Adaptive Self-maintenance Agricultural Robotic Systems for Cultivation on Mars

Report 2023

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Contents

Problem definition and motivation

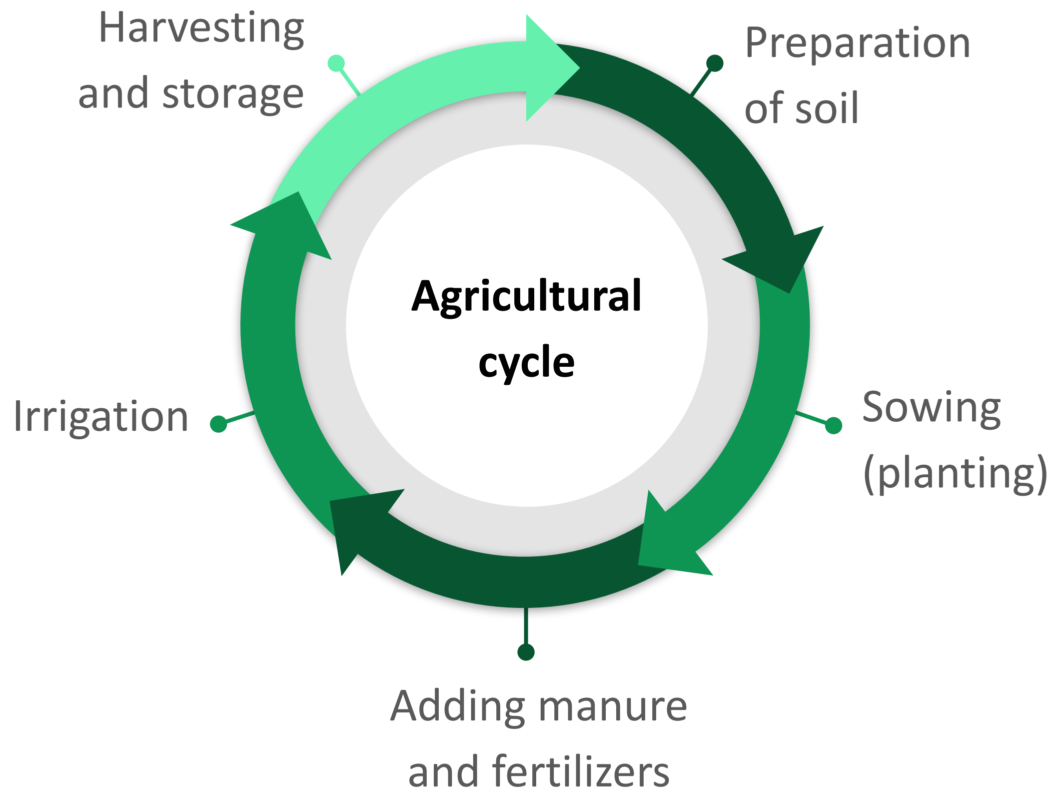
- Cultivation on Mars without human involvement could be helpful for colonizing the planet.
- Agricultural robots are more vulnerable to damage, wear-off, or malfunction, compared to other robotic systems.
- Due to the absence of humans, maintaining space robotics systems is a challenging task.
- Utilizing available resources and adapting to the environment autonomously is essential for making space robotic systems sustainable.

Research goals

- Sustainability of robots with self-maintenance
- Evolution of structure or movements depending on the movements
- Optimization of resource consumption

