CPSwarm Newsletter

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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 swarm of Cyber-Physical Systems (CPS) design and engineering, and to provide 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 objectives aim 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.

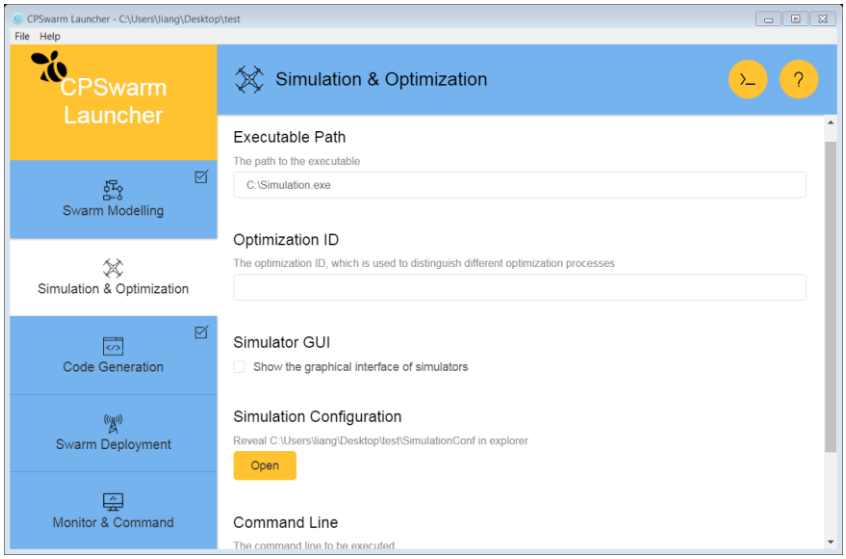
This newsletter presents the CPSwarm results that have been achieved during the first two years of the project. The developed CPSwarm tools that support its vision to deal with the aforementioned challenges are introduced as well.

The CPSwarm Workbench Tools

CPSwarm Workbench is a toolset comprised of the Modelling Library, the Modelling Tool, the Optimization Tool, the Optimization Simulator, the Code Generator, as well as the Deployment Tool. It provides an integrated solution for swarm development from the modelling/design to the deployment phase. The CPSwarm Workbench is the major interaction point between external users and the CPSwarm system.

The CPSwarm Launcher

The CPSwarm Launcher is the glue for the complete toolset in the workbench. It provides a user-friendly GUI, from which user can launch software tools easily. In addtion, the launcher also assists the user in managing asset files related to a CPSwarm project, as well as guides the user to navigate the CPSwarm workflow in a wizard-like



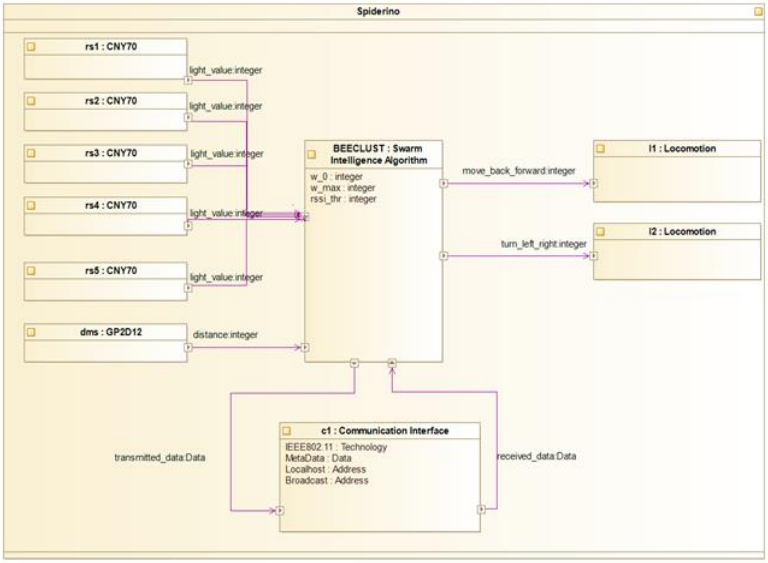
Design IDE and Workbench for Swarm of Cyber-Phyisical Systems

Swarm Modeling

CPSwarm Modelling Tool allows the definition of two main aspects of a swarm member:

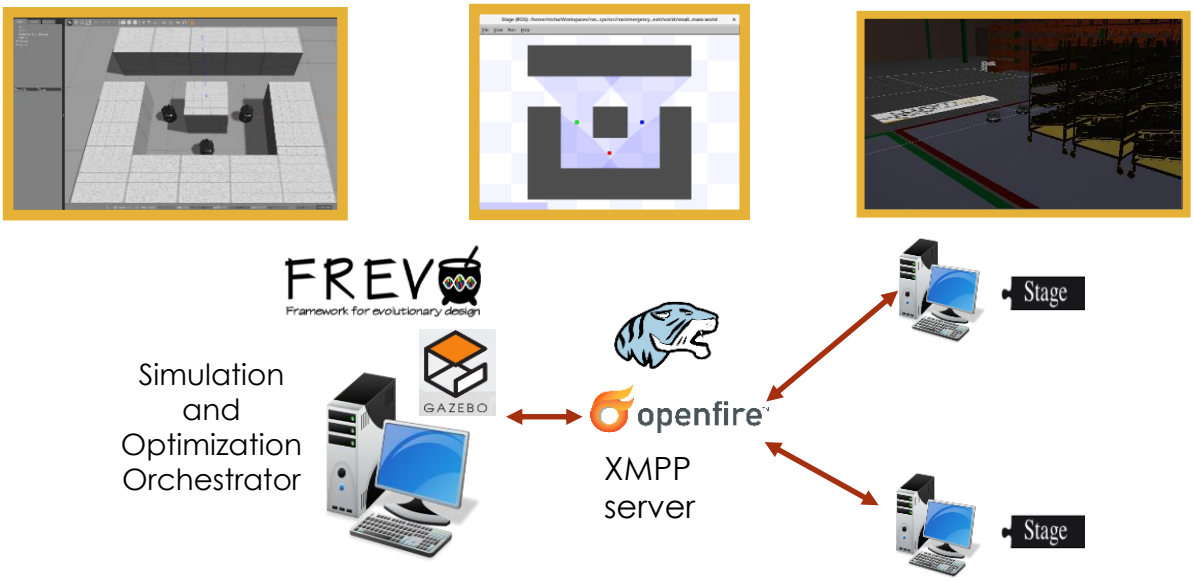
- ✓ Its architecture as a set of CPSs composed of hardware components,
- ✓ Its behaviour as set of individual state machine.

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



The CPSwarm Workbench Tools

Simulation and Optimization

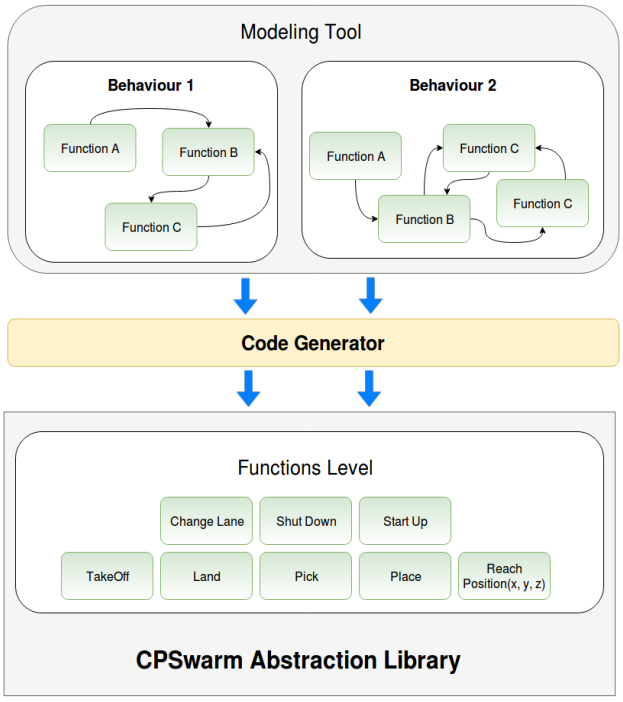


The Simulation Environment is used to evaluate the performance of a swarm solution. It can be used as a stand-alone component or in combination with the Optimization Tool (e.g. FREVO) to iteratively evolve the controller algorithm/module. During optimization, candidate controllers are ranked based on 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, with support planned for ARGoS and V-REP.

