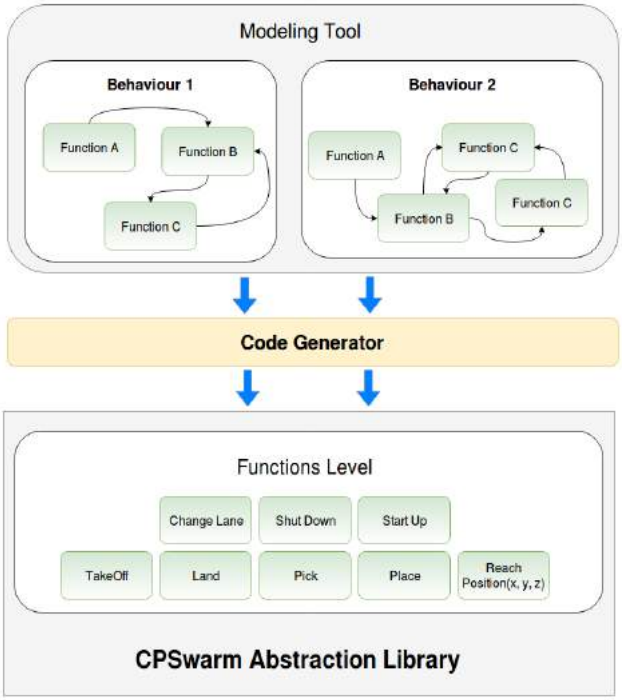


The Simulation and Optimization Environment is used to evaluate the performance of a swarm solution. It can be used as a stand-alone component or in combination with the Optimization Tool (i.e., FREVO) to iteratively evolve the controller algorithm/module. During optimization phase, candidate controllers are ranked based on a fitness score computed by executing the controller in a predefined environment. Successful candidates are adapted to produce a new generation of controllers. Designed using a distributed approach based on the XMPP protocol, simulations are executed in parallel on ROS-based integration tools, such as Stage and Gazebo. For more details, please refer CPSwarm Simulation and Optimization Environment on GitHub.

Code Generation

The role of the Code Generator is to serve as a "glue" level between the platform-independent algorithms realized using the Modelling Tool and the Abstraction Library. In this sense, the Code Generator performs two different tasks:

- ✓ Interpret CPS models defined through the CPSwarm Modelling Tool using specific formalisms (e.g., SCXML).
- ✓ Then, generate CPS modules and libraries that can be passed to the Deployment Tool to be installed on the actual CPSs

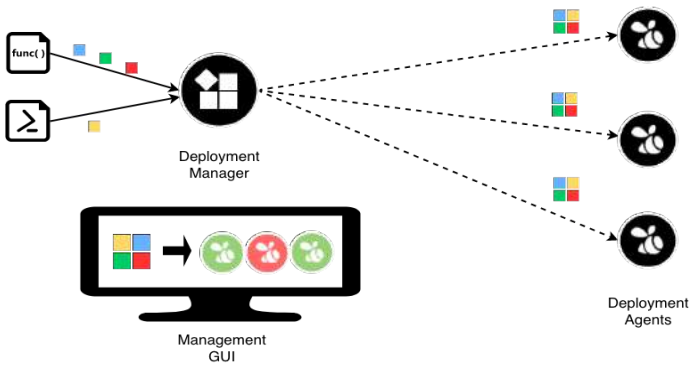


For more details, please check out Code Generation Tool .

