



Damage Detection Algorithm for Spacecraft Situational Awareness

Swarm Intelligent Approach

Constraints

- Subagents use 2D Measurement Frame
 - All calculations are in a 2D solution space
- Aggregation/consensus of data occurs at Queen
 - Queen has limited 2.5D subagent domain, i.e. all agents are deployed in a normal vector to plane of Queen
 - Queen does all communication with spacecraft avionics
- Subagents have no awareness of other agents except Queen

Queen (Subagent Decision Aggregator)

Queen decides if a particular sub surface (SA) has damage if the aggregation of the subagents decide that damage has been detected. The sensor types are weighted based on the accuracy and assurance of the measurement and compared against delta to determine if damage has occurred.

$$Q_{SA} = \sum_{n=1}^N w_i q_i$$

$$Q'_{SA} = \begin{cases} 1, & Q_{SA} \geq \delta \\ -1, & \text{Otherwise} \end{cases}$$

Subagent Detection Algorithm

The subagent detection algorithm is determined from the sensor inputs \mathbf{x} . The weights and offsets to the algorithm are predetermined and vary depending on the location of the spacecraft being examined. The sign of the output is the decision, where a value greater than 0 indicates damage has occurred, otherwise damage has not occurred over a sub surface SA. Sigma represents the sigmoid function which is differentiable everywhere in \mathbb{R} .

$$q_{SA} = \sigma(\mathbf{w} \cdot \mathbf{x} + \mathbf{b})$$

Scanning Time

Zarya Module $\sim 1.9 \times 10^6$ cm² sub surfaces

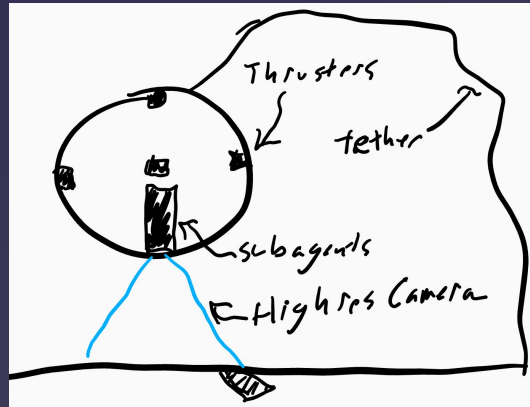
1 sub surface = 1 cm²

Each subagent with 100 Hz scan rate (100 sub surface per second)

Approx. 5 hours 15 minutes for complete module scan

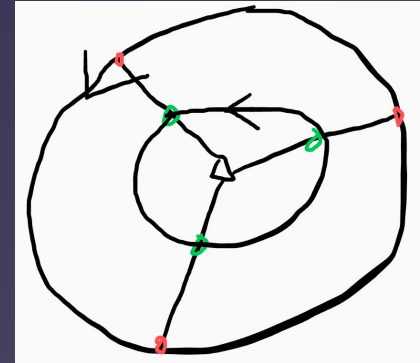
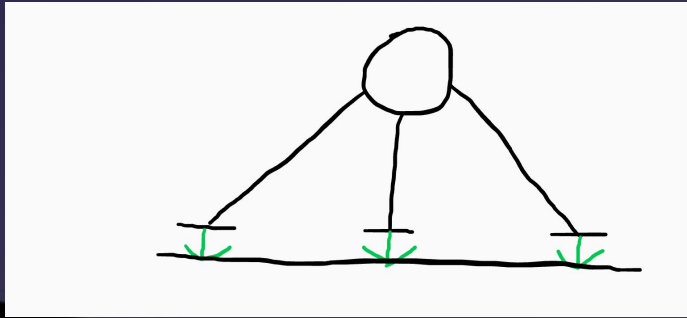
Queen Initial Scan

The queen is tethered to the spacecraft for relaying information back to the spacecraft and allows the queen to be recovered in case of failure. The initial scan will be done with a high resolution camera and then the subagents will be deployed from stowage to provide scans using a diverse set of sensors. The thrusters have two nozzles and the queen will have four thrusters.



Queen and Sub Agents

Subagents will deploy from the queen and the queen will rotate as the subagents collect the sensor input. The sensors underneath the subagents are shrouded to reduce noise and point normal to the spacecraft surface. The tether will provide power and communication between the subagents and the queen. The rotational track gets smaller as the sensors are moved closer to the center of the scan area.



Subagents

The subagents sensors will include:

Infrared - Detect surface damage

Optical - Detect surface damage and discoloration of surface

Synthetic Aperture Radar (SAR) - Detect surface damage and possibly sub-surface damage

Nature Concepts Applied

- Swarm Intelligence from ants
- Infrared Sensor from vipers
- SAR sensor is similar to echolocation in some mammals
- Optical Sensor is from the eye
- Tethering is from umbilicals found during gestation periods of animals

Operational View