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:

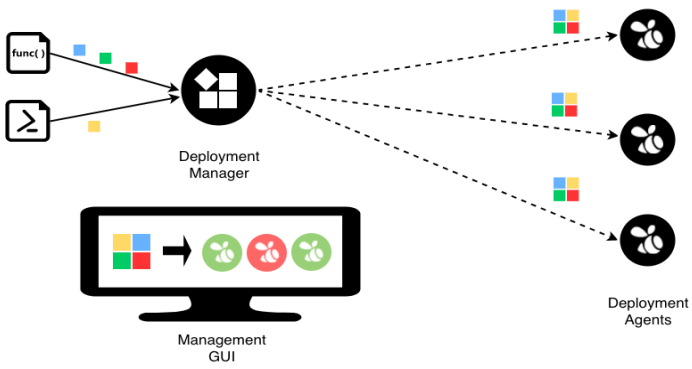
- ✓ Interpret CPS models defined through the CPSwarm Modeling Tool using specific formalisms (e.g. SCXML).
- ✓ Generate CPS modules and libraries that can be passed to the Deployment Tool to be installed on the actual CPSs



The CPSwarm Workbench Tools

Swarm Deployment

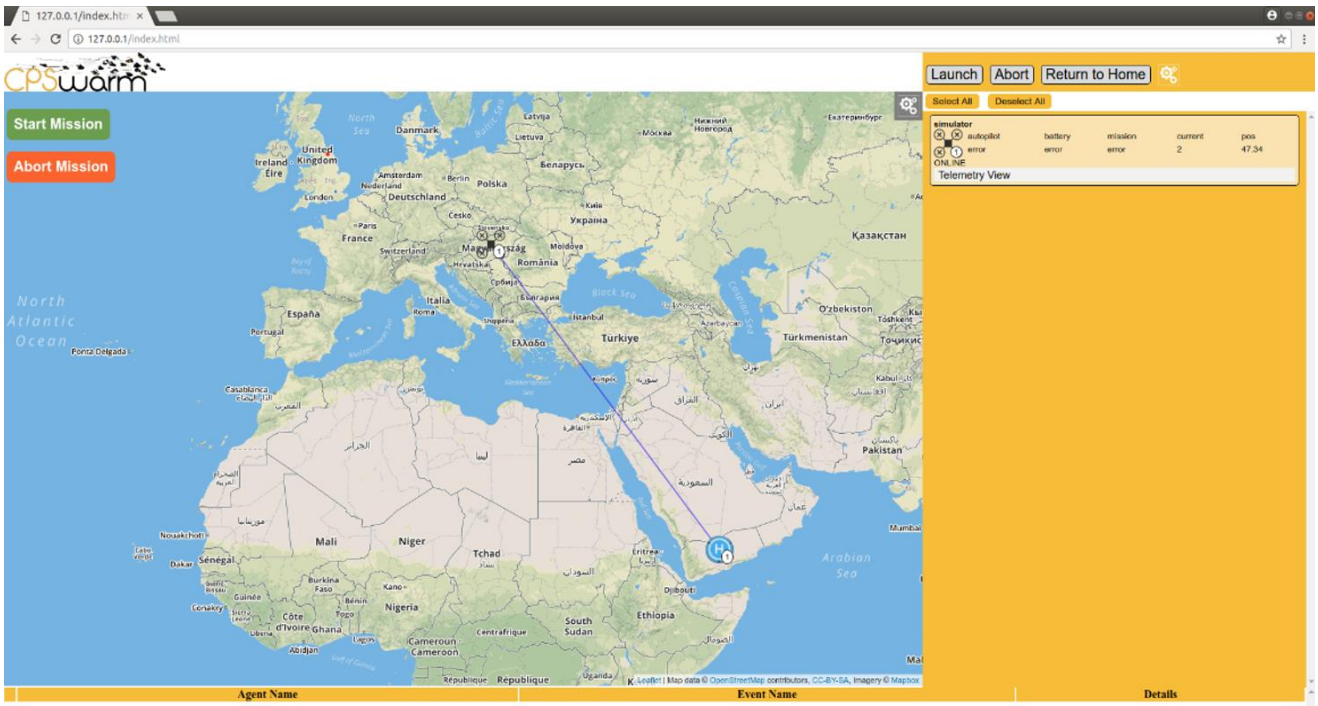
The CPSwarm Deployment Tool is a lightweight software update and monitoring system for resource-constrained IoT devices. It aims to provide secure, practical and easy to use utilities for over-the-air (OTA) provisioning of software on small computers (e.g. Raspberry Pi or other device with ARM or x86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



The manager is a 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.