The CPSwarm Workbench Tools

Swarm Deployment

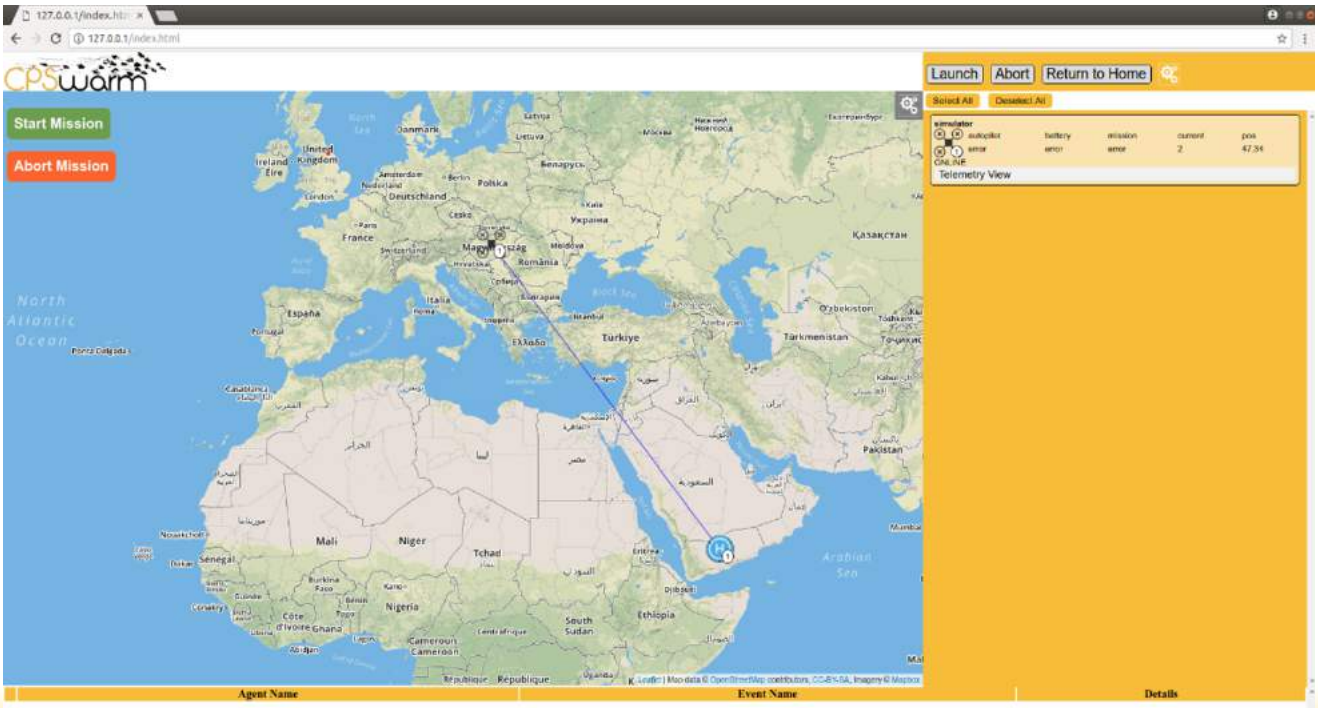
The CPSwarm Deployment Tool is a lightweight software update and monitoring system for resource-constrained IoT devices. It aims to provide secure, practical, and easy to use utilities for over-the-air (OTA) provisioning of software on small computers (e.g. Raspberry Pi or other device with ARM/x86 architecture).



The manager is centralized web service exposing APIs and a GUI for various deployment-related operations, ranging from compilation to installation and runtime. Deployment agents run on individual devices, performing deployment-related tasks. More details can be found Deployement Tool UI .

Monitor and Command

The Monitoring Tool runs in the Runtime Environment. it can discover the events provided by the swarm members via the “communication Library”. It sends configuration commands for modification of the swarm behavior. The swarm members can receive commands such as “Start” or “abort mission” or similar.
A user can configure swarm parameters according to situation aware needs. The position of the swarm members can be visualized.



First CPSwarm Live Demos

Mainly, CPSwarm deals with three use cases: The first one deals with the cooperation between autonomous drones and autonomous vehicles the second one deals with the cooperation between autonomous robots in industry 4.0 settings, and the third one deals with platooning of autonomous vehicles to form one seamless autonomous system. In Turin, Italy, on 27/09/2018 , the CPSwarm project had its M18 review meeting. The review location was at the aero club of Turin (ex-airport of the town) in order to allow for the live demonstrations of two use cases:

