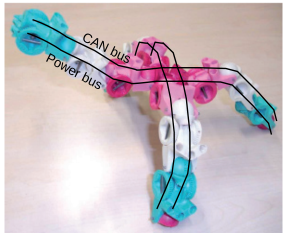
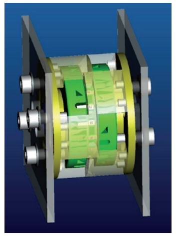
Replicator

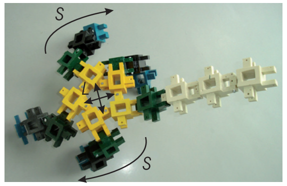
FP7 - 216620

First Sight and Steps

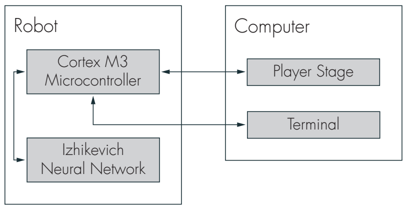
A Replicator possesses already a wired/wireless bus system for message and energy exchange, and first sensing, locomotion, docking and lifting/bending capabilities to exhibit various asymmetrical shapes and kinematic behaviours.



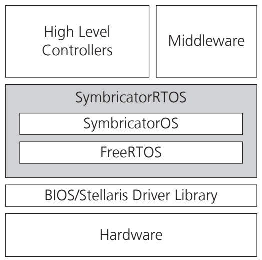




The software architecture and approach developed by the project enables a Replicator to develop and evolve cognitive sensor and control modules without any human supervision. A bio-inspired evolutionary approach is chosen for software development compliant with the possible changes occurring at micro-robotic and multi-robot hardware structure levels. Drivers are provided by the Stellaris Driver Library. Above this the SymbricatorRTOS is composed of the FreeRTOS layer, which provides the Real-Time System, and the SymbricatorOS layer, which implements the low-level controller. Above the SymbricatorRTOS there are the Middleware layer for aggregation of robots into a more advanced multi-cellular organism. The High Level Controllers are responsible for evolutionary, learning, adaptive and other behaviours of the single robot and of the aggregated organism.



This generic hooking system enables different Replicator modules to interact and co-evolve with each other by defining a NeuralNetworkTask and making use of Address Event Representations (AERs). Such a NeuralNetworkTask combines e.g. a SensorTask and an ActuatorTask to achieve a particular goal such as finding victims of an earthquake. This can be simulated and empirically modelled in the Player/Stage environment: systemic and environmental physics can be grounded.



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Robotic Evolutionary Self-Programming and Self-Assembling Organisms

http://www.replicators.eu
http://www.symbrion.eu

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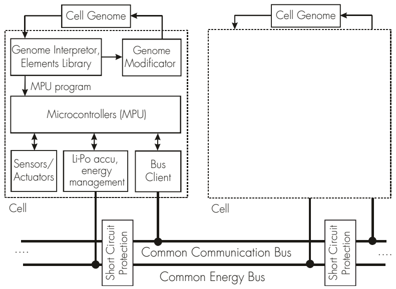
The Project

The Replicator project funded by the European Commission focuses on the development of an advanced robotic system, consisting of a super-large-scale swarm of small autonomous mobile micro-robots that are capable of self-assembling into large artificial organisms.

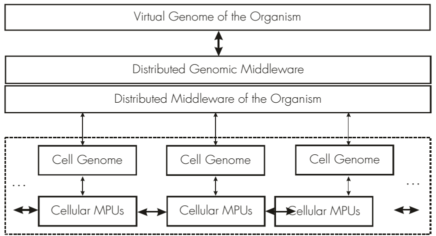
These robotic organisms possess common energy and information buses as well as reliable legged, wheeled or climbing locomotion, based on modular sub-systems which can be autonomously reconfigured.

Thanks to the heterogeneity of the elementary robots and their capability to share resources and to communicate, these robotic organisms are able to achieve a large computational power, rich close- and far-range sensing and rich morphodynamics. Thereto, they can autonomously harvest the energy from external power sources.

The main goal of the project is the development of an organism that assembles itself from distributed micro-robots that are in interaction with the environment and themselves, meanwhile keeping in mind their systemic limitations, e.g. energy, and targets, like searching victims, and environmental spatio-temporal constraints. The central features to be acquired by an organism are situational awareness, capability of self-assembly and distributed but coordinated control of engaging itself and its environment. The frameworks describe how the software genotypes and phenotypes of the organism change upon interaction and co-evolution with themselves and the environment, and how they remain compliant with the underlying distributed hardware of the micro-robots.

