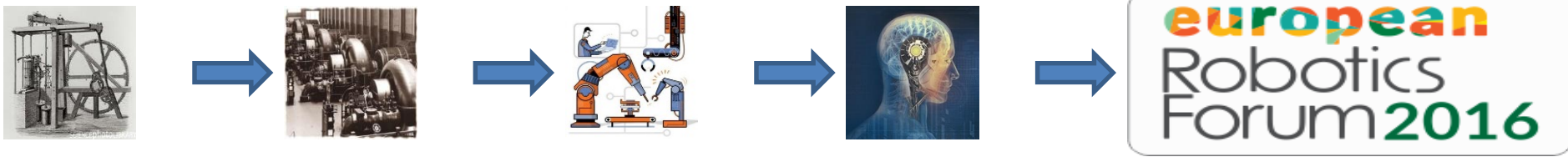# Swarm cooperative manufacturing outcomes of the SwarmItFIX EU project

R. Molfino, K. Sagar, D. Zlatanov, M. Zoppi
Univ. Genoa (IT)

WorkShop Work Flow

Robots 4.0

Adaptive Grippers
Dexterous Manipulators and Human Manipulation
Multi-Modal/Arms "drum-circle"

Manufacturing 4.0
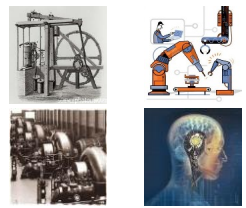
Human Robot Collaboration
Cognitive Manufacturing
Cooperative Manufacturing

Flexibility 4.0

Service Oriented Approach in Flexible Manufacturing
Task Planning in Flexible Manufacturing
Open Dynamic Manufacturing Operating System in Flexible Manufacturing

SwarmItFix

1-SwarmItIFX- Drilling demo.mp4
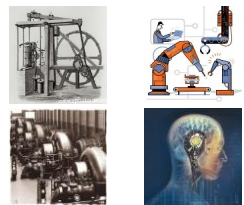

2-SwarmItFIX- Milling demo 2.mp4

3-SwarmItFIX Milling demoB.mp4

SwarmItFix

(a) (b) (c) (d) (e)
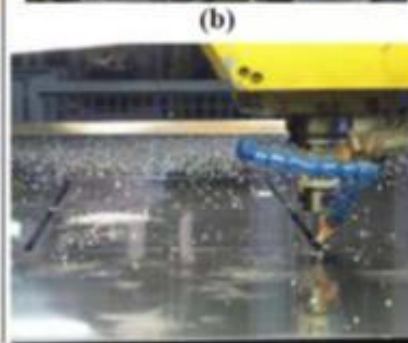
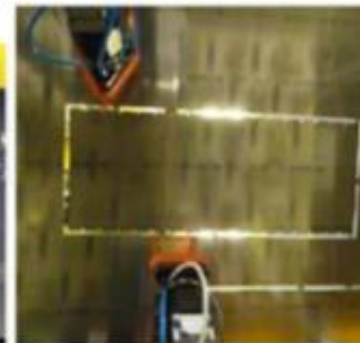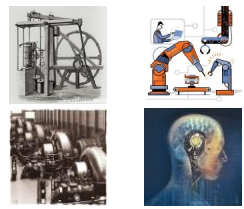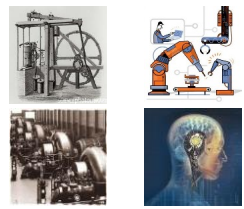# Outline

Industry 4.0

SwarmItFix joining the roadmap towards Industry 4.0

Contributing Hardware/Architectural features
- Novel bench concept introducing a new locomotion
- Mobile Base platform serving a function of Robot carrier & Individual functioning agent
- Parallel Kinematic Manipulator with spherical wrist depicting a separate class of robots for specific functions
- Adaptable gripper using smart material technology