1) Autonomous Drones and Rovers

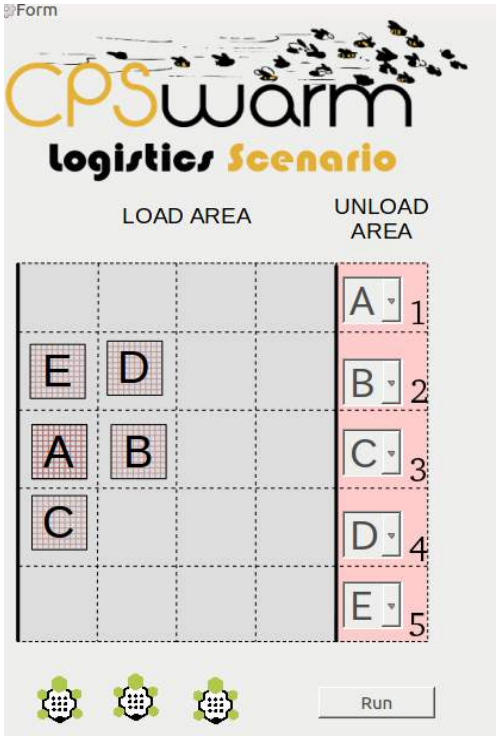
DigiSky was the responsible presenter of this demonstration. The test setting was composed by a mixed swarm of 2 drones and 2 rovers. The scenario has simulated an industrial plant where the swarm conducted a SAR operation. A control station was used to configure some parameters of the mission (e.g. the extension of the area to monitor) and to collect data coming from the sensors placed on the CPSs. During the mission, drones and rovers collaborated in order to find persons trapped in the industrial area (represented by QR code markers) and helped them to reach the exits of the plant. We demonstrated that the swarm can reduce the inspection/detection times compared to a single UAV/rover application.

Mission Description:

- ✓ The drones patrol the selected area using an optimized swarm strategy
- ✓ The rovers wait for a call for intervention
- ✓ All the members of the swarm communicate each other their position
- ✓ The drone communicate the position of the marker to the rovers and start to hover above the marker communicating possible changes of position
- ✓ The rovers decide which one is more suitable to reach the casualty
- ✓ The selected rover reach the marker using an emergency exit strategy to reach the closest exit. For more details, please click HERE for watching a video about this demo.

2) Autonomous Robots

ROBOTNIK was the responsible presenter of this demonstration. The scenario was divided in two areas: the load area (where the carts were) and the unload area (where the carts must be moved). Three robots were positioned in a well-known positions at the beginning of the demo.



Given a list of requirements defined by the position that each cart must occupy in the unloading area, the system auto-organized the robots to bring each cart to its corresponding position of the unload area.

To assign a mission, the system selected the closest free or idle robot to the cart of the mission. If there was no robot free, the system waited until one robot was free or idle. Other missions could be added meanwhile.

To manually interact with the entire system, a control box with three physical buttons was build. The functionality of the green one was to add new missions, the red one to stop all the robots and the yellow one was to re-arm the system in case there was an emergency stop.

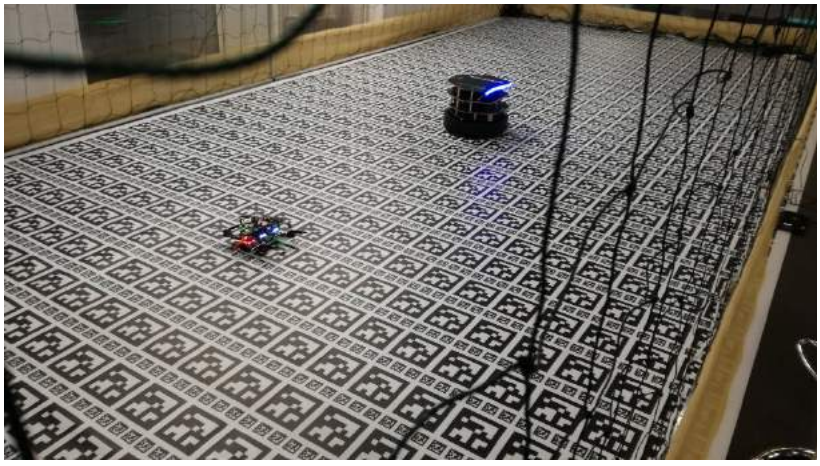
When all the requirements are done (all the missions are finished) the robots come back home (starting point) and the demonstration finishes. For more details, please click HERE for watching a video about this demo.

