# Abstract

Industry 4.0 is the result of rapid technological advancement, dictated by Moore’s. Industry 4.0 seeks to enhance on Industry 3.0's automation by allowing devices to interact with one another, commonly known as the Internet of Things (IoT). Due to the widespread growth of IoT, various data from sensors is made accessible as what’s known as big data. Coupled with deep learning, these data are used to train machine models to make decisions. Resulting in an intelligent system that makes decisions without human involvement. Industry 4.0 has created an opportunity for a future where smart factories can leverage some of the most cutting-edge developing technology to automate and enhance many processes. Unmanned Aerial Vehicles (UAVs) is one such example. In Industry 4.0, UAVs have been deployed to perform task in smart factories that performs automatable and tedious tasks. Hence, this report aims to covers the usage and capabilities of UAVs in Industry 4.0. More specifically, the development and design of an intelligent UAV system for Industry 4.0.

# UAVs in industry 4.0

In Industry 4.0, autonomous UAVs are used to achieve a wide range of missions. Missions include warehouse operations – Inventory management, indoor intra-logistics, and inspections and surveillance[1]. Manufacturing – Inspection and maintenance [2]. For Warehouse management, UAVs are equipped with RFID scanners and Cameras for QR code and deployed to perform stock taking. Additionally, they have capabilities to transfer inventory from one location to another and lastly, check for pallet placement and detect theft. For Manufacturing, UAVs carry out inspection on equipment using infrared sensors to detect anomalies and cameras to deploy computer vision to detect cracks.

# Classification of UAVs

Generally, there are 4 categories of UAVs. Multi-rotor drones consist of a flight controller and 3 to 8 propellers. The flight controller collects data from the inertia measurement unit (IMU) and performs sensor fusion to accurately collect orientation and heading data. By applying a field of mathematics, control theory, the flight dynamics can be modelled for stable flight. Due to the lower cost and better maneuverability compared to fixed winged UAVs, multi-rotor drones are commonly used in smart factories. Figure 3A shows the categories of drones.

zDiagram

Description automatically generated

Figure 3A: Categories of UAVs [3]

Additionally, the level of aerial autonomy can be further classified based on inputs, capabilities reactions and decisions. Currently, drones have reached Level 4A of autonomy, where is senses and navigates with the assistance of an external computer. Figure 3B shows the categories aerial autonomy.

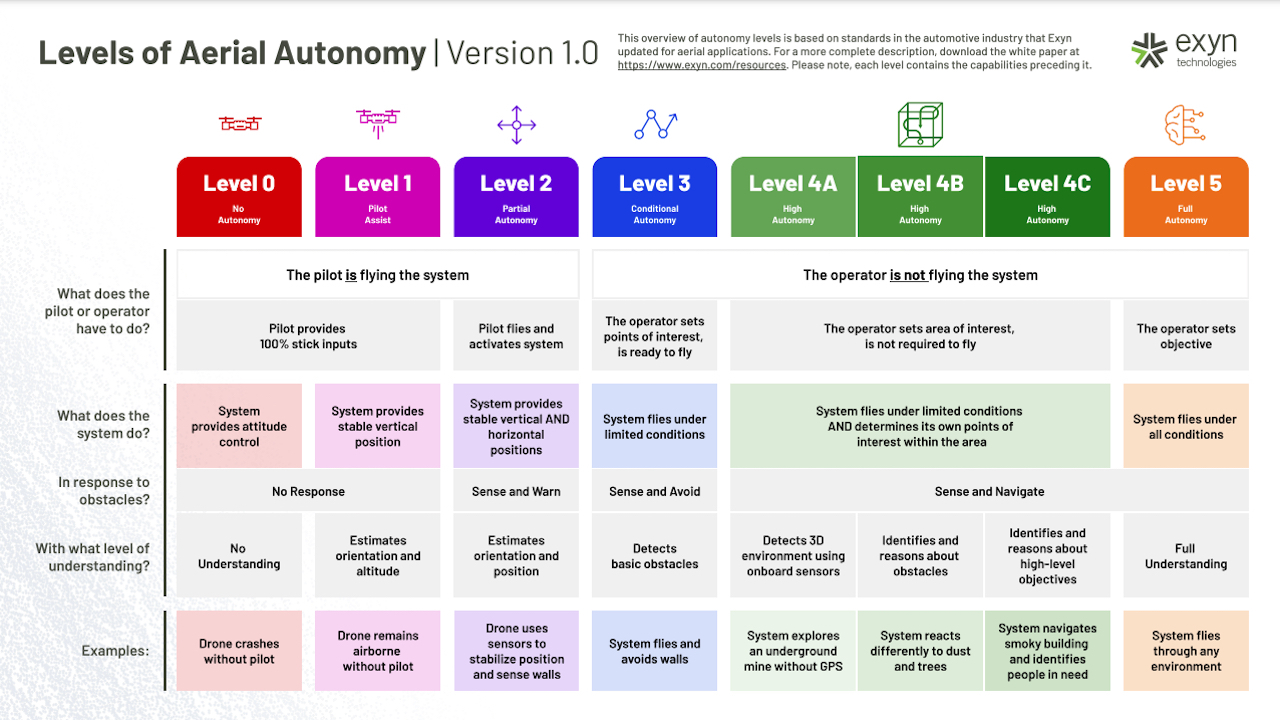


Figure 3B: Levels of autonomous UAV[4]

In this report, more emphasis will be placed on the development of Level 4A UAVs in smart factories.

# Function principles of UAVs

In smart factories, drones are IoT devices that communicate together and by transmitting information, it results in a collective perception. Although mapping may be completed, the environment may not be deterministic due to human interaction in the system. Hence, UAVs operate in a Partially Observable, Stochastic, Collaborative, Multi-agent, Dynamic, and Continuous environment. Hence, smart factories UAVs must be goal based, utility agents. Agents are things that senses and act on the environment. Goal based agents have sensors to localize their position and aims to reduce their position to their goal. Utility agents aims to minimize the total costs which could be path time or power consumption, or various parameters based on pareto optimal points. By having sensors to detect objects and indoor localization or cameras to perform simultaneous localization and mapping (SLAM), the UAV should be able to run search algorithms such as A\* to reach the end goal based on current state, as well as update its current state based on its perception from sensors. Figure 4A shows how SLAM is implemented. Figure 4B shows a graphical representation of A\* algorithm.

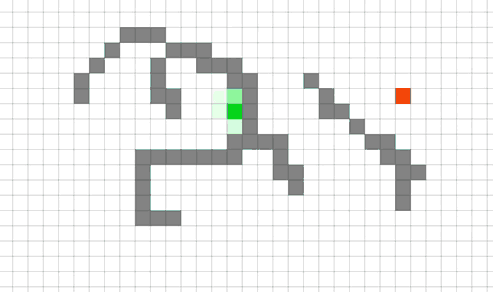
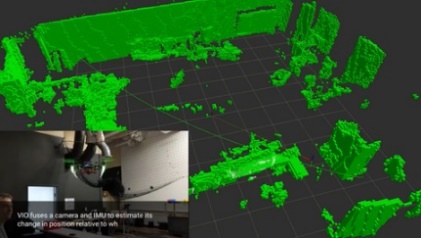


Figure 4A: Graphical representation of SLAM Figure[5] Figure 4B: Graphical representation of A\* Algo[6]

# Infinium Scan

Infinium Robotics is a company that develops collaborative drones for stock taking in smart factories [7]. The system consists of a camera and RFID reader equipped UAV, an unmanned ground vehicle (UGV) and a ground control system (GCS). UAVs are tethered to the UGV using a cable that transmit power and data where the tethering connection acts like a prismatic joint (1DOF).



Figure 4D: Infinium Scan Drone[8]

Firstly, mapping is done to collect obstacle data and free space. By modelling the dynamics of the UAV/UGV, a configuration space is created. Figure 4D shows a 3D plot of configuration space based on a 2D, rotating robot.

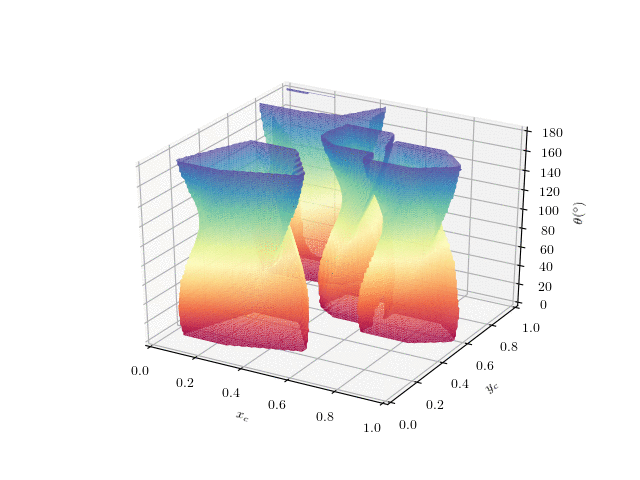


Figure 4D: Visualisation of configuration space on a 2D rotating robot [9]

With this data, a ground control system (GCS) completes a search algorithm of minimum path cost for the UAVs to possibly scan the items for stock taking. This is done by calculation of minimum total path costs of UGVs while preventing collision. To calculate the height of the UAVs, inverse kinematics based on the final position of the drone is used to calculate the required elevation from the UGVs. The waypoints are then transmitted over to UGVs. Localization is done on the UGVs, and by travelling to the selected waypoints, the position of the UAVs may be maintained by relative position sensor. This allows the UAVs to reach their final waypoint to complete scanning. Finally, the scanned data is uploaded to the warehouse management system (WMS).

# Challenges with UAVs

In smart factories, drones compete with existing solutions like cranes, conveyors, and robotic arms. While outdoor drones can use conventional global positioning systems (GPS) for localization, positioning, and routing, indoor drones require complex technologies, such as laser rangefinders (e.g. simultaneous localization and mapping (SLAM)), ultra-wideband radio signals (a form of “indoor GPS”), or more expensive technologies, such as motion capture systems (e.g. Khosiawan and Nielsen, 2016). Safety, noise and privacy also remain of considerable concern. Moreover, doors, cables, cranes, equipment and people limit the maneuverability of drones, and the confined spaces in manufacturing facilities can create turbulence.

# Learning approach

# References

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