autoNomous, self-Learning, OPTImal and compLete Underwater Systems NOPTILUS

FP7-ICT-2009.6: Information and Communication Technologies

Final Project Review

Situation Understanding (WP6)

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Porto, Portugal

WP6 Reminder

➢ **WP6 Ojective**
- ▪ *recognize interesting events in streams of observations*
- ▪ *observations*: (abstracted) sensor data
- ▪ *events*: patterns in observation streams

➢ **Models**
- ▪ Probabilistic Context-Free Grammars (PCFGs)

➢ **Task 6.1: Event Recognition**
- ▪ real-time, hierarchical parsing for on-line recognition

➢ **Task 6.2: Grammar Learning**
- ▪ off-line learning of PCFGs from past AUV mission logs

➢ **Task 6.3: Integration**

Outline

- **WP6 Update**
  - DUNE code (on-board) integration
  - dedicated Git account
  - experimentation
- **WP6 Overview**
  - real-time, hierarchical parsing for on-line recognition
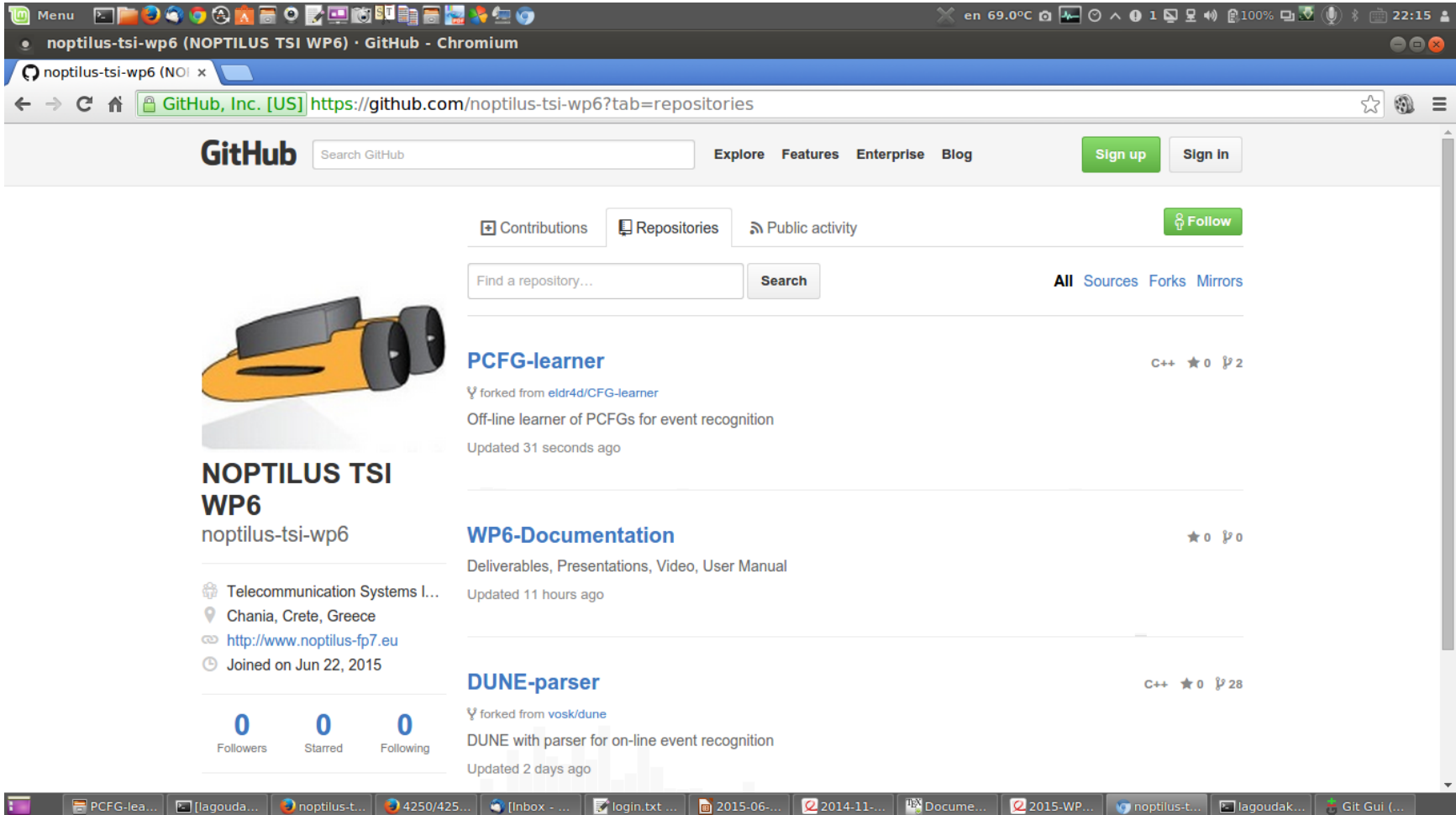 - off-line learning of PCFGs from past AUV mission logs
- **WP6 Conclusion**
  - contribution
  - considerations

WP6 Update (M43-M51)

recent developments

Integration: AUV+Dune+Parser

Thanks to Jose Braga for assistance!

WP6 Dedicated Git Account

https://github.com/noptilus-tsi-wp6

WP6 Git Repositories

➢**WP6 Documentation**
- supporting documentation for WP6
- deliverables, presentations, video, user manual

➢**DUNE-parser**
- a modified DUNE with original code for parser
- on-line, on-board event recognition
- main contributor: *Emmanouil Orfanoudakis*

