Sabertooth A Hybrid AUV/ROV offshore system

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SAAB WORLDWIDE

Employees 2010

<table>
<thead>
<tr>
<th>Country</th>
<th>Employees</th>
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<td>Sweden</td>
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<td>USA</td>
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<td>Switzerland</td>
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<td>Germany</td>
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<td><strong>Total</strong></td>
<td><strong>12,536</strong></td>
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[Map of global locations with employees distribution]
SAAB Seaeye Ltd

A company within the Saab Group

Fareham, United Kingdom – Commercial ROV

Linköping, Sweden – Defence ROV & AUV
COMPANY HISTORY

- It all started **100 years ago**.
- In **1910**, production of the first Swedish developed torpedo, the M12, commences in Karlskrona.
- In **1941**, the company relocates from Karlskrona to Motala.
- In **1991**, Sutec is acquired.
- In **2007**, Seaeye is acquired.
Double Eagle Sarov

- Semi autonomous AUV for military applications
- Developed 2005 - 2008
- Functions
  - Localization
  - Mapping
  - Object recognition (mines)
  - Mission planning
  - Obstacle avoidance
  - Mine detection
- Sensors
  - Motor encoder
  - Gyroscope
  - GPS
  - Camera
Seaeye Sabertooth
New combination of existing technology

Double Eagle SAROV

Seaeye WROV

SUBROV

Sabertooth
Seaeye Sabertooth
Design and benefits

The Sabertooth system is designed to:
• Remotely do inspection and intervention without the need for a supporting ship
• Autonomously do surveys and transit between work sites
• Work as a battery powered ROV using 9 km long fiberoptic tether giving it extremely long range as well as a very low footprint
• Do tunnel inspections

The main benefits of this are:
• Cost reductions, reduced ship time.
• Access to installations that cannot be reached with ships due to ice or weather conditions.
• Faster response and mobilization time.
• Extremely long tether excursions (+20km)
Seaeye Sabertooth

Main elements

- Seaeye Sabertooth AUV
- Operator station
- TMS Garage
- Docking station
- Communication
- Tools and sensors
Seaeye Sabertooth Design

Sensors:
- Cameras
- Imaging sonar
- Obstacle avoidance sonar
- Pressure sensor
- Hydrophone

Navigation
- IMU/DVL
- Passive nodes/landmarks for local navigation (RFID, reflectors)
Seaeye Sabertooth Design

Operator Console

- Similar to a conventional ROV console.
- Multiple computer screens
  - Mission planning data,
  - 3D visualization,
  - sonar and video data.
Seaeye Sabertooth

Docking Station

- Non Galvanic charging, data up and download
- Secure stowing place.
- Allows for new tools and payloads
- Power and communication interface
- Control module with the following functions:
  - Power transformer/switching
  - Ethernet switch
  - Interface to electromagnetic communication antennas and network
Seaeye Sabertooth
Communication

- Electromagnetic (RF)
  - Electromagnetic transmitters and receivers
  - Overlapping node spacing (redundancy)
  - Bandwidth approx. 100 kb

- Short communication tether
- F/OTether (Thin & Thick)
- Thick Power F/O Tether
Seaeye Sabertooth Tools

- Rotating torque tool
  - Loads on the valve is limited by a number of design features:
    - Small weight and size
    - Neutrally buoyant
    - Balancing thrust from the AUV
    - Flexible joint

- Future tool and sensor potential
  - CL 7 torque tool
  - tools for non Destructive Testing (NDT) and
  - Hydrocarbon leak detectors

- Tool skid docking
  - The same principles that are used for communication and power transfer
  - Built in batteries
  - Tools work independent of the AUV.
  - Protective structure for storage
Sabertooth Operation

Sabertooth has a behaviour based control system.
- Several goals simultaneously, e.g. run a track from one end of a structure to the other with a second objective of always having a standoff of 1.5 meters and a third objective avoiding obstacles.

The Sabertooth can be operated in 3 different modes.
- Autonomous, the vehicle is instructed to perform a specific task such as a transit to a location or a pre-programmed inspection/survey.
- Operator assisted operation, the vehicle is given step by step instructions such as move forward 3 meters. Operations are subject to constraints such as standoff, minimum height, speed etc. Each step is then verified by video or sonar data sent back through low bandwidth communication.
- Manual operation, the vehicle is operated manually but with assistance from onboard IMU/doppler allowing slow (limited by bandwidth) operation. This can be used in the final approach and operation of, for example, a valve.
MISSION
- PLANNING AND EXECUTION

Missions consist of Actions:
- Sequential discrete events
- Well-known transition models
- For example: Transport, Search, Docking

Actions consist of Behaviors:
- Parallel continuous control functions
- Activated during runtime
- Example: AvoidObstacle, GotoWaypoint(W), GetGPS-position
BEHAVIOR-BASED CONTROL

- Each behavior can voice its opinion on best course of action
- Behavior responses as utility functions
- An arbitration mechanism coordinates behaviors to maximize utility
- Dynamic activation level and static priority determines behavior influence.
- Reference values passed to low-level control system: roll, pitch, heading and speed in x, y, z.
**Intervention**

The vehicle swims of on a programmed track to a work site. IMU/doppler navigation keeps the vehicle on track while the sonar based standoff behavior stops the vehicle 3 meters in front of the site.

**Step by step control**

At this point the vehicle goes into operator assisted mode. The vehicle is step by step led to apply the tool. Low bandwidth images are sent back confirming each move.

**Target objects**

Targets can be selected for each move.

**Perform operation**

Operation is completed. The vehicle returns and initiates docking.
OBSTACLE AVOIDANCE
BEHAVIOR-BASED CONTROL: EXAMPLE

1: Track following: — Follow track closely for best sonar coverage and platform stability.

2: Waypoint navigation: — Ensure that the overall goal of reaching the next waypoint is met.

3: Obstacle avoidance: — Steer the vehicle clear of obstacles. Activation rises with hazard proximity.

4: Avoid past: — Influences the vehicle to favor a new path to avoid getting stuck in circular behaviors.

5: Emergency stop: — Influences the vehicle cruising speed to decrease with obstacle proximity. Ultimately forces the vehicle to a full stop if too close.
OBSTACLE AVOIDANCE

 Responses are weighted together and the maximum is chosen as the response to send to control system

Behavior response from Track Follow behavior and Obstacle Avoidance weighted together
Environmental Monitoring

- Environmental sensors
- Obstacle avoidance
- Pipe tracking
- Reactive control
- Radio Communication
Tunnel Inspection, another behaviour
Advanced Tunnel Inspection