SmartEdge

Use Case: Autonomous Mobile Robots for Smart Factories

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SMARTEDGE Project

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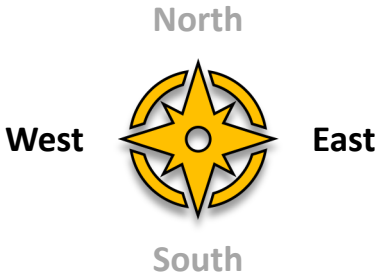
https://www.smart-edge.eu/

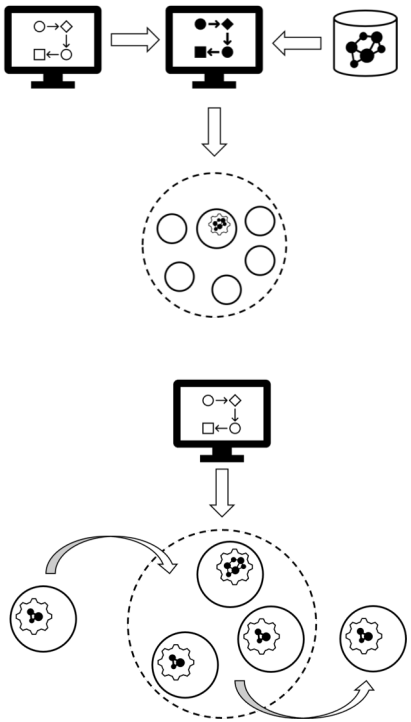
Why Use Swarms in Smart Factories

- Smart Factories
  - Smaller more flexible local factories
    - ✓ Closer to customers they supply
      - Reduced transportation CO^2 emissions
      - Shorter more robust supply chains
      - Easier to recycle component back into production
    - ✓ Larger range of products – smaller batch sizes
      - Dynamic production lines
      - Copes with indeterminant multi-agent environment ← Humans are messy
      - Similar costs
  - Enabling smart factory technologies
    - ✓ Robotic Flexible Assembly Cells (RFACs)
    - ✓ Autonomous Mobile Robots (AMRs) ← Dell Technologies' use case
    - ✓ Made up of swarms of intelligent edge devices called nodes
      - Peer-to-peer collaboration at the edge
      - Coming together to achieve a common goal
      - With minimal central supervision
      - Some degree of local problem-solving ability
      - Heterogeneous devices contributing different capabilities and skills
      - Communicating using common semantics interfaces