➢**PCFG-learner**
- original code for off-line, off-board learning of PCFGs
- grammars for normal/abnormal event recognition
- main contributor: *Nikolaos Kofinas*
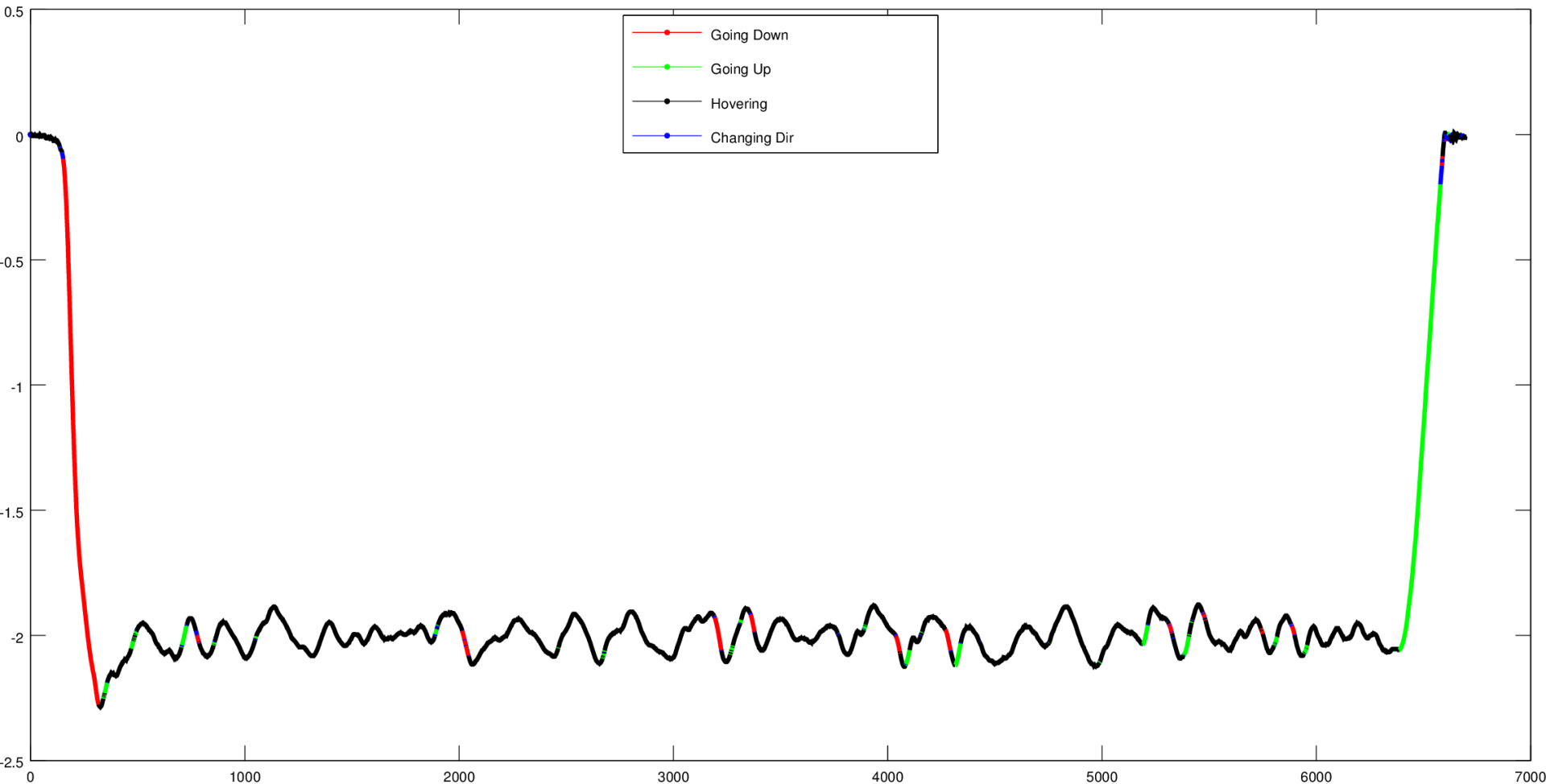
WP6 Experimentation

➢**March-May 2015 Test Runs**

- LSTS (hybrid) and APDL (real) experiments
- active parsers onboard the AUVs during a mission
- no reported CPU overload, glitches, crashes, ...

➢**May 27, 2015 Demo Run**

- open sea experiment with real AUVs
- two active parsers on **noptilus-2** and **noptilus-3**