Software/Information Features
- Concept of Centralized planning approach using Constraint Satisfaction Problem (CSP) depicting how cooperative task planning can be approached
- Individual On-board controllers on the agent providing efficient communication and freedom to extend to a decentralized control
- Dedicated pneumatic control system coupled with planning for efficiency and precise operation
- Path Planning strategies for individual mobile base agents to execute various tasks
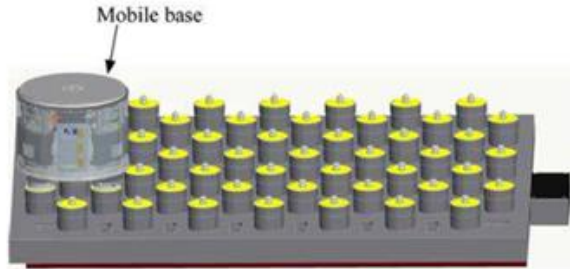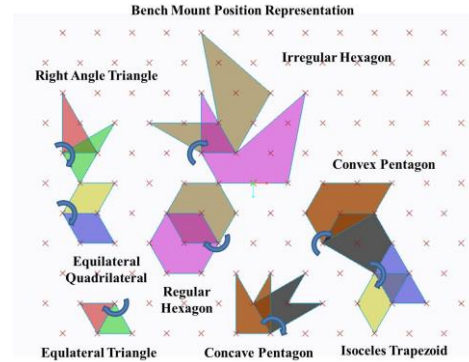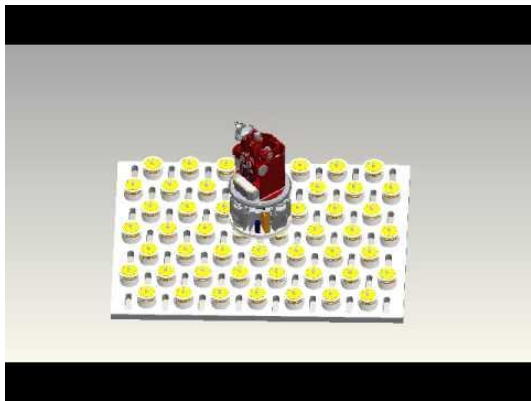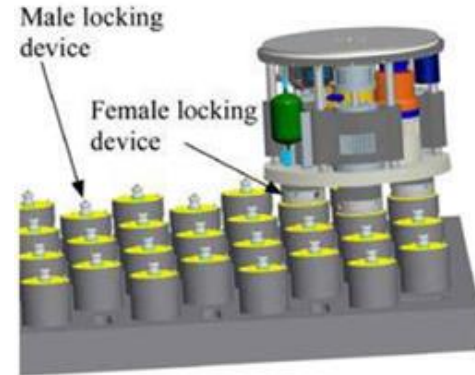
Hardware Features

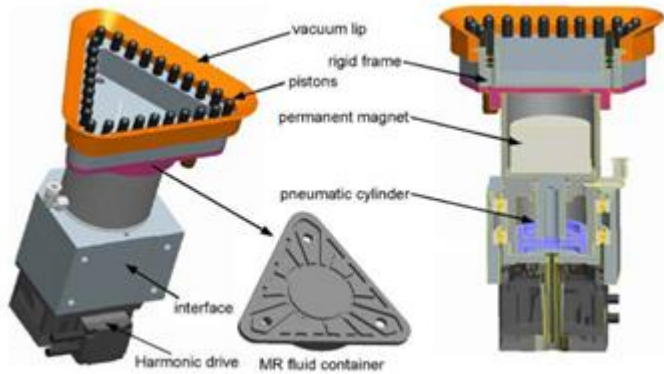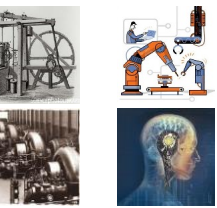## Robot 4.0
Bench & Mobile Base