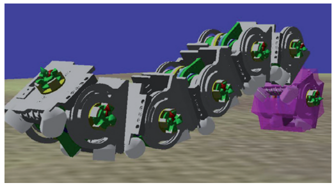


Ultimately, these robotic organisms, which are extremely adaptive, robust, scalable and rich in sensing and actuating capabilities, will be used to build autonomous sensor networks, capable of self-spreading and self-maintaining in open-ended, even hazardous, environments. After an earth-quake, for instance, a rescue worker or wheeled robot has major difficulties to enter a collapsed building and explore the underground rubble for victims. A Replicator on the contrary will be capable of disassembling and subsequently entering such inhospitable places. Furthermore, this organism will be capable of aggregating to crawl over obstacles of different sizes to reach victims. The organism will do so by adapting and evolving its functional shape to the observed environmental constraints and dynamics.



In short, a Replicator explores its environment to find energy resources, to determine potential dangers and to optimally achieve its goals. Upon exploration the organism learns and adapts - reprograms – its morphogenetic tactics and strategies to overcome systemic and environmental problems. All these tactics and strategies are stored in non-volatile memory to prevent the organism to loose its collective experience and intelligence when energy resources are drained or malfunctions occur.

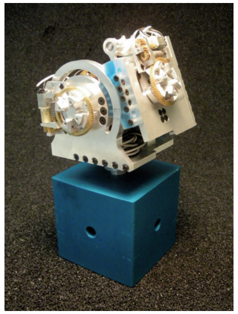
Innovation



The Replicator project brings about innovations in the fields of micro-robotics, large-scale swarming robotics, morphogenetic robotics and evolutionary robotics.

In the field of micro-robotics the project contributes to further miniaturization of laser scanning and vision systems; the improvement of multi-sensor fusion capabilities (for acquiring internal and world models), the locomotion and actuation capabilities, and perception, cognition and navigation capabilities of a robotic organism; improving distributed multi-processor computational capabilities of a robotic organism that truly empowers the above robotic functionalities.

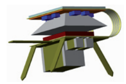
In the field of large-scale swarming robotics the project contributes to the development of multi-robots that display ever higher collective functional fitness by adapting the multi-robot morphodynamic tactics and strategies to its own systemic and environmental evolution.



In the field of reconfigurable robotics the project contributes to new swarming concepts based on aggregation; new docking elements; new electronics with a common energy and communication buses; (systemic and environmental) synergetic awareness.

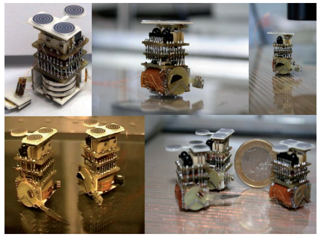
In evolutionary robotics the project provides a new approach to the morphogenesis of multi-robotic systems; a novel concept of collective evolution of morphogenesis; novel bio-inspired and genome-based approaches to control of multi-robotic systems.

Building on Success



The Replicator project originated from research activities within the EC funded projects Intelligent Small World Autonomous Robots for Micro-manipulation (I-Swarm), Miniaturised Co-operative Robots advancing towards the Nano-range (MiCRON) and the open-source project Swarmrobot.

The I-Swarm project contributed to the mass-production of large-scale swarms of mm^3 sized micro-robots and to the improvement of polymer actuation, collective perception, usage of micro scaling effects, artificial and collective intelligence.



The MiCRON project contributed to the development of a cluster of autonomous but cooperative cm^3 sized mobile micro-robots for performing complex manipulation tasks such as transporting µm-sized objects. These wireless micro-robots, each equipped with on board electronics for control and communication, are capable of co-operation to accomplish a range of tasks associated with the assembly and processing from nano- to micro scale ranges.

The Swarmrobot project contributed to the understanding of the underlying principles of robust and efficient information and knowledge processing, adaptation and learning within resource limited autonomous systems by investigating artificial self-organization, emergent phenomena, and control in large robotic groups.

The results of these three projects form the prerequisites for achieving in the end the scientific and technological objectives and socio-economic impacts of the Replicator project. The flexible hard- and software architecture and the self-organizing multi-robotic sensor, cognition and actuator modules in interaction and co-evolution with the environment ensure the organism to exhibit diverse creative and purposeful morphodynamics, useful e. g. in rescue missions.