Demo Results: Annotated Depth

2015-05-27-apdl-demo/lauv-noptilus-3/143426

Demo Results: Annotated Pitch

2015-05-27-apdl-demo/lauv-noptilus-3/143426

Demo Results: Annotated Depth

2015-05-27-apdl-demo/lauv-noptilus-3/093556

Demo Results: Annotated Pitch

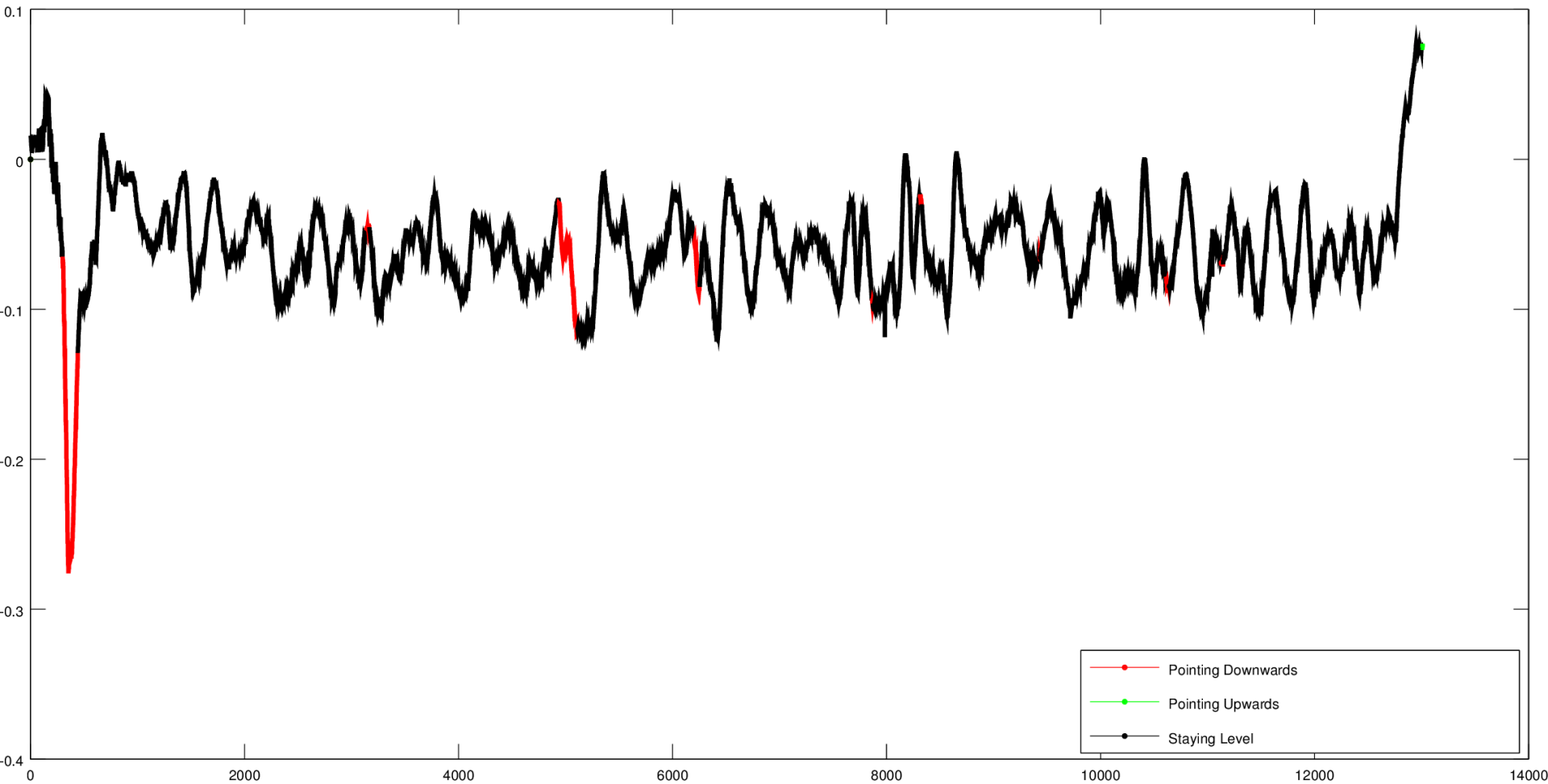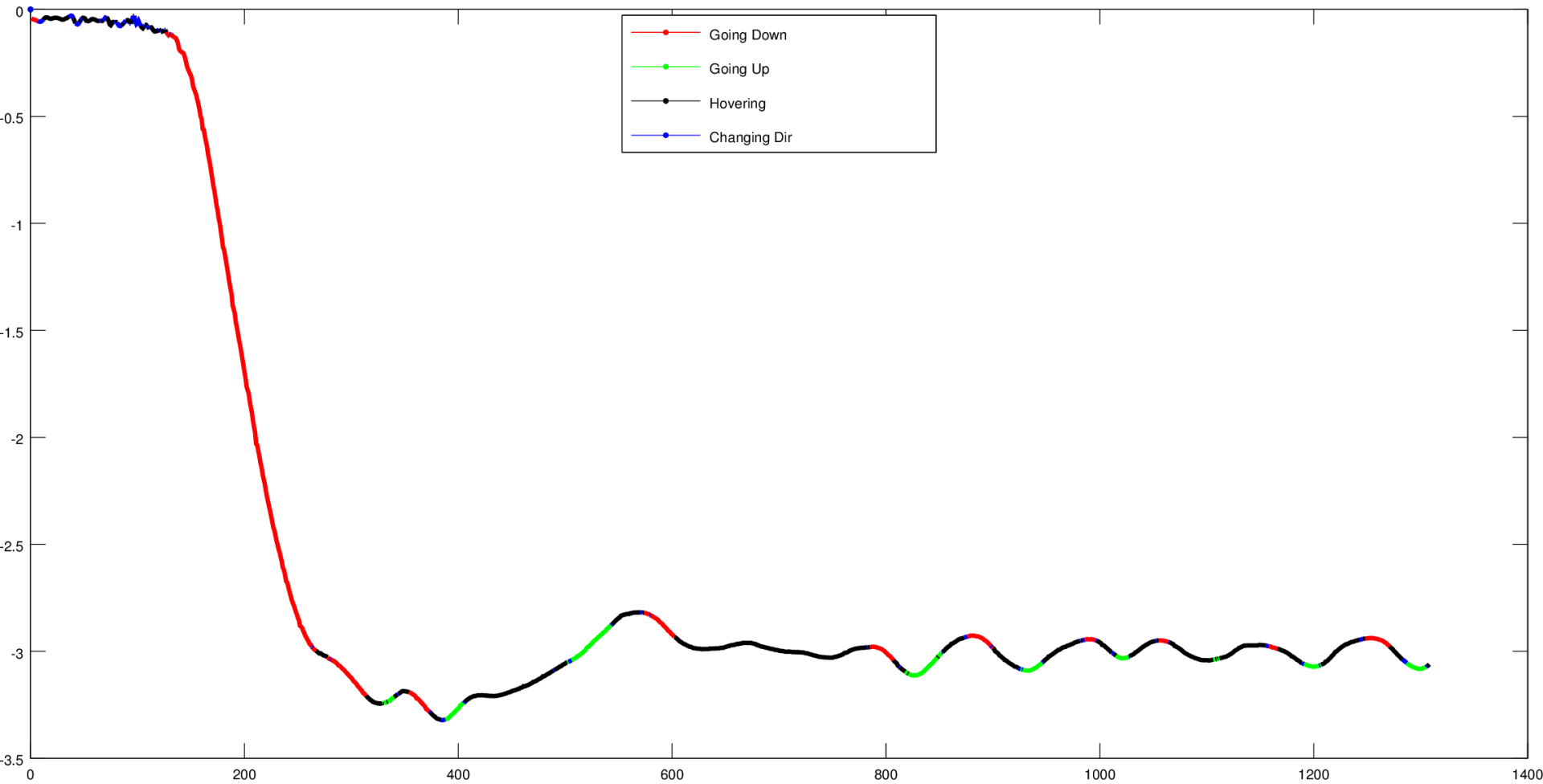