Exploring the Deep With SONIA

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Martin Morissette, Software Team Leader

SONIA AUV Project
École de Technologie Supérieure
http://sonia.etsmtl.ca

TS-1990
SONIA
Java™ Platform Powered Autonomous Underwater Vehicle

Learn how a team of undergraduate engineering students used Java™ technologies to build a winning Autonomous Underwater Vehicle platform
Agenda

Overview of SONIA AUV System, Mechanical and Electronic Design
Software Architecture
Test and Debugging Tools
Demo of the 3D AUV Simulator
Development Methodologies
Conclusion
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System, Mechanical and Electronic Design
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SONIA AUV Project
“Système d’Opération Nautique Intelligent et Autonome”

- Founded in 1999
- Entirely managed by volunteer undergraduates
- Team of ~30 engineering undergrad students
- Low-budget project
SONIA AUV Project
“Système d’Opération Nautique Intelligent et Autonome”

SONIA 2006 competition team
École de Technologie Supérieure
Overview of the University

- 4th largest engineering university in Canada
- 5000 undergraduate and graduate students
- Applied engineering faculty of the Université du Québec network
- 4-year, 120 credit co-op engineering program
- Only admits professionally trained technicians
- Official language: French

Autonomous Underwater Vehicle

What is an AUV

- Sensors based underwater navigation
- Controlled by Artificial Intelligence (AI)
- Interacts with its environment
- AUVs are NOT remotely operated
AUVSI and ONR’s International AUV Competition

Overview of the Competition

• Held at SPAWAR System Center San Diego, CA
• Focus on autonomous operations
• Annual competition
• Teams from Canada, India, Japan, USA…

AUVSI and ONR’s International AUV Competition

2006 Mission

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SONIA AUV System Design

- Watertight
- Neutral buoyancy (+ 0.5 %)
- Battery operated
- Shallow water operations
- Four degrees of freedom (heave, sway, surge, yaw)
- Mass inferior to 25 kg
- Rapid deployment
- Easy access to electronic components
Sensor Overview

- Compass
- Passive SONAR
- Firewire Cameras
- Active SONAR
- Inertial Measurement Unit
- Pressure Sensor
- Mission Switch
- Kill Switch
DEMO

3D Vehicle Design
Agenda

Overview of SONIA AUV System, Mechanical and Electronic Design

Software Architecture

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Development Methodologies

Conclusion
Switch from C/C++ to Java Platform

Reasons for the Switch

- Widespread OO language amongst undergrads
- Platform independent (Linux, Windows, Mac OS X)
- Open source tool availability
- Checked exceptions
- Pervasive memory protection
- Exhaustive APIs
Switch from C/C++ to Java Platform

Impacts of the Switch

- Faster development: designed from scratch an improved system within one year
- Maintainability: same version since the switch throughout many generations of developers
- Scalability: support for new devices, new communication protocols, etc.
Java Technology in Robotics

How to Integrate Java Technology

- Memory allocation at startup
- Limit dynamic instantiation
- Modular design with intelligent devices
- Profiling of critical modules
- Object pooling, recycling used objects
Software Architecture

JMX™ = Java Management Extensions specification
Software Architecture
AUV4
Capabilities

• Sensor interface
• Data fusion
• Navigation and control
• Decision taking
• Artificial intelligence
• Data logging
AUV4 Architecture

Control Loop

- Navigation decisions taken within a single thread (loop)
  - Synchronized with actual navigation sensors
  - Deterministic execution of tasks
  - Processing over a same timeframe sensor value set
  - Simplify overall system
  - Prioritize navigation over global services
AUV4 Architecture

Control Loop

```java
public void run() {
    markBeginning();                        //Mark the beginning of an iteration

    applyNextDeviceValue();               //Baseline the values for determinism
    this.refreshSelfEnclosedDevices();   //Process polling based devices

    supervisor.process();                 //Check for warning conditions
    mission.process();                   //Process AI
    controllerManager.process();         //Process navigation controllers
    commControlProcess.process();        //Process Tx communication

    markEnd();                            //Mark the end of an iteration
    displayStats();                      //Display stats (incl. overrun detection)
}
```
AUV4 Architecture

Mission

• Simple state machine

• Advanced AI inside each state
  • Expert systems
  • Neural network
  • Fuzzy logic