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

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 month 18 review meeting. The review location was at the Aero Club of Turin (former airport of the city) in order to allow for the live demonstrations of two use cases:

1) Autonomous Drones and Rovers

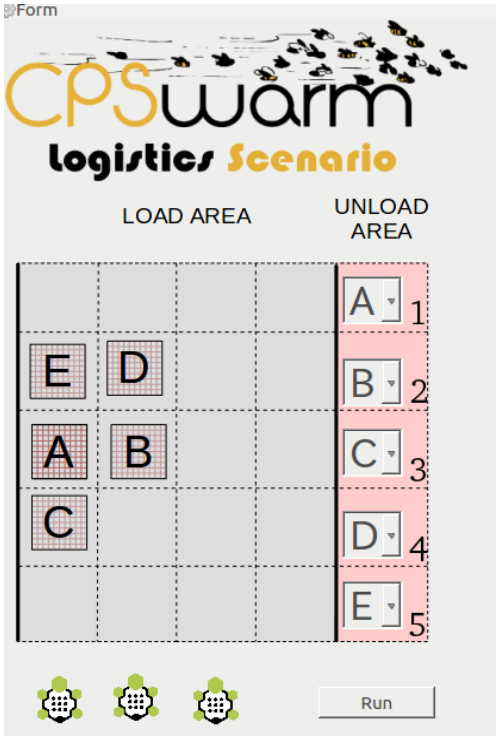
DigiSky was the presenter responsible for this demonstration. The test setting consisted of a mixed swarm of 2 drones and 2 rovers. The scenario has simulated an industrial plant where the swarm conducted a search and rescue (SAR) operation. A control station was used to configure some parameters of 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 their position with each other
- ✓ 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 of them is more suitable to reach the casualty, then the selected rover starts the rescue mission and reach the closest exit.
- ✓ More details are shown in this video

2) Autonomous Robots

ROBOTNIK was the presenter responsable for 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 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 at 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 built. The functionality of the green one was to add new missions, the red one stopped all the robots and the yellow one was recommenced the mission following an emergency stop.

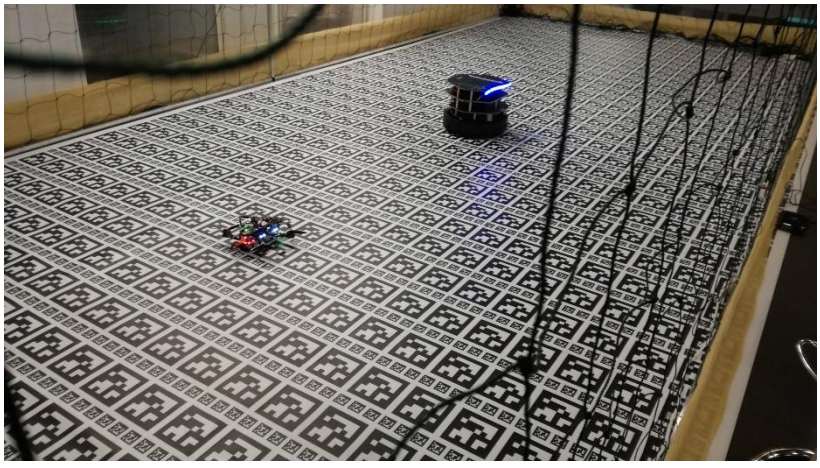
When all the requirements are done (all the missions are finished) the robots come back home (starting point) and the demonstration finishes. More details are shown in this video.

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 focused on the European Union's priorities in the digital transformation of society and industry. Two live demos were presented.

1) Search and Rescue Demo

CPSwarm presented a live demonstration on search and rescue application partially realized using an initial version of the CPSwarm Workbench. The demo was based on the project results that were presented during the intermediate review meeting in September 2018.



Demo Setting:

- ✓ The scenario presents a heterogeneous swarm of 1 drone and 2 rovers (Turtlebots).
- ✓ The drone localizes itself in the cage (x and y coordinates) using an ultra-wideband (UWB) based localization system.
- ✓ The drone estimates its altitude by 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.
- ✓ The drone and the rovers communicate using 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 its distance from the target and sends this 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. More details are shown in this video.

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. Each Spiderino is composed of a 3d-printed adapter, a customized circuit board, Arduino Pro Mini microcontroller and the part of the Hexbug spider toy. A demo using a group of autonomous Spiderinos was presented during the CPSwarm presentation at ICT 2018 in Vienna.

The Spiderinos start looking for a light source and stop when they find it. Six sensors (CNY70) are employed to Spiderino 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 find a light source. More details are shown in this video.

The main properties of the Spiderino 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: The hardware and software of the robot will be freely available

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.

CPSwarm Details

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CPSwarm Consortium

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

CPSwarm contact

Project Coordinator:
Claudio Pastrone
claudio.pastrone@linksfoundation.com

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