Examples for different structures for agricultural robots

Agricultural cycle



Agricultural robots

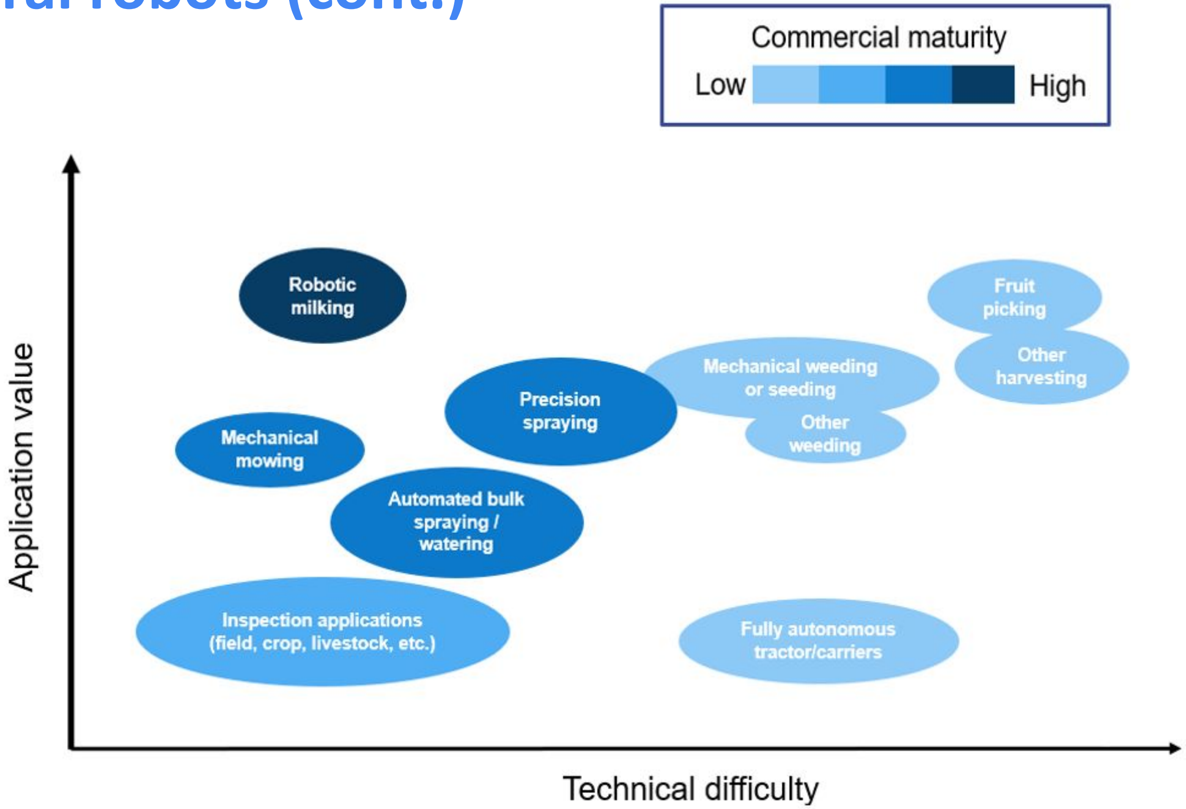
- Wheeled robot with cartesian manipulator
- Wheeled robot with articulated manipulator
- Drones

Ecorobotix

IDTechEx

Dji MG-1S agri drone

Agricultural robots (cont.)



Source: https://www.idtechex.com/ja/research-article/idtechex-outlines-the-future-of-the-agricultural-robotics-industry/25744

Self-maintenance

- Self-maintenance is a part of reliability engineering, which involves designing and building systems that can independently identify any loss or potential loss of function and then automatically restore functionality to maintain availability and improve system resilience.
- Self-maintenance has five stages: monitoring, trigger, evaluation, implementation, and verification.

Self-maintenance stages

- Monitoring: Observing system functions to reduce the chance of degradation or a failure.
- Trigger: The point that decision which is been made to perform SE.
- Evaluation: Evaluate the damage which has occur or will occur.
- Implementation: Fix the damage or failure.
  - Design
  - Fabricate
  - Assemble
- Verification: Check and confirm the new system performance.

Evolutionary robotics

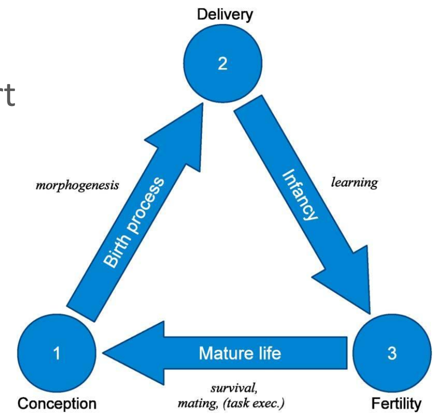
Virtual creatures

- Fewer constraints
- Hard to implement in real world
- High diversity
- High performance
- Doesn't have pre-defined body parts

Manufacturable robots

- More constraints
- Manufacturable
- Low diversity
- Low performance ⚠️
- Have pre-defined body part

- Common factors
  - Evolution happens in the simulated environment
  - Follow the triangle of life to evolve
  - Brains for agents are dynamically created and trained independently in the environment



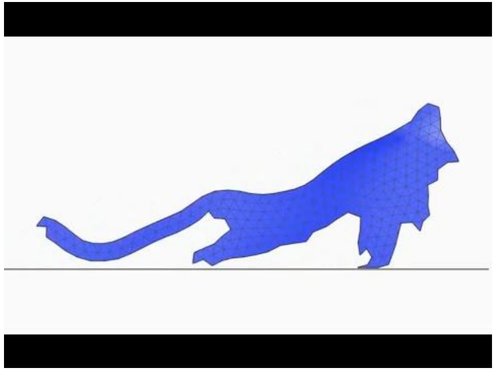
Triangle of life

(Source: https://doi.org/10.1162/ARTL_a_00231)

Virtual creatures

- Computer-generated or simulated beings that mimic the behaviors and characteristics of real-life creatures

Karl Sims - Evolved virtual creatures (1994)

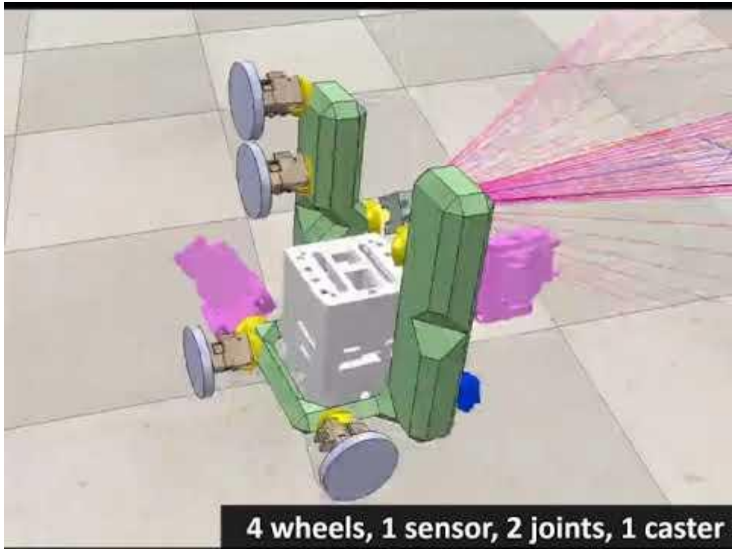


2D virtual creatures (2014)

Virtual creatures with muscles (2015)

Manufacturable evolutionary robotics

- Robotic systems that can be autonomously designed, optimized, and physically manufactured using evolutionary algorithms



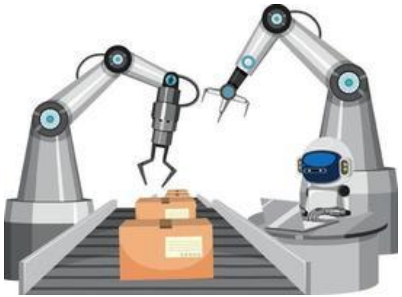
Autonomous design and fabrication
(2020)

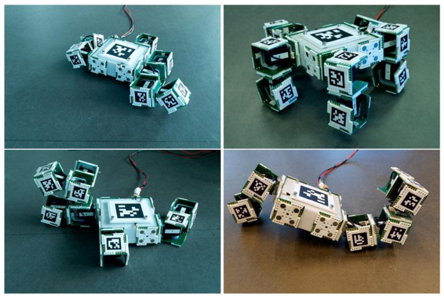
Assembling process of printed robot parts
(2020)

Available robotic architectures

- Task specific single robot
- Single robot with modular architecture
- Swarm robots (homogeneous)
- Swarm robots (heterogeneous)

Self-maintenance complexity



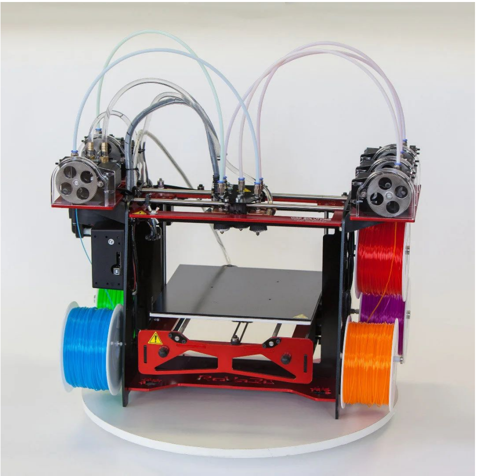


Analogy

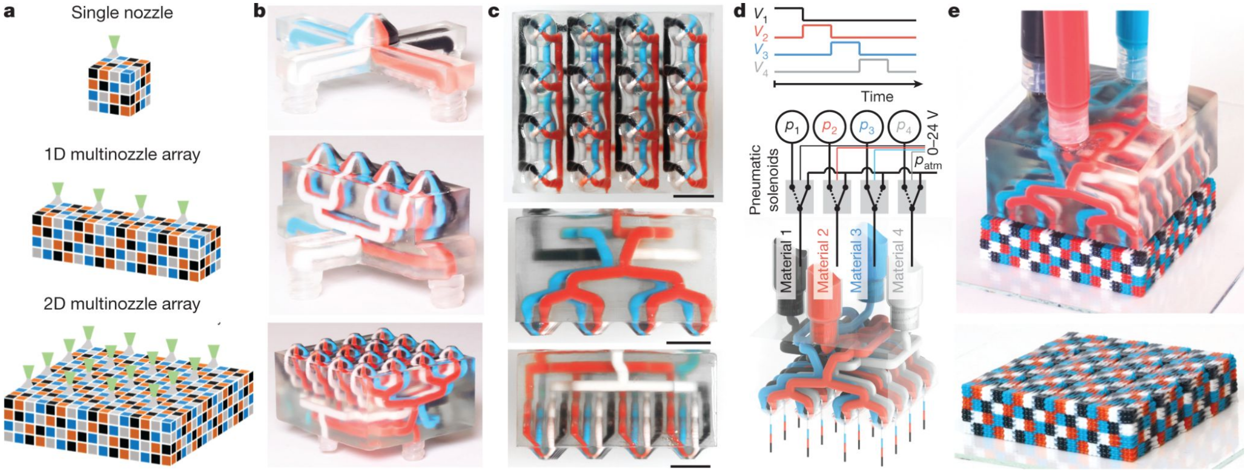
Ant-society	**Heterogeneous swarm robot system**
Queen	Centralized controller/decision maker ⚠️
Workers	Entities that performing tasks (planting, irrigation, harvesting, etc.)
Specialist	Entities that has special abilities (fabricators, assembers)

Fabrication technologies

- Multi-material multi-nozzle 3D printers
- Conductive printing materials



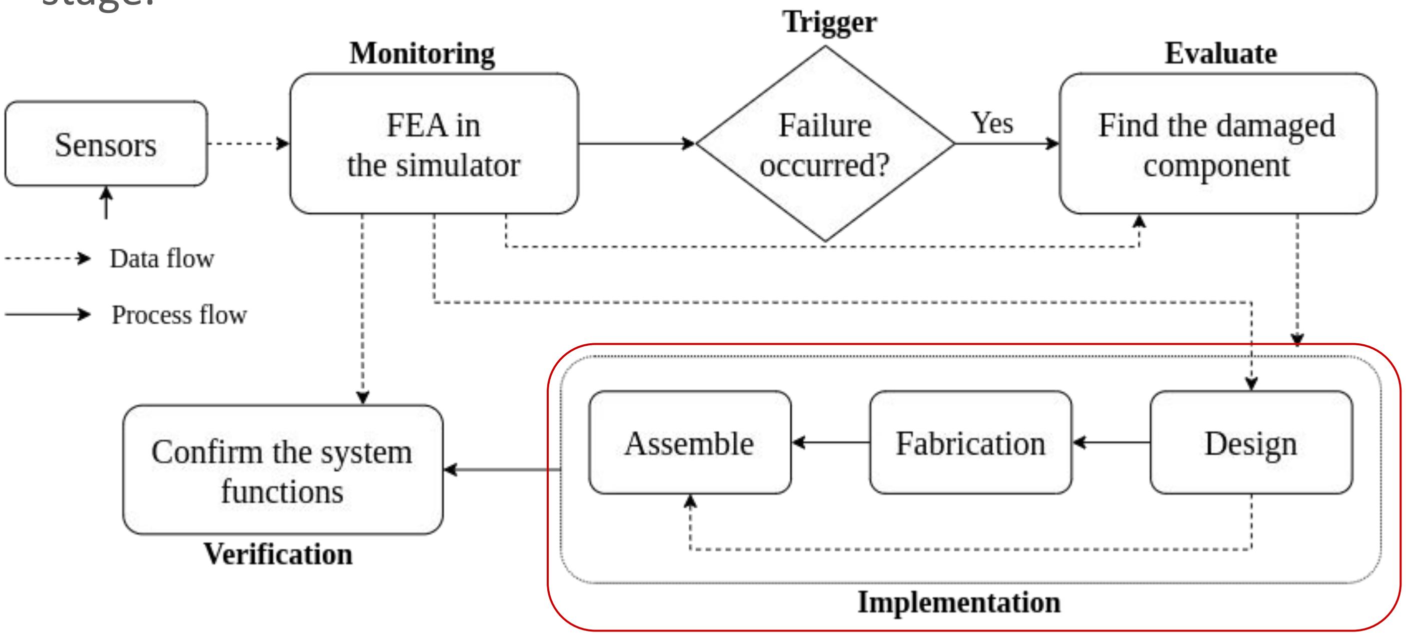
Source: https://hackaday.com/2016/06/20/mosaic-palette-single-extruder-multi-color-and-multi-material-3d-printing/



Source: https://www.nature.com/articles/s41586-019-1736-8

Process breakdown

- This research will be started from autonomous assembly in the implementation stage.



Process flow and data flow of self-maintenance

References

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Thank you