CPSwarm@ICT2018

In Vienna, Austria on 4-6 December 2018, the CPSwarm project presented its unique technology at ICT 2018: Imagine Digital – Connect Europe. This research and innovation event focus on the European Union's priorities in the digital transformation of society and industry. Two live demos have been presented.

1) Search and Rescue Demo

CPSwarm presented a live demonstration about a Search and Rescue application partially realized using the initial version of the CPSwarm workbench. The demo was based on the project results that have been presented during the intermediate review meeting in September 2018.



Demo Setting:

- ✓ The scenario presented a heterogeneous swarm of 1 drone and 2 rovers (Turtlebot).
- ✓ The drone localizes itself in the cage (x and y coordinates) using an ultra-wideband (UWB) based localization system.
- ✓ The drone estimates its current altitude fusing information coming from sonar and a camera framing an AprilTags carpet.
- ✓ The camera can also infer the current orientation/heading of the drone from the carpet.

- ✓ The rovers localize themselves using a lidar-based system aligned with the UWB system.
- ✓ Communications between drone and rovers lay on a local Wi-Fi network.

Mission Description:

At the beginning of the Search mission, the drone autonomously patrols a selected area using a specific strategy. The rovers wait for a call for intervention.

When a drone discovers one of the casualties (Represented by markers): The drone communicates the position of the marker to the rovers. Each rover computes his distance from the target and sends this info back to the drone. Then, the drone selects the closest rover to perform the Rescue mission of the target, and starts hovering above the marker communicating possible changes of position. For more details, please click HERE for watching a video about this demo.

2) Spiderino Demo

The "Spiderino" robot platform has been developed by our partner Alpen-Adria-Universität Klagenfurt. "Spiderino" is a low-cost robot and designed for swarm research and educational purposes. "Spiderino" is composed of a 3d-printer adapter, a customized circuit board, Arduino pro mini microcontroller, and the location of the Hexbug spider toy. During the CPSwarm presentation at ICT 2018 in Vienna. A demo using a group of autonomous Spiderinos has been performed.

The Spiderinos start looking for a light source and stop when they find it. Six sensors (CNY70) are employed in Spiderino, which can measure distances and detect obstacles based on the amount of reflected light from an obstacle. This method is prone to ambient light, but it can be also used to make the robots finding a light source. For watching a video about this demo, Please click HERE.

The main properties of the Low-cost platform, Spiderino:

- ✓ Swarm-oriented: The robot can be used in swarm robotics experiments
- ✓ Easy to use: User friendly programming of robotic functions
- ✓ Open-platform: All models and blueprints of the robot will be freely available information

CPSwarm Publications

- ✓ Designing Swarms of Cyber-Physical Systems: the H2020 CPSwarm Project. ACM Int. Conference on Computing Frontiers. Siena, Italy. May 2017.
- ✓ Spiderino - A low-cost Robot for Swarm Research and Educational Purposes. Int. Workshop on Intelligent Solutions in Embedded Systems, Hamburg, Germany. June 2017.
- ✓ Modelling a CPS Swarm System: A simple case study. Int. Conference on Model-Driven Engineering and Software Development. Madeira, Portugal. January 2018.
- ✓ Distributed Simulation for Evolutionary Design of Swarms of Cyber-Physical Systems. Int. Conference on Adaptive and Self-Adaptive Systems and Applications. Barcelona, Spain. February 2018.
- ✓ Designing Cyber-Physical Systems with Evolutionary Algorithms. Cyber-Physical Laboratories in Engineering and Science Education. Springer. May 2018.
- ✓ The CPSwarm Technology for Designing Swarms of Cyber-Physical Systems. Research Project Showcase of Software Technologies: Applications and Foundations (STAF) 2019, Eindhoven, The Netherlands, July 2019.
- ✓ Scalable Distributed Simulation for Evolutionary Optimization of Swarms of Cyber-Physical Systems. SysMea, International Journal on Advances in Systems and Measurements , August 2019.

CPSwarm Details

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CPSwarm Consortium

Nine partners from six different EU countries are on board in the CPSwarm project.

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