SUB-SEA INSPECTION USING AUTONOMOUS UNDERWATER VEHICLE (SPINAV)

From Test Tank to Deep Water

SPINAV is an ongoing Joint Industry Project that is moving cutting-edge autonomous inspection technology from proof-of-concept trials in the test tank (completed November 2004) to an offshore trial using an unmodified commercial work-class ROV or AUV of opportunity. This article reviews the background to the technology and discusses details of the development process and wet trials.

The initial part of this ongoing project, SPINAV-1, the proof-of-concept trial had several sponsors: BP, Subsea7, Conoco-Philips and the UK Government Department of Trade and Industry. SPINAV-2, the offshore work-up project, is now underway; started in July 2005 and running for twelve months, it is sponsored by BP and Scottish Enterprise. Both these JIPs were organised through the ITF (Industry Technology Facilitator). Current practice for most forms of offshore inspection is to use an ROV equipped with video camera and other sensors, such as AC Impedance sensor, with forward-looking sonar for localisation in poor visibility. Occasionally, towed side-scan can be used (e.g. pipelines) for low-fidelity information.
Invariably the pilot controls vehicle and sensors. The task is tedious in the extreme, requiring high levels of pilot concentration for extended periods to keep station, especially in deep water. Sea currents further complicate ROV positioning due to drag and disturbance from the umbilical or tether. Inspection can only be carried out in conditions of good visibility for ROV station keeping by pilot. ROVs move relatively slowly and require a dedicated support-vessel on station. Opportunistic inspections are unlikely, due to the cost and logistics of mob/demob, launch and recovery.

The SPINAV Approach
With the introduction of autonomous inspection systems with automatic control of the ROV the quality of collected data can be improved by sensor-control fixed stand-offs and by having a more stable vehicle platform. In addition, the use of automatic navigation and trajectory-planning techniques reduce pilot burden. The SPINAV approach involves the pilot manoeuvring the ROV to within sensor (typically sonar) range of the structure for inspection. The automatic inspection procedure may then be started up; the SPINAV system will autonomously navigate the ROV and its inspection payload skid around the structure. At the end of the procedure the pilot takes over manual control once again. Figure 1 shows the SPINAV system concept and Figure 2 shows the reality, with the SPINAV system working on a host AUV Rauver. The blue beam of the Fluorosene sensor can be seen coming from the SPINAV Toolskid, with the Didson acoustic camera mounted next to it.

Commercial Advantages
By targeting the existing fleet of offshore ROVs, automatic inspection using SPINAV gains an early entry to market. As the use of inspection-AUVs (Autonomous Underwater Vehicles) matures, SPINAV will be available as a mature technology to support commercial operations. The net commercial effects of autonomous or hands-off inspection are several. More regular inspection results in fewer losses in production, leading to reduced likelihood of breakdowns and improved quality of inspection data (better sensors and navigation). Inspection costs are reduced through increased speed of inspection, automatic checking of coverage (no missed areas) and fewer â€˜re-inspectionsâ€™ due to autonomous collection of additional data at anomaly sites.
SPINAV-1 developed the foundation technologies required, such as real-time tracking of a riser, real-time position control of the vehicle relative to the riser, anomaly detection and adaptive mission management, allowing the vehicle to autonomously change its mission if anomalies are detected. In SPINAV-1 these technologies were thoroughly in-water tested using Heriot-Watt Universityâ€™s AUV Rauver, and demonstrated live to sponsors and interested parties, including major oil, gas and military organisations, in the Subsea7 12m diameter x 8m-deep Test Tank in Aberdeen, UK. During these trials the SPINAV system was shown to cope with wave action caused by strong winds blowing over the exposed test tank. Figure 3 shows the SPINAV system working on the host AUV Rauver during the final demonstration.

Developing SPINAV-2
Development of SPINAV-2 is now underway. The foundation technologies developed in SPINAV-1 will be extended to work on a broader range of targets such as jackets, ship-hulls, anchor chains, etc. The vehicle control system will be extended to include an adaptive autopilot, allowing the SPINAV system to be flown on any available vehicle without lengthy autopilot re-tuning. The data visualisation process will be greatly improved using texture-mapped 3D mosaics and easy methods of checking inspection coverage. Other anomaly detection sensors, such as Cathodic Protection (CP) probes, will be reviewed. These improvements will be field-tested in sheltered water, lake or harbour, using Heriot-Watt Universityâ€™s AUV Rauver, before being moved onto an unmodified commercial work-class or inspection-class ROV ready for full offshore trial. The sheltered-water trials will be completed in December 2005, with the offshore trial following when ship time and weather permit, in early 2006.

Extended Technologies

The foundation technologies developed during SPINAV-1 and being extended during SPINAV-2 are:

- embedded Adaptive Command, Control and Mission Management (CCMM)
- real-time tracking of riser position using acoustic camera
- autopilot control capable of following trajectories relative to the riser, even when riser moves
- fast processing and display of inspection data.

The CCMM module sits above all other embedded vehicle modules and is the interface between the pilotâ€™s SeeTrack graphical mission planning tool and the vehicle. As most missions mainly involve moving from one place to another, the CCMM deals mainly with the Autopilot module. The CCMM module presently sends commands at 1-second intervals to the lower level â€˜real-timeâ€™ modules such as the Autopilot. If an anomaly is detected the CCMM module will adapt its mission to perform a close video inspection of the area of interest. Once this has been performed the normal mission is resumed. In SPINAV-2 the CCMM module will receive an incremental upgrade to allow complex 3D manoeuvres and mission adaptation around generic structures, not just risers.

Object tracking such as riser or wall tracking is performed by image processing performed in real time upon various types of sensor data. For SPINAV-1 the Didson acoustic camera was used, managed by a driver module that takes care of setting the correct ranges and operating modes. The raw Didson image is then employed by the Tracker module, which uses image-processing techniques to recognise any riser in the image and determine range and bearing to the riser centre with respect to the vehicle. For SPINAV-2 a combination of other tracking-suitable sensors will be explored.

An autopilot monitors vehicle position and responds to movement requests by calculating the necessary thruster settings to achieve this position. It adjusts thrusters at five times a second, which is generally enough to control the relatively slow ROVs or AUVs in use today. This provides a very smooth, precise and efficient level of vehicle control and is markedly different to that produced by a human ROV pilot. In SPINAV-1 the autopilot had to be manually tuned to suit the vehicle under control, but SPINAV-2 will see the addition of an â€˜autotuneâ€™ facility, allowing the autopilot to take control of different vehicles without a long tuning period.

Visualisation of the mass of inspection data is performed using SeeByteâ€™s SeeTrack system. In SPINAV-1 vehicle track, video data and fluorosene concentration were combined into a single, easy-to-use 3D world. Using this it was possible to immediately see any dye in the water, click on the point in question and view a video picture of that area. This simplified the entire analysis task for the operators.

The developmental platform chosen for the sheltered-water trials of SPINAV is Heriot-Watt Universityâ€™s Rauver AUV, a <250kg auv capable of hovering, inspection and light intervention, as well more conventional survey missions. open construction ease interfacing enable it to be used a convenient test-bed for various payloads. can function either or battery-operated rov.

Demonstrating Skills

During SPINAV-1 a live demonstration was given to various oil, gas and military representatives. The objective was to inspect an 8m-tall, 13cm-diameter riser which had a transparent bottle of fluorosene dye representing a plume attached at an arbitrary point. The SPINAV system running on the Rauver AUV dived and began circling the riser until it saw the bottle of dye with its fluorosene sensor. At this point, the CCMM commanded a close inspection of the area of interest before resuming its normal inspection mission. At the end of the inspection, which took about 15 minutes in total, Rauver surfaced and the data was downloaded into SeeTrack via Rauverâ€™s surface WiFi connection. Within 20 minutes of Rauver surfacing, the operator was able to show observers the entire mission in 3D, together with fluorosene-concentration maps and close-inspection video footage of the dye bottle. A screenshot of the SeeTrack view of the demonstration is shown in Figure 4. In SPINAV-2 this will be extended to allow full 3D texture-mapped mosaicking of video and Didson data, together with indications of any coverage gaps. An early version of this is shown in Figure 5, showing a 3D view of a vehicle, its track and some 3D structures waiting for video or Didson data to be mosaicked onto them.