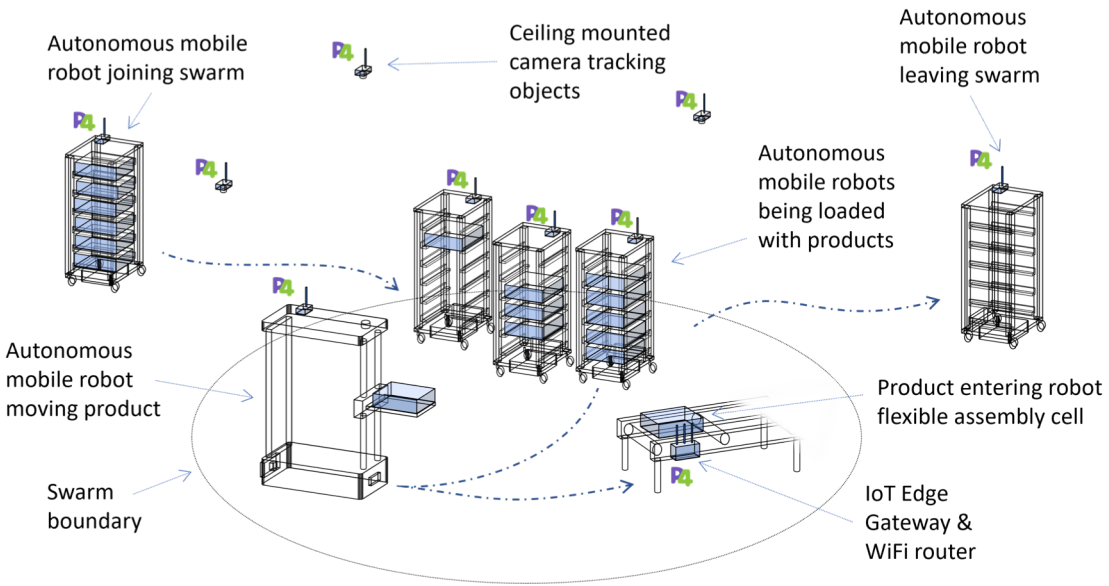
Static bound and dynamic swarm

- SmartEdge supports several types of swarm
  - Statically bound swarms
    - ✓ Swarm nodes defined at design time and allocated to swarm
    - ✓ Nodes remain with the swarm throughout its operational lifespan
    - ✓ Useful for supporting brownfield devices and backwards compatibility
  - Dynamic swarms (goal oriented) ← Manufacturing use case
    - ✓ Swarm starts with a seed node around which the swarm forms
    - ✓ Devices are actively enlisted into the swarm to provide skills the swarm needs to fulfil its goal
      - Make use of swarm contracts to enlist devices into swarm
    - ✓ Swarm nodes remain independent agents and can leave the swarm if required
      - e.g. battery level running low
    - ✓ When the goal is achieved the swarm brakes up
      - But with a little bit of stickiness
  - Dynamic swarm (device oriented) ← Traffic use case
    - ✓ Similar to goal oriented swarms but more for the benefit of the individual device
    - ✓ Requires a certain number of core swarm nodes
    - ✓ Devices request to join the swarm because it provides a benefit to them
      - e.g. faster transition through road traffic junctions



AMRs vs AGVs

- AGVs - Automated Guided Vehicles
  - Been in our factories for decades
  - Tend to follow predefined routes
  - When they encounter an obstacle
    - ✓ they stop
- AMRs – Autonomous Mobile Robots
  - Newer addition to our factories
  - Can navigate their environment
    - ✓ typically using SLAM
  - Limited intelligence to avoid obstacles



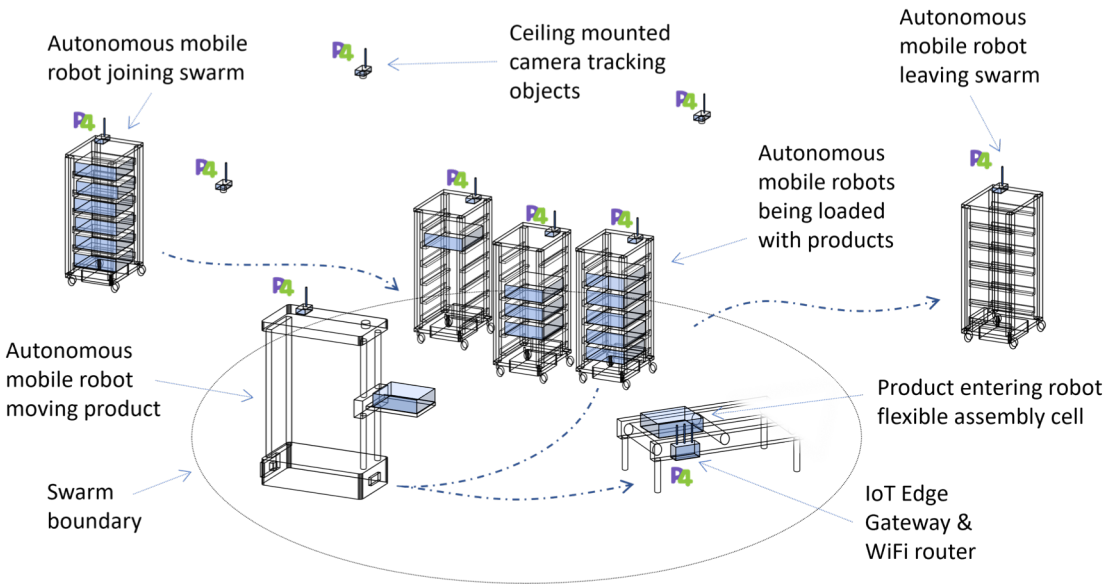
- SmartEdge AMRs
  - Form swarms of AMRs that collaborate in achieving a common goal
  - Use semantic integration to communicate within the swarm
  - Use semantic SLAM to better understand their environment
    - ✓ And modify their behaviour appropriately

SLAM: Simultaneous localization and mapping

Semantic SLAM: arXiv:2201.11625: SemRob: Towards Semantic Stream Reasoning for Robotic Operating Systems

Heterogeneous Swarm Devices

- SmartEdge supports different edge devices
  - With different skills and capabilities
  - e.g. ceiling mounted cameras or flexible assembly cells
- Swarm nodes can borrow sensor streams and even environmental 3D models from other nodes
  - And even share data processing task between swarm nodes
- Much of the swarm formation and management is handled in the network layer
  - Developed in the P4 network programming language