Current Geometry of bench pins are based on an Equilateral triangle

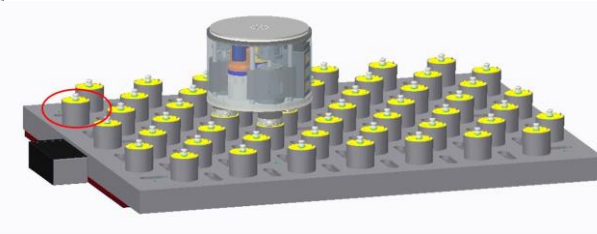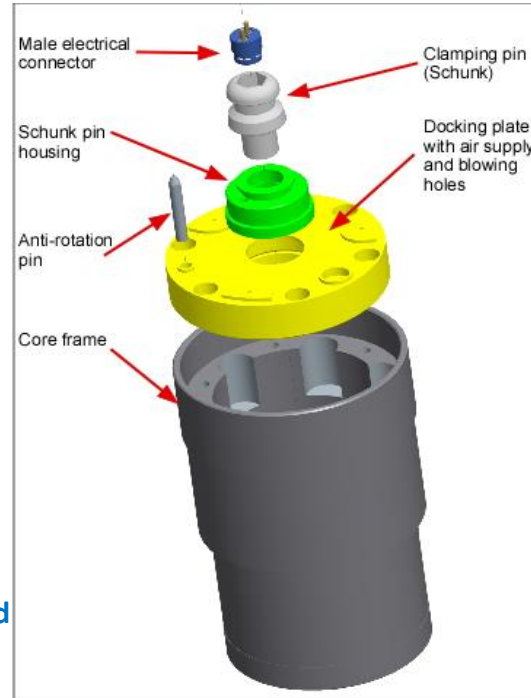**Various Geometry of the Agent can be mounted on the representative bench pins**
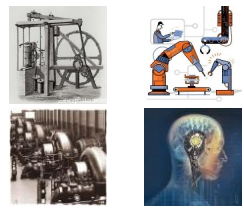
Hardware Features

Vaccum gripper

Novel adaptable vaccum gripper combining feature of Magnetorheulogical Fluid (MRF), permanent magnet and vaccum suction to provide adapable vaccum head positioning
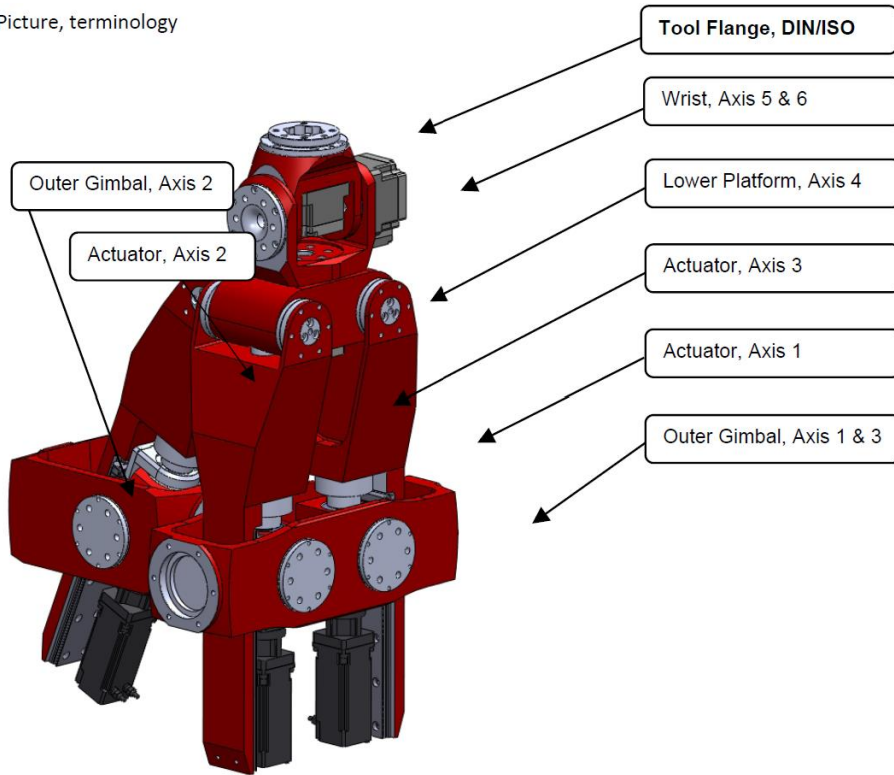
Base Pin offering Electrical power supply enabling cable free operation which is ideal and conducive for a swarm agent environment. Swarm Agent planning and motion can be performed on this bench where agents execute a planar motion.
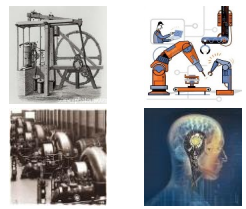
Hardware Features