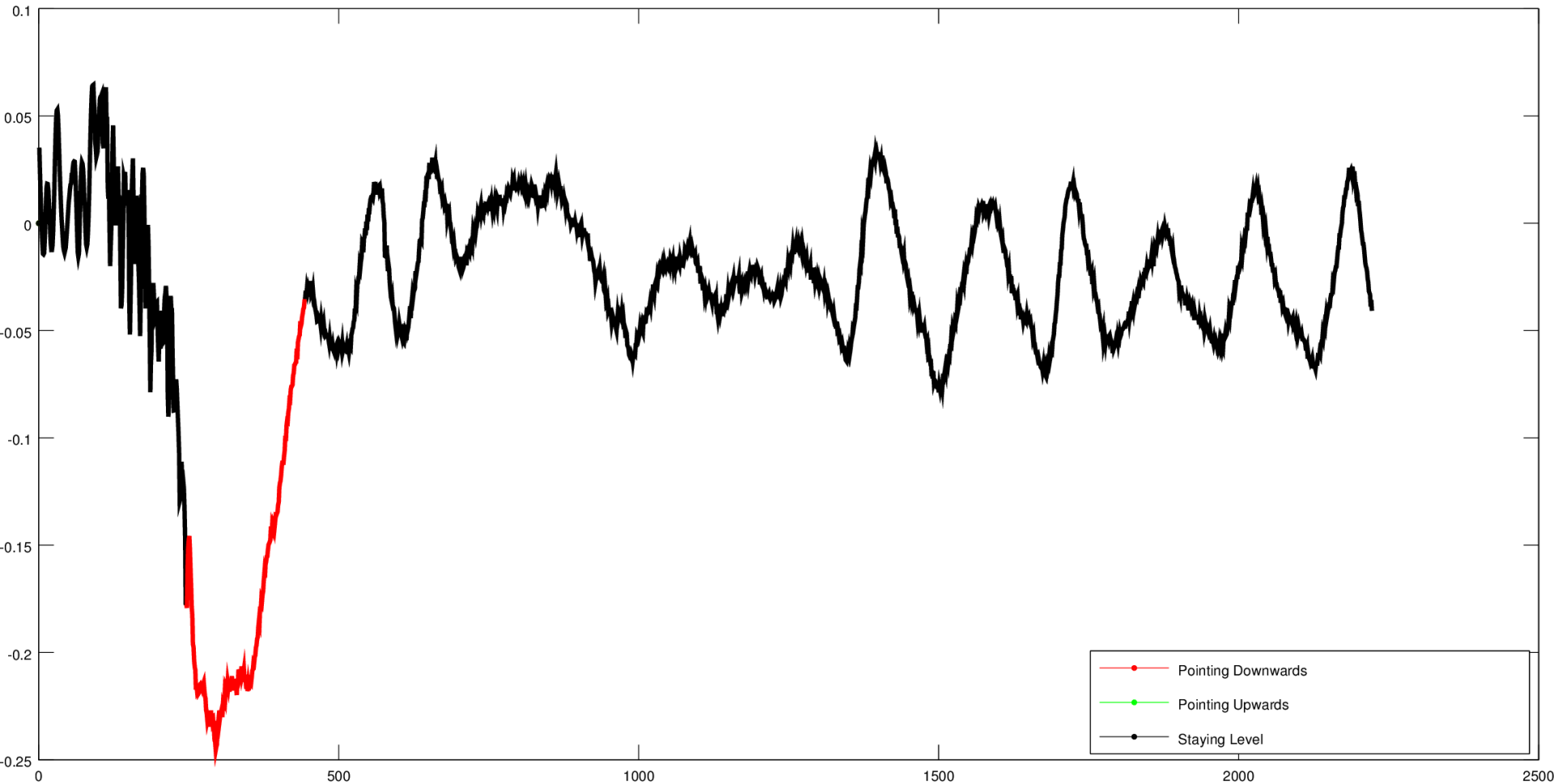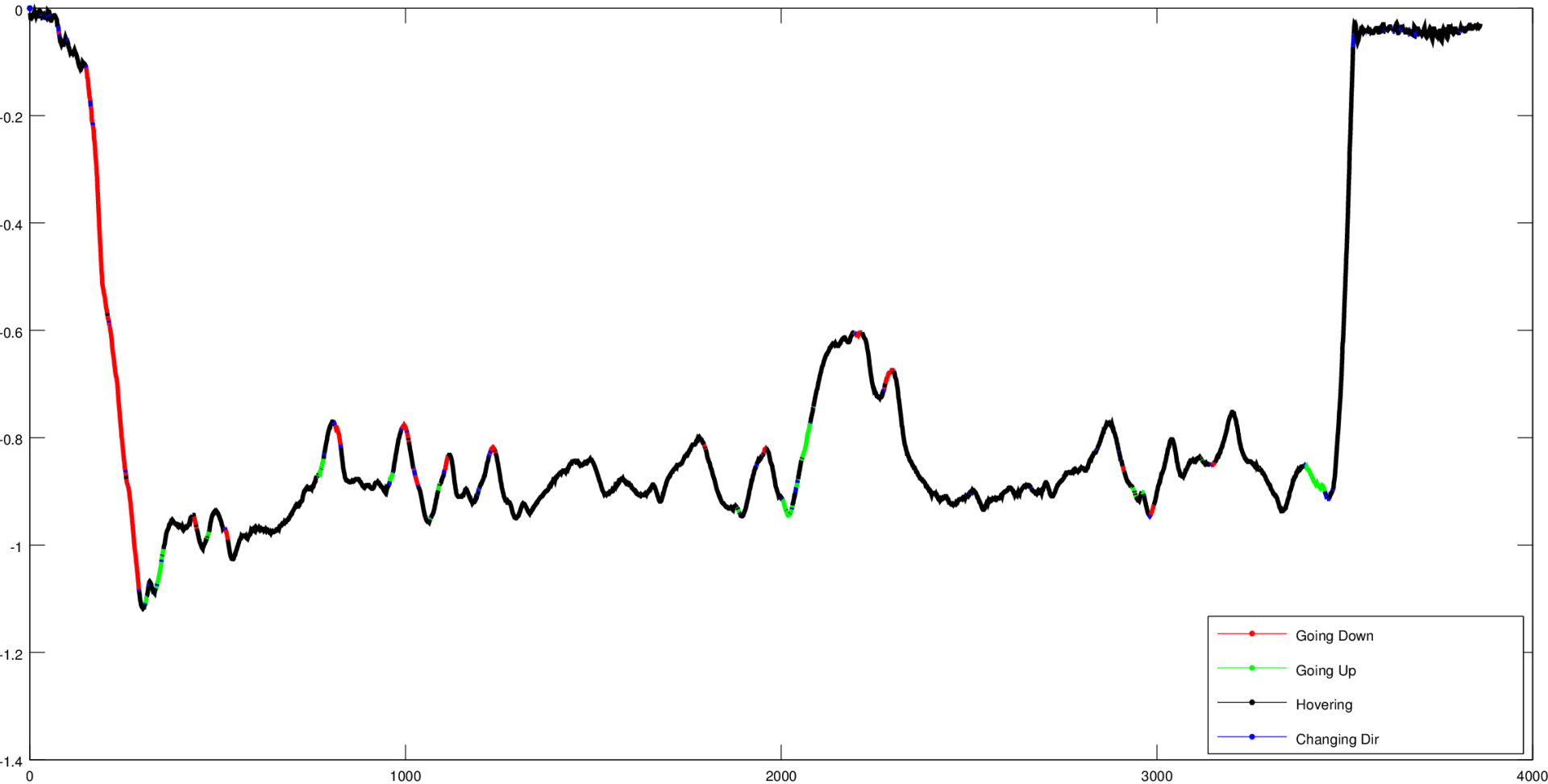**2015-05-27-apdl-demo/lauv-noptilus-3/093556**
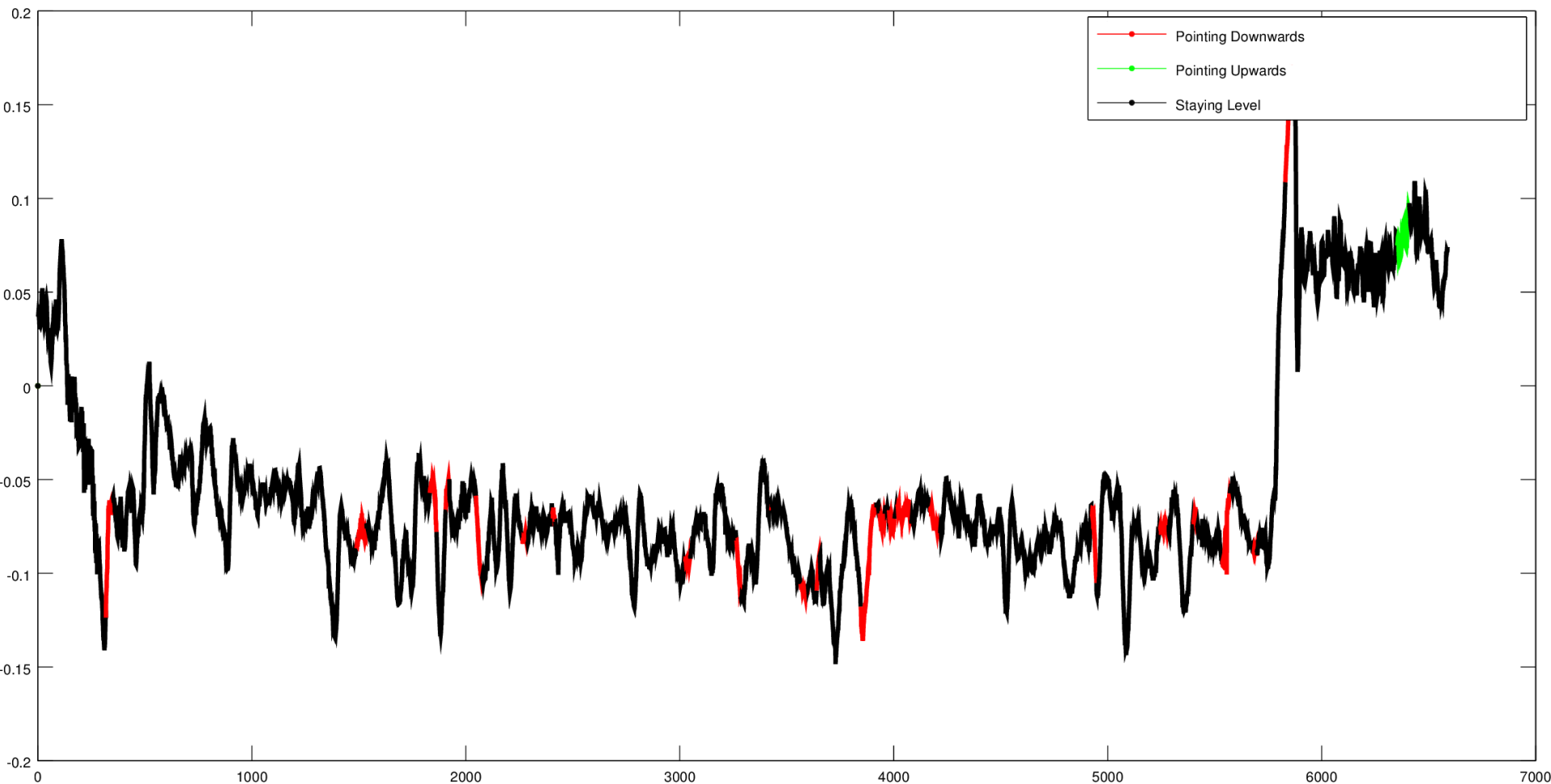
Demo Results: Annotated Depth