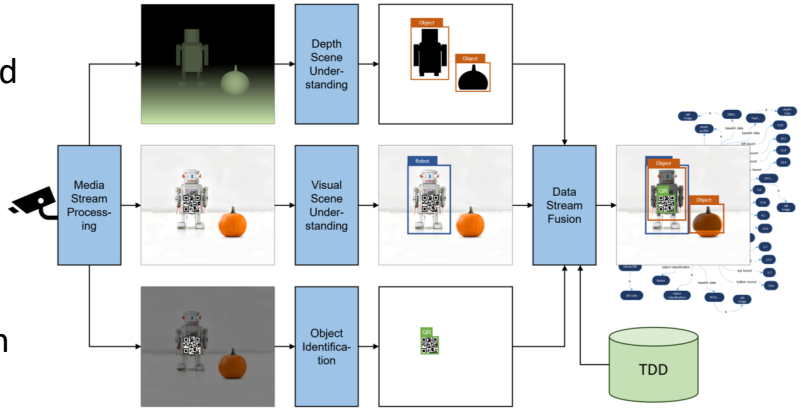


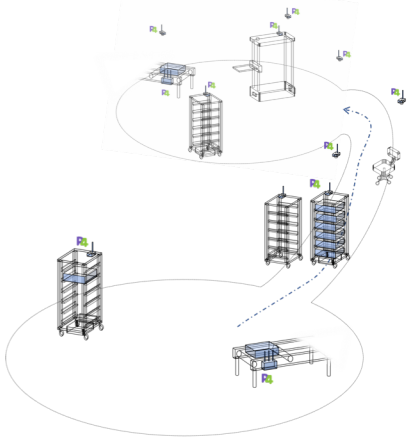
Web of Things

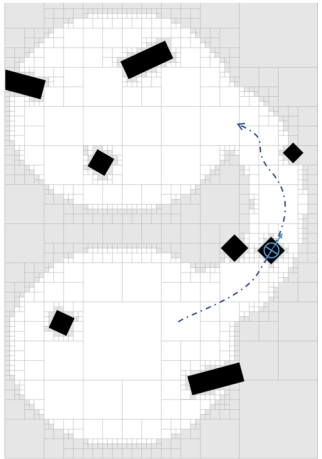
- Web of Things (WoT)
  - A set of guidelines and standards coordinated by the W3C
  - Used to model the nodes in the swarm in terms of their:
    - ✓ Properties
      - e.g. a thing's location or what skills it has
    - ✓ Action – operations that can be performed on a thing
    - ✓ Events – notifications that can be emitted by a thing
  - Can be used to construct a digital twin of the thing
- Can also be used to model other things in the environment that the swarm nodes interact with
  - Objects
  - Other independent agents
    - ✓ e.g. people
- The properties, actions, and events are grouped together into a Thing Description (TD)
  - And the TDs are stored in a Thing Description Directory (TDD)
  - SmartEdge makes extensive use of the TDD to build swarms
  - TDDs can be a central resource or implemented as distributed replicas

A Common Scene Understanding Between Swarm Nodes

- Swarm nodes comprehend their environment by building scene understanding graphs of what is around them
  - ❑ Each swarm node can have a different perspective
  - ❑ And augmented with thing descriptions from the TDD
    - ✓ Which provides additional context
- The scene graphs are shared between swarm nodes in real-time
  - ❑ And can be used to build 3D models of the environment
    - ✓ Which can also be shared with other nodes in the swarm
- This will enable a blind AMR (no sensors) to navigate around the factory by utilising semantic data feeds from other swarm nodes
  - ❑ A 3D semantic environmental model can be converted into a 2D occupancy grid used for navigation of the AMR
  - ❑ Or modify its behaviour depending on the type of obstacle
    - ✓ People can be asked to move – caster chairs could be pushed

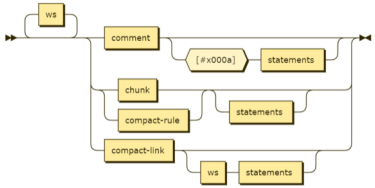






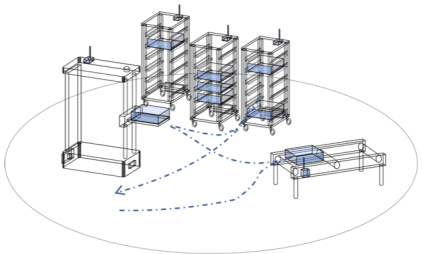
Swarm Node Collaboration

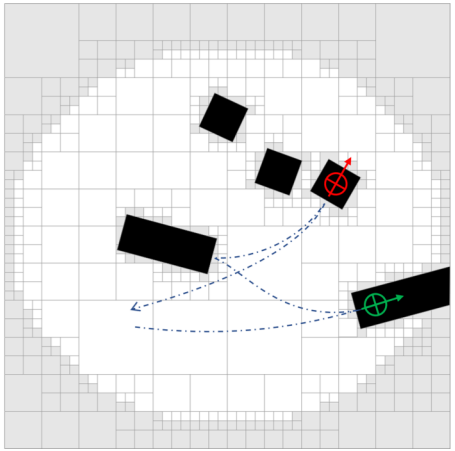
- Nodes in a swarm can communicate and collaborate to achieve a common goal
  - e.g. moving products from flexible assembly cells into autonomous mobile racks
- The actions performed by the swarm nodes are coordinated by an orchestrator
  - The orchestrator is just a node in the swarm with the right set of skills
  - Orchestrator can execute a plan implemented in W3C's Chunks & Rules
    - ✓ Or other rules engine