Picture, terminology

Tool Flange, DIN/ISO

Wrist, Axis 5 & 6

Outer Gimbal, Axis 2

Actuator, Axis 2

Lower Platform, Axis 4

Actuator, Axis 3

Actuator, Axis 1

Outer Gimbal, Axis 1 & 3

PKM Agent

Specific kinematics:

- Exechon 6 axis configuration
- 3 linear axes connected to a moving platform (Lower Platform)
- 3 rotary axes serial linked to the moving platform

Hardware Features
## Existing Industrial Significance

Manufacturing Application

- **Reconfigurable Fixture for sheet metal machining in aerospace applications**
- **Concept of plug and play with cable- free operation in the SwarmItFix environment**
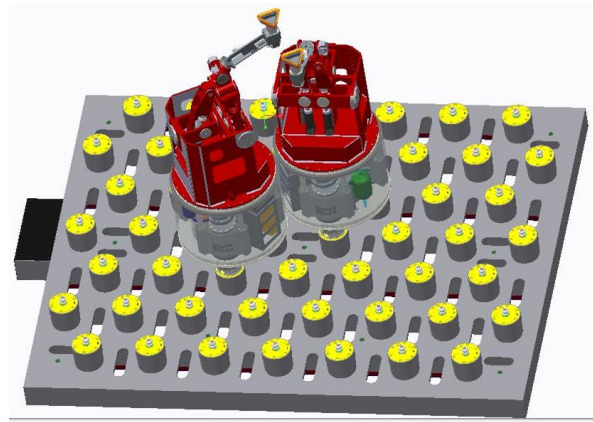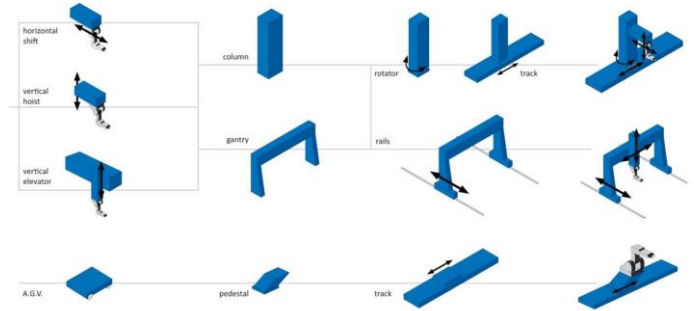- **Adaptable gripper to provide fixturing support for any 3D contour shape to be fixtured**
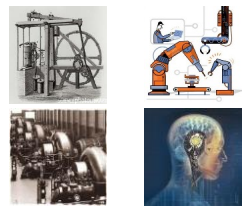
Hardware Features
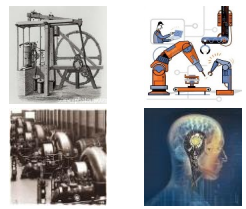## Alternative Industrial Significance
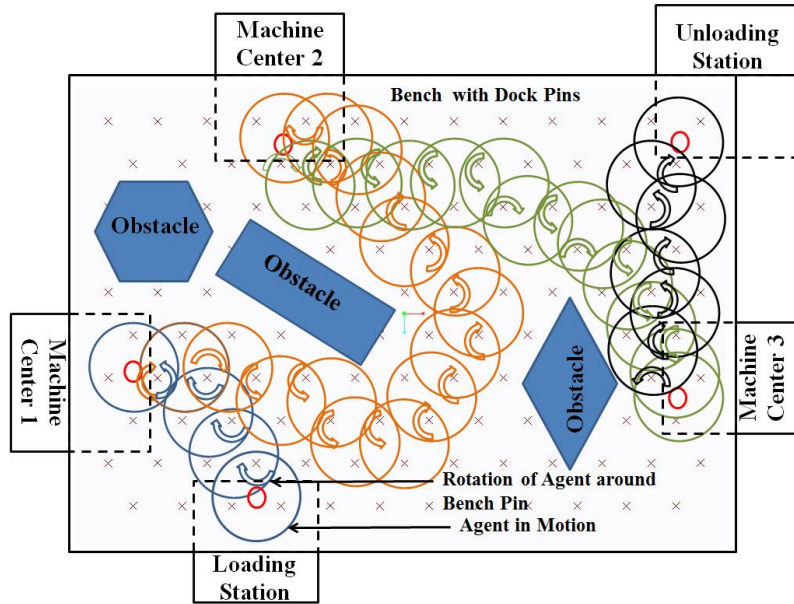
Material Handling Scenario (MHS)