2015-05-27-apdl-demo/lauv-noptilus-2/140711

Demo Results: Annotated Pitch

2015-05-27-apdl-demo/lauv-noptilus-2/140711

WP6 Overview

on-line, on-board, real-time parsing
for PCFG-based event recognition

PCFG-Based AUV Event Recognition

> **Probabilistic Context-Free Grammars**
>   - formal model for specifying syntax (complex patterns)

> **Benefits**
>   - compact and hierarchical representation of sequences
>   - human-readable, self-explanatory production rules
>   - a variety of algorithms for parsing and learning
>   - applications in formal and natural language processing

> **Our Approach**
>   - averaging and quantization of chosen data stream(s)
>   - efficient parsing over a rolling window using grammar(s)
>   - broadcast of recognized events through messaging
>   - abstract description, reduction of communication

AUV Mission Log
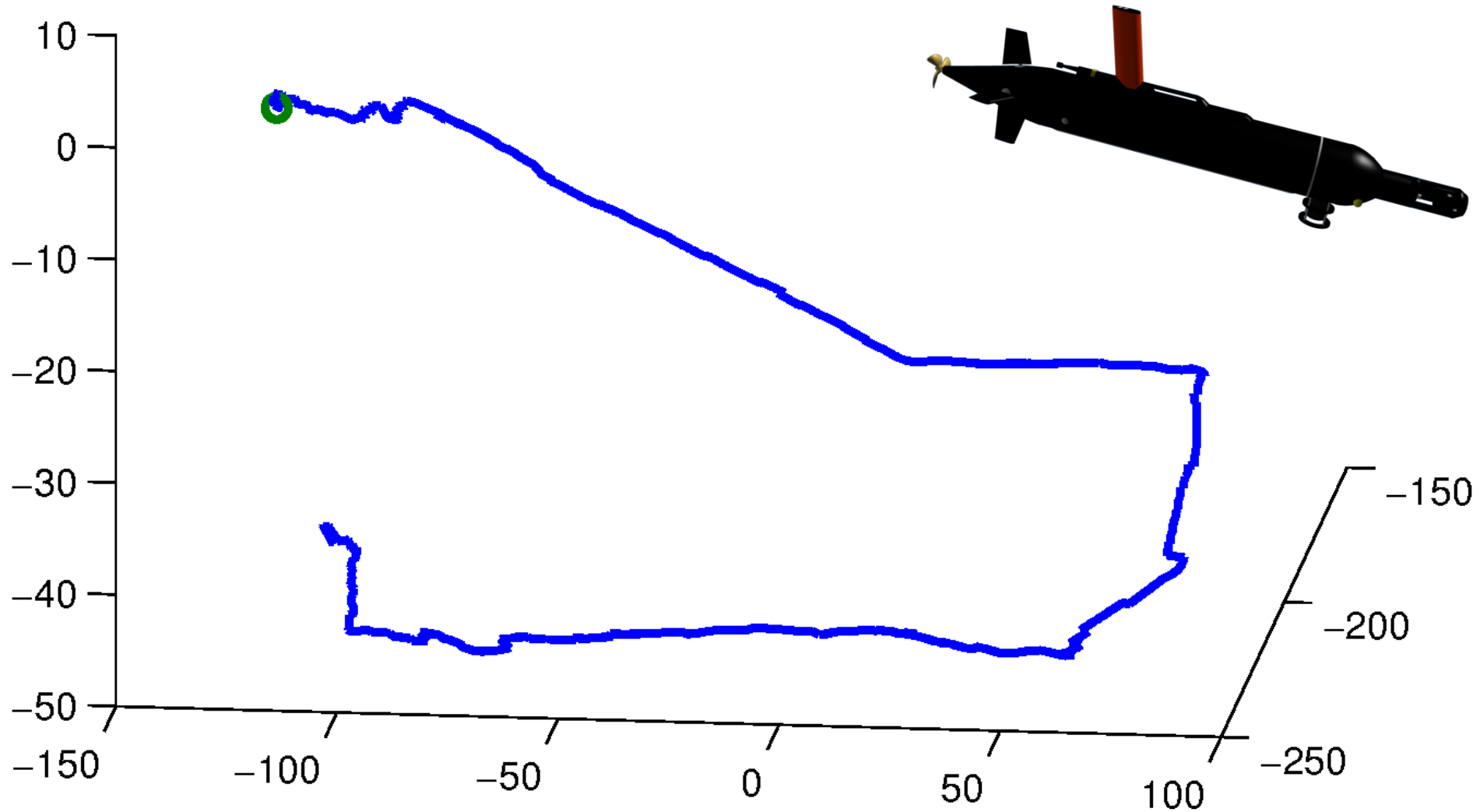
Diving Behavior Events

Objective

- event recognition regarding AUV diving behavior
- focus on joint patterns in depth and pitch streams

Hierarchical Grammar

- level 1: independent grammars for depth and pitch events
- level 2: grammar for the combination of level-1 outputs

Diving Behavior Events

Level-2 Parser

Depth Events

Pitch Events

Level-1 Depth Parser

Level-1 Pitch Parser

Depth Observations

Pitch Observations
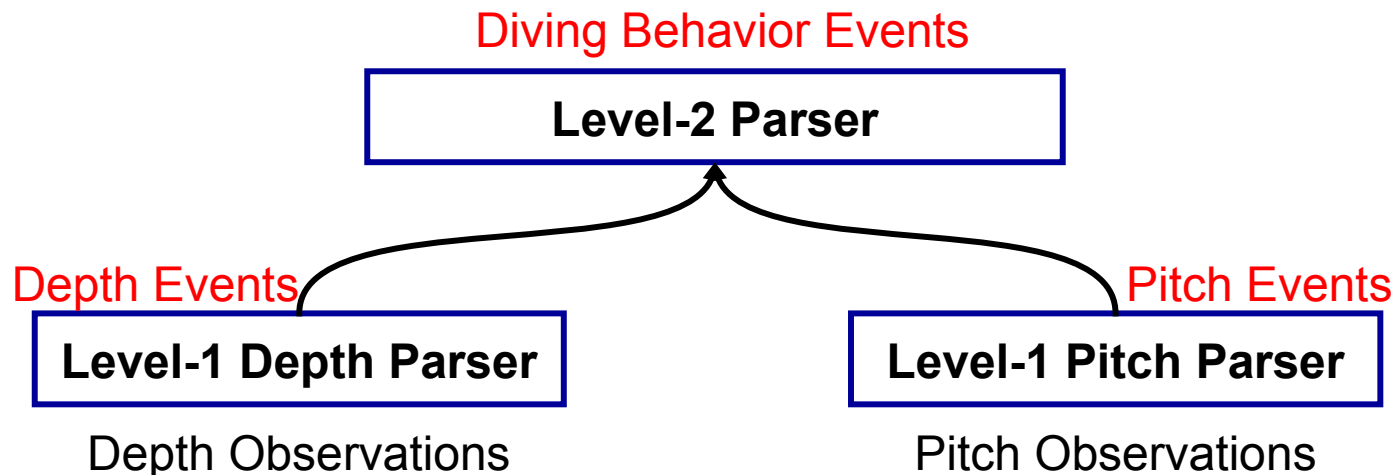
Diving Behavior Event Recognition
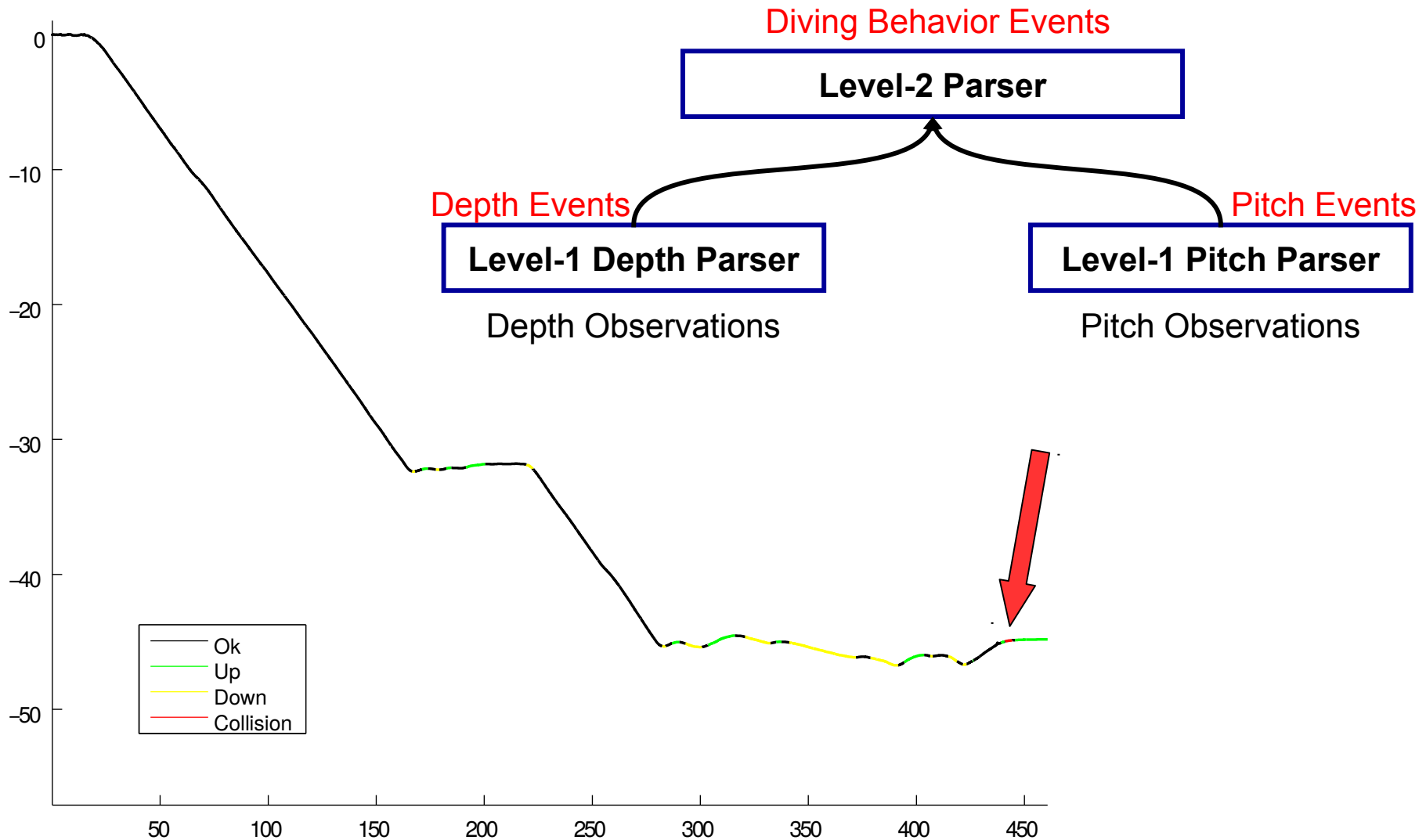
WP6 Overview