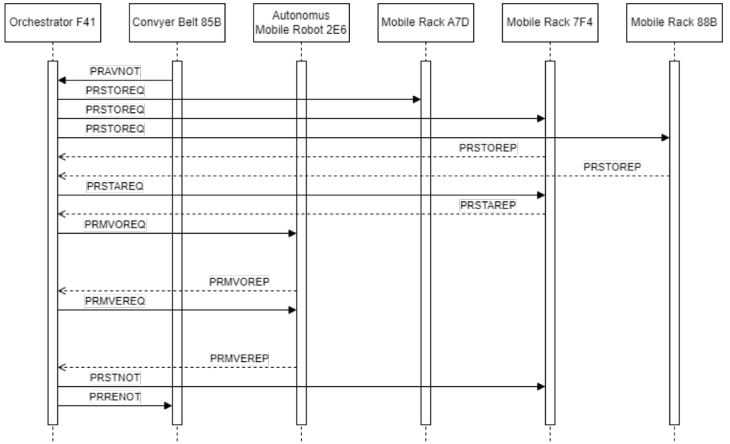


https://w3c.github.io/cogai/

- Swarm nodes exchange messages and negotiate actions between themselves

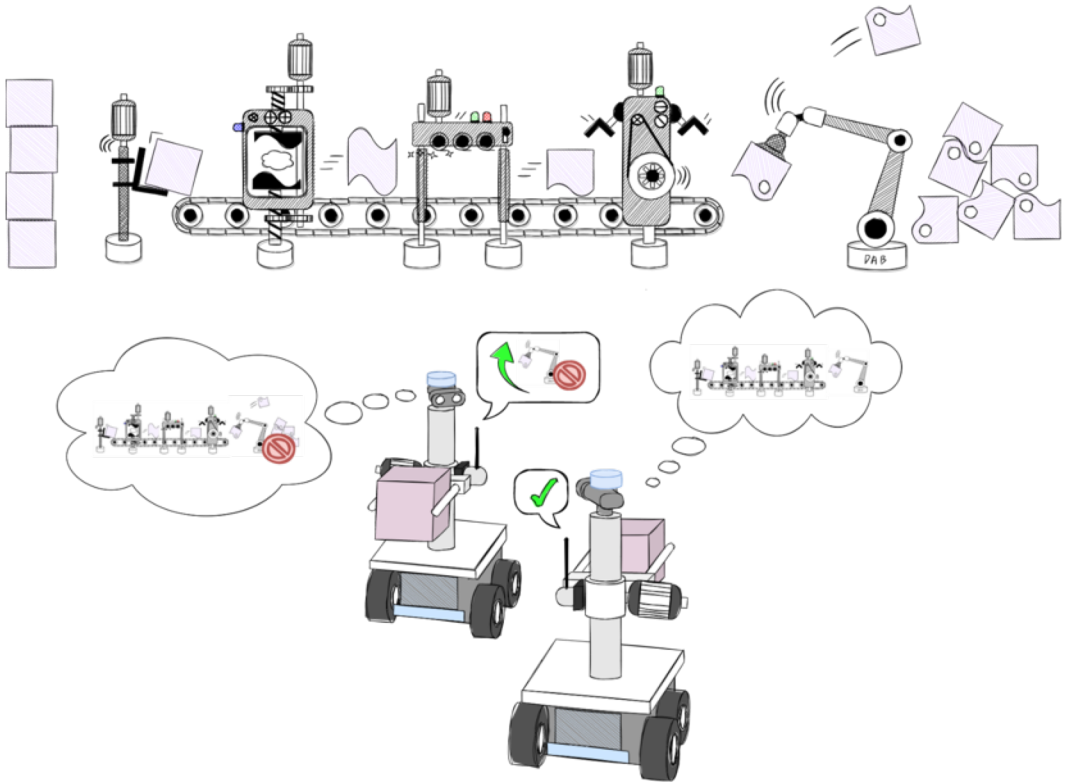






Summary

- We need more flexible, adaptable, and productive smart factories
- Swarms of autonomous mobile robots can help implement smart factories and cope with uncertain environments
- Different types of swarms can be used for different use cases
- Swarm nodes share semantic information to have a better understanding of their environment
- Swarms enable collaboration between nodes in a trusted and safe manner to achieve common goals



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