SwarmItFix mobile base platform

Mobile Base platform offers better reachability than traditional gantry for limited workspace environment with simple and easier control than the wheeled platforms
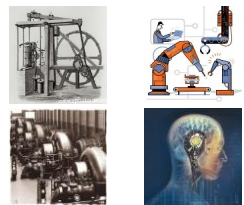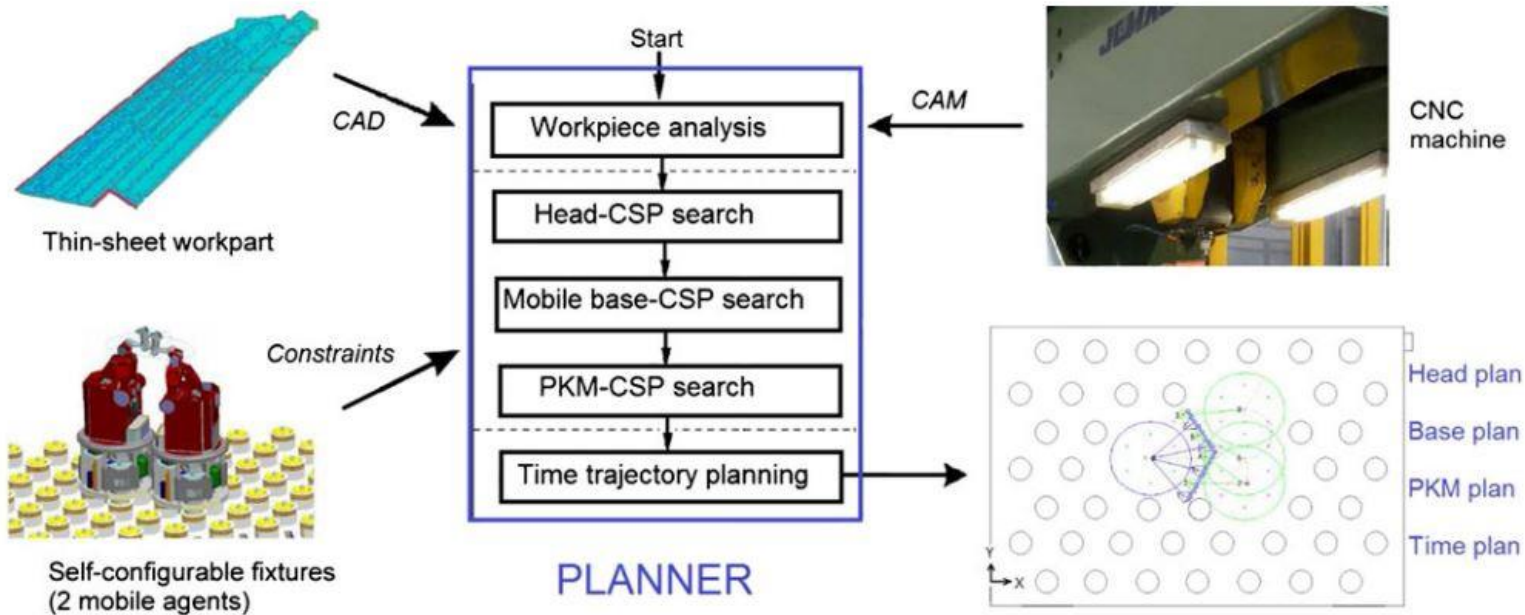
Information Features

Software/Information Feature

- **MROC++ Environment for Central server to agent communication through Wireless protocol**
- **CSP Constraint Satisfaction Approach to provide fixture plan based on machining contour**
- **Pneumatic Control for cheap free environment and accurate positioning of agents on bench pins**