off-line, off-board grammatical inference
for learning PCFGs from AUV logs

Normal/Abnormal Events

> **Learning**
>   - can we learn a grammar from past mission data?

> **Considerations**
>   - likely interesting events are unusual and unexpected
>   - in most missions almost nothing abnormal occurs
>   - *idea*: instead of looking for the abnormal and rare, …
>   - … why not go after the normal and frequent?
>   - easier to model normal as opposed to abnormal

> **Normal Operation**
>   - typical patterns in motion and measurements (PCFG!)

> **Abnormal Operation**
>   - any pattern that does not occur in normal operation

PCFG Learning

- **Structured Prediction**
  - make a prediction about a structured object (grammar)

- **Grammatical Inference**
 - infer a PCFG (symbols, rules, probabilities) from words

- **Training Data**
  - corpus of positive (normal) examples only
  - must generalize (but not too much) and must not overfit

- **Our Approach**
  - Bayesian maximization of grammar posterior over data
  - beam local search to avoid local minima
  - incremental progress towards higher posterior gain
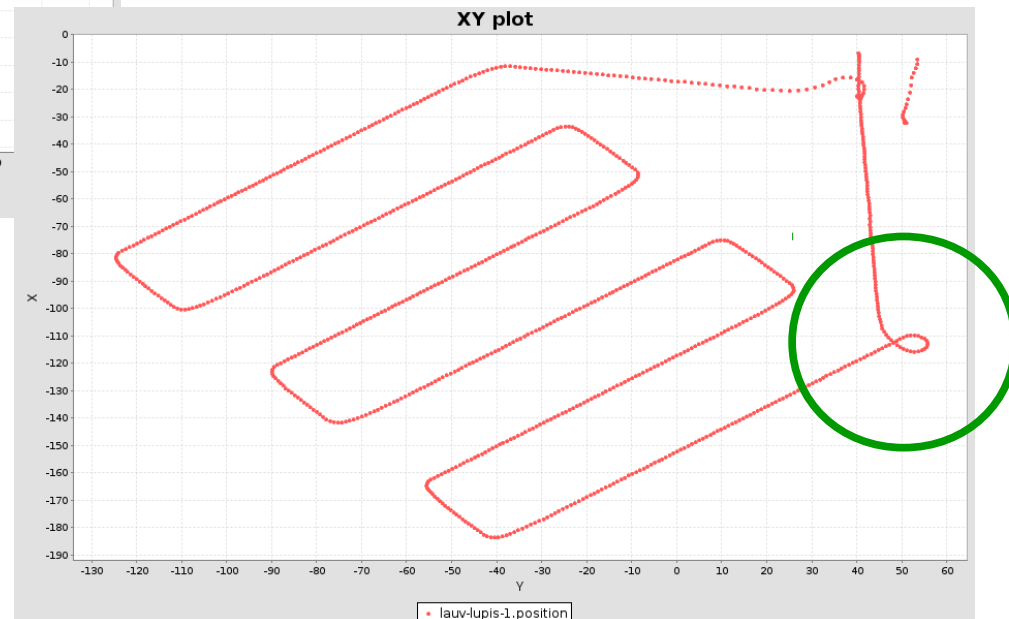 - leads to a good grammar, but not necessarily optimal