• Easily reconfigurable
Code Sample—State Template

public class StateDemo extends NormalState {
    public void setupDevices() {
        // Setup sensors/actuators the state interacts with
    }

    public void init() {
        // Called whenever the mission enters this state
    }

    public String process() {
        // Called by the control loop where the state can
        // process sensor data and act upon it
    }

    public void exit() {
        // Called upon exit of this state
    }
}

public String process() {
    Point2D p = hydro.getPingerPosition();
    elevFilter.addValue(p.getY());

    if (p.getY() <= maxElevationForGoodHeading) {
        heading.setTarget(hydro.getValue());
    } else {

        if (elevFilter.isFilled() && elevFilter >= elevationForSurface) {
            if ((currentTime - startOfState) > minTimeMs) {
                MissionLog.getInstance().log("Let's surface!");
                speedMeter.setTarget(0.0);
                return NEXTSTATE_ON_SUCCESS;  // Trigger for surface!
            }
        }

        MissionLog.getInstance().log("Elev. high, but delay not over");
    }
}
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Software Architecture
Telemetry
Remote measurement and management

• Enables
  • Remote configuration
  • Remote monitoring
    • Sensors
    • Actuators
  • Remote control
  • Data logging info

• APIs
  • Swing
  • Java Management Extension (JMX™)
  • JGraph
Telemetry
Remote measurement

Display Sensors/Actuator Values

Graphical Display of Value Evolution vs. Time

Provides Navigation Information
Telemetry
Mission editor
Software Architecture
Vision Client
Remote management

• Enables
  • Remote configuration of vision system
  • Remote monitoring of vision algorithm outputs
  • Customization of vision algorithms

• APIs
  • Swing
  • QuickTime for Java technology (QTJava)
Vision Client
Remote management
Software Architecture
Simulator

Underwater 3D Simulator

- Simulates
  - Physical properties of the vehicle
  - Electronic interface
  - Simulates competition environment
  - Custom physic engine and model
- Easily test control and AI
- APIs
  - Java 3D™ API
Simulator
DEMO

Tools
Agenda

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Team Work

- Volunteer students
- Satellite members
- Unpredictable productivity
- Remote development (West-East-Europe)
- Different knowledge and backgrounds
- Multidisciplinary team
- Money is not a motivation
Methodologies

- Open source development tools
- Versioning system: SVN
- Project management and bug tracking: TRAC
- Content management: Wiki
- Code review: Diff email + RSS feed
- Pair programming
- Nightly build: Sending annoying emails on failure
- Standardized coding methodology and tools
Methodologies
Project planning in TRAC

Note:
- Timeline, roadmap, tickets (bug tracking) available online to all developers
- Allow remote management with team members in Boston, Menlo Park and Holland
- All modifications to tickets are subject to change notification (via RSS and email)
Methodologies

Change notification

Changeset 5236

Timestamp: 03/29/07 18:31:41 (2 weeks ago)
Author: fpageau
Message: Added the IMUHeading in the HeadingStatus tx handler to be compliant with the 2007 Nav board

Files: trunk/SimSonia/src/simulator/net/protocoleCAN/handlers/tx/HeadingStatus.java (1 diff)

Note:

- Reviewed by all members of the field of study (Software, Electrical or Mechanical)
- Distributed as a RSS feed and ASCII based emails
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## Competition Ranking

**AUVSI final standings: From 2003 to 2006**

<table>
<thead>
<tr>
<th></th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cornell Univ.</td>
<td>1&lt;sup&gt;st&lt;/sup&gt;</td>
<td>2&lt;sup&gt;nd&lt;/sup&gt;</td>
<td>8&lt;sup&gt;th&lt;/sup&gt;</td>
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<td>Duke Univ.</td>
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<td>5&lt;sup&gt;th&lt;/sup&gt;</td>
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<tr>
<td>MIT</td>
<td>4&lt;sup&gt;th&lt;/sup&gt;</td>
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<td>3&lt;sup&gt;rd&lt;/sup&gt;</td>
<td>6&lt;sup&gt;th&lt;/sup&gt;</td>
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<tr>
<td><strong>SONIA AUV—ETS</strong></td>
<td>2&lt;sup&gt;nd&lt;/sup&gt;</td>
<td>3&lt;sup&gt;rd&lt;/sup&gt;</td>
<td>2&lt;sup&gt;nd&lt;/sup&gt;</td>
<td>3&lt;sup&gt;rd&lt;/sup&gt;</td>
</tr>
<tr>
<td>U. of Florida</td>
<td>8&lt;sup&gt;th&lt;/sup&gt;</td>
<td>7&lt;sup&gt;th&lt;/sup&gt;</td>
<td>1&lt;sup&gt;st&lt;/sup&gt;</td>
<td>1&lt;sup&gt;st&lt;/sup&gt;</td>
</tr>
<tr>
<td>U. of Victoria</td>
<td>10&lt;sup&gt;th&lt;/sup&gt;</td>
<td>10&lt;sup&gt;th&lt;/sup&gt;</td>
<td>16&lt;sup&gt;th&lt;/sup&gt;</td>
<td>14&lt;sup&gt;th&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Source: AUVSI, *Final standings.*