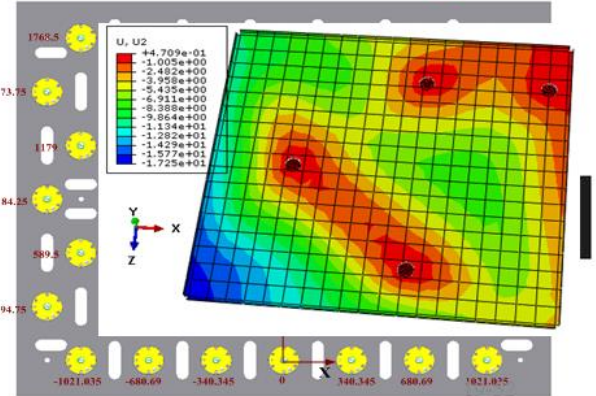# Information Features
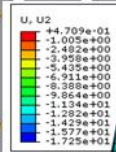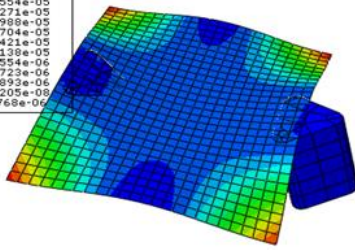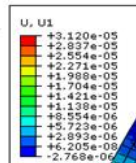Existing Industrial Significance

Thin-sheet workpart

Self-configurable fixtures
(2 mobile agents)

Start

CAD → Workpiece analysis ← CAM

Head-CSP search

Mobile base-CSP search

Constraints →

PKM-CSP search

Time trajectory planning →

PLANNER

CNC machine

Head plan

Base plan

PKM plan

Time plan

Information Features
Existing Industrial Significance

- **Fixture Layout Optimization (genetic algorithm)**
  2D & 3D Case simulation

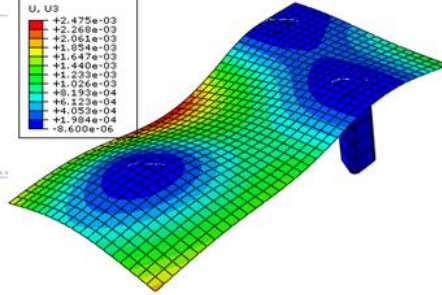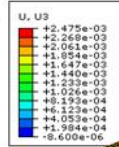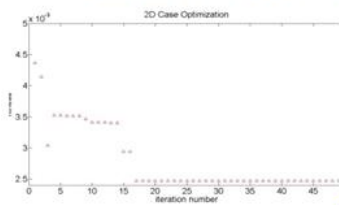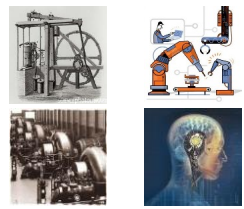- **Example case of fixture Layout Optimization**
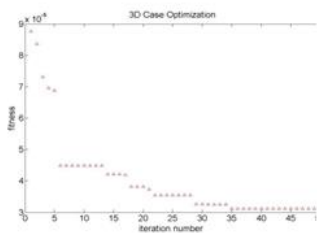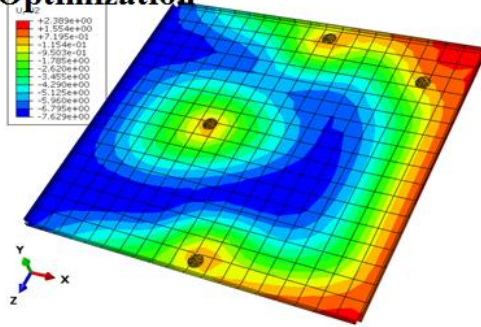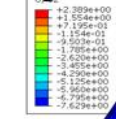
Path Information Features
## Alternative Industrial Significance

Current Approach

Graph Network based on Network Flow approach

- **Agent Assignment to task**
- **Agent Sequence Prioritization**
- **Collision detection with static obstacles (Winding Number algorithm) and other agents**
- **Collision management with offline and online (Adaptive shortest path) techniques**
- **Time Tabling**

Further Explorative

Multi-Agent plan based on Potential Field Techniques and other decoupled approach
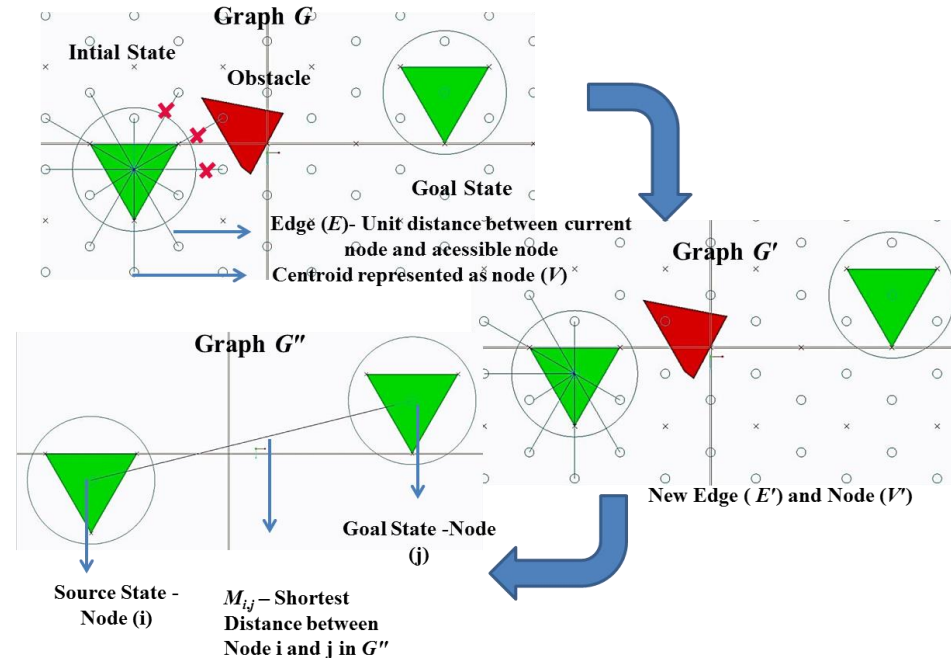
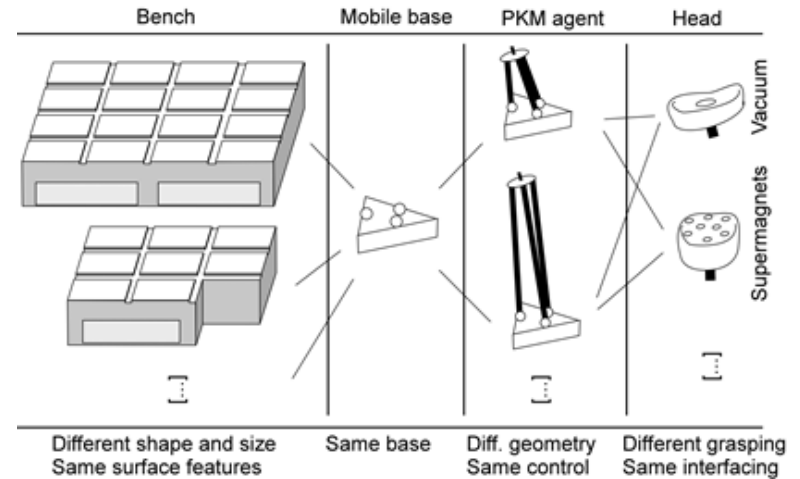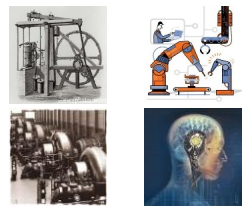Graph Evolution of Topology Graph to TSP Graph
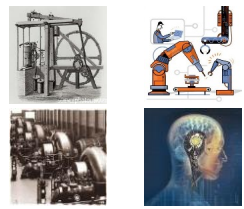
Flexibility

Flexibility

- **Inherent design enables Flexibility and Modularity**
- **Intelligent Centralized Control using Constrained Satisfaction Problem (CSP) Approach**
- **Swarm Agent Approach: Decentralized control can be implemented enabling Multi- Agent On- board control**

Bench	Mobile base	PKM agent	Head
Different shape and size Same surface features	Same base	Diff. geometry Same control	Different grasping Same interfacing

CONCLUSIONS

- **SwarmItFix has contributed and empowered on all three frontiers of Robot 4.0, Manufacturing 4.0 and Flexibility 4.0**
- **Appropriate Technology can be adapted by the Industry from the outcomes of the SwarmItFix Project to achieve Industry 4.0**