AUV Normal and Abnormal Behavior
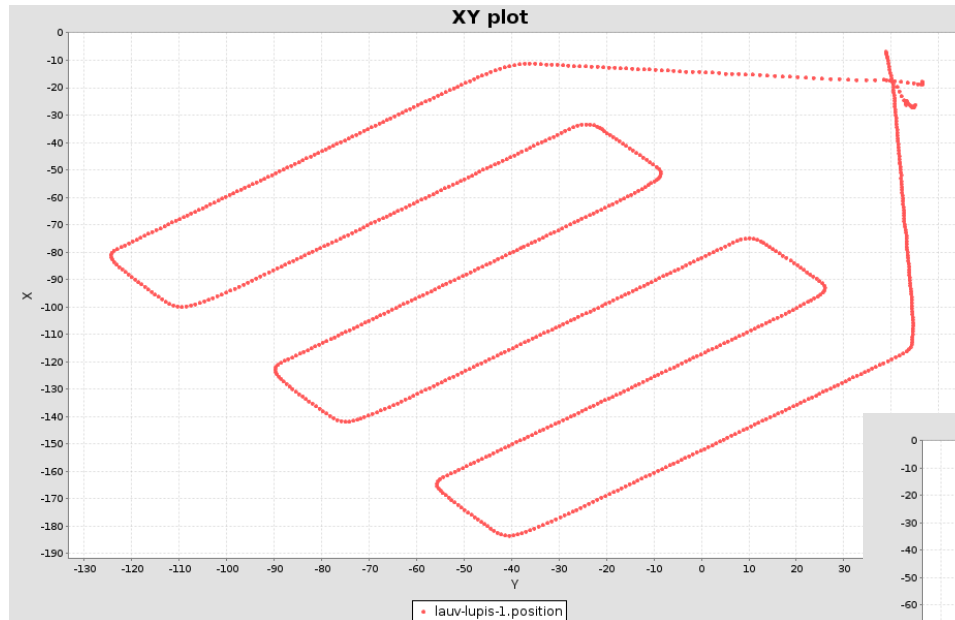
Normal
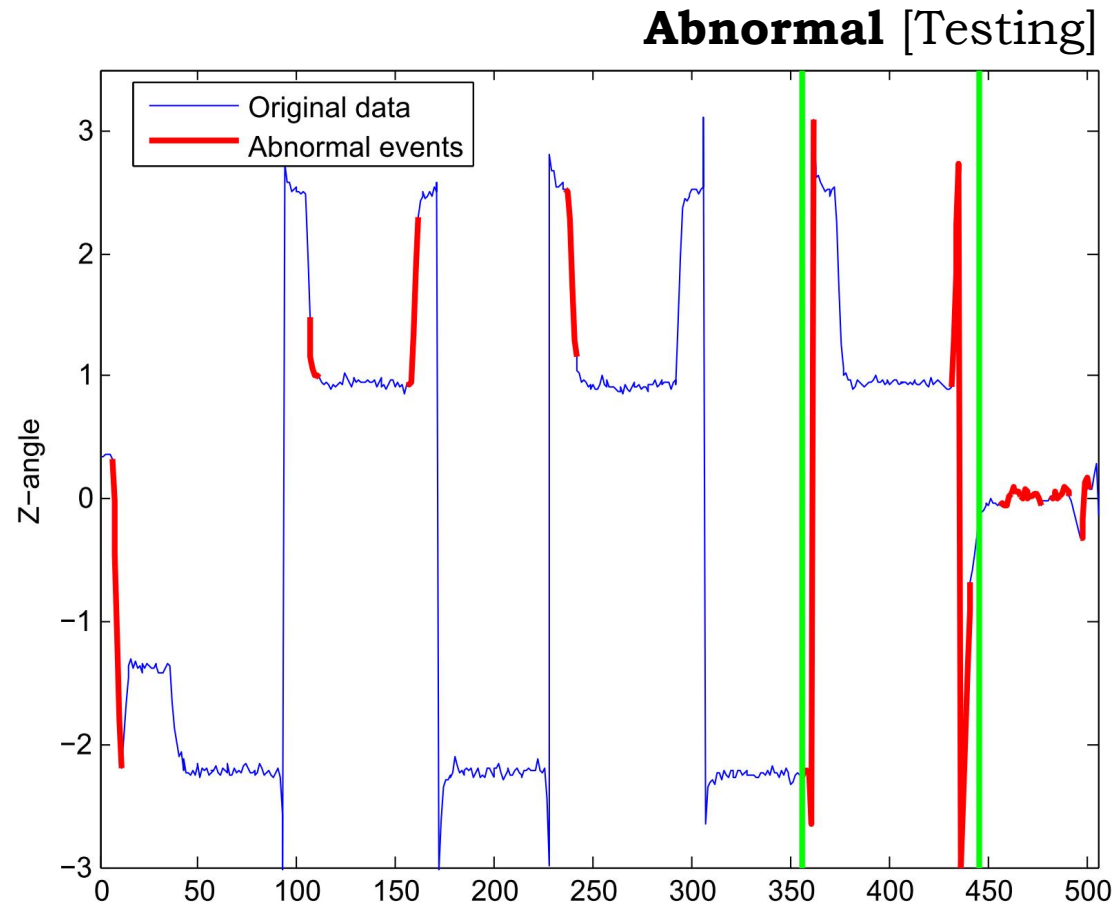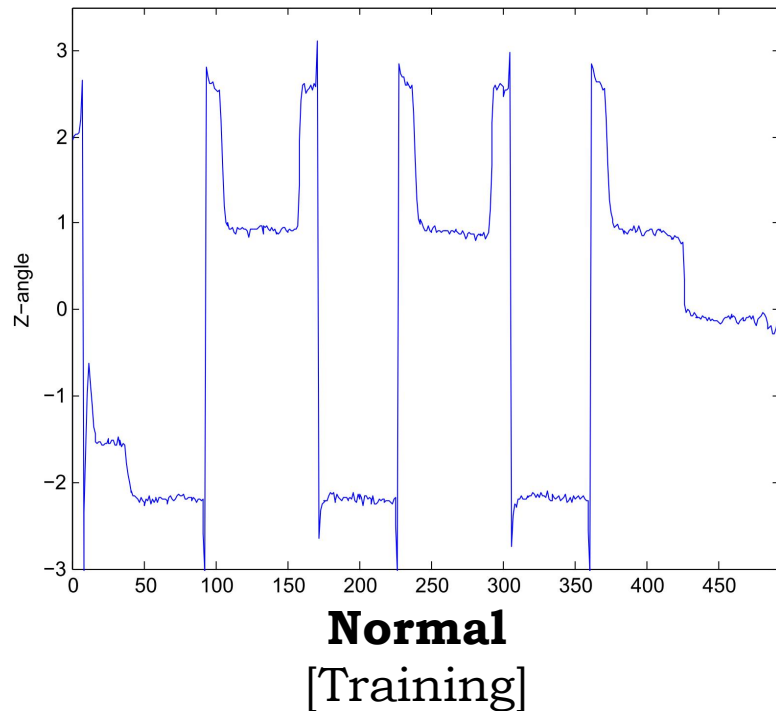[Training]

Abnormal
[Testing]

Relevant data stream
   * yaw (*z*-angle) of the AUV

Recognition with Learned Grammar

- training corpus: 129 examples
- learned grammar: 33+12 symbols, 12+7 rules

Normal
[Training]

Abnormal [Testing]

WP6 Conclusion

contribution and considerations

WP6 Project Contribution

➤ **WP6 Function**
- *recognizing interesting events in streams of observations*

➤ **On-Line Component: Event Recognition**
- real-time, hierarchical parsing for on-board recognition
- several active parsers on-board on various data streams
- hand-crafted or learned grammars for capturing events
- broadcast of reported events to any other DUNE tasks

➤ **Off-Line Component: Grammar Learning**
- off-line learning of PCFGs from past AUV mission logs
- modeling patterns of normal operation/events only
- abnormality = non-parsable pattern in data stream used
- learned grammars transferred to AUV for on-