<http://www.auvsi.org/competitions/water.cfm>
## Budget Comparison

### AUVSI final standings: From 2003 to 2006

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<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Cornell Univ.</td>
<td>X</td>
<td>30,000</td>
<td>X</td>
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<tr>
<td>Duke Univ.</td>
<td>X</td>
<td>65,000</td>
<td>113,050</td>
<td>93,100</td>
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<tr>
<td>MIT</td>
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<tr>
<td><strong>SONIA AUV—ETS</strong></td>
<td><strong>22,000</strong></td>
<td><strong>30,000</strong></td>
<td><strong>44,000</strong></td>
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<td>U. of Florida</td>
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<td>X</td>
<td>X</td>
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<tr>
<td>U. of Victoria</td>
<td>13,000</td>
<td>X</td>
<td>X</td>
<td>160,000</td>
</tr>
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</table>

Sources: Burdyny, Matt. U. of Victoria
http://www.duke.edu/web/robotics/html/auv_budget.htm
http://www.news.cornell.edu/chronicle/02/8.15.02/Chronicle.pdf

Note: All budgets are in USD for ease of comparison.
Funding and Sponsorship
Past, present and future overview

SONIA AUV had a $70,000 CDN budget in 2006
- 74% of funding was from private donations
- 29 sponsors contributed to the project

SONIA AUV has a $60,000 CDN budget in 2007
- 10% of the funding is still to secure
- 25 sponsors renewed their support

SONIA AUV needs to acquire new sensors for 2008–2009
- Doppler Velocity Log (DVL): positioning sensor worth $25,000
- Altimeters: 2x distance sensors worth $3000 each
- Your support is essential to our success
Summary

- Switch to Java technology for improved results
- Java technology is a prime choice for robotics
- Teamwork, creativity and innovation
- Low cost solutions
- Adapted methodologies
For More Information

List

- Sun Microsystems, 2006, *Meet SONIA*,


- AUVSI, 2007, 10th AUVSI & ONR AUV competition,
  <http://www.auvsi.org/competitions/water.cfm>
## Glossary

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
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<tbody>
<tr>
<td>AI</td>
<td>Artificial Intelligence</td>
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<tr>
<td>API</td>
<td>Application Programming Interface</td>
</tr>
<tr>
<td>ASCII</td>
<td>American Standard Code for Information Interchange</td>
</tr>
<tr>
<td>AUV</td>
<td>Autonomous Underwater Vehicle</td>
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<tr>
<td>AUVSI</td>
<td>Association for Unmanned Systems International</td>
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<td>CDN</td>
<td>Canadian currency</td>
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<tr>
<td>DVL</td>
<td>Doppler Velocity Log</td>
</tr>
<tr>
<td>ETS</td>
<td>École de Technologie Supérieure</td>
</tr>
<tr>
<td>IMU</td>
<td>Inertial Measurement Unit</td>
</tr>
<tr>
<td>ONR</td>
<td>Office of Naval Research</td>
</tr>
<tr>
<td>OO</td>
<td>Object Oriented</td>
</tr>
<tr>
<td>RSS</td>
<td>Really Simple Syndication</td>
</tr>
<tr>
<td>SONIA</td>
<td>Système d’Opération Nautique Intelligent et Autonome</td>
</tr>
<tr>
<td>SPAWAR</td>
<td>Space and Naval Warfare Systems Center</td>
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<td>SVN</td>
<td>Subversion (<a href="http://subversion.tigris.org/">http://subversion.tigris.org/</a>)</td>
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<td>TRAC</td>
<td>Open source, minimalist, web-based project management and bug-tracking tool. (<a href="http://trac.edgewall.org/">http://trac.edgewall.org/</a>)</td>
</tr>
<tr>
<td>USD</td>
<td>United States currency</td>
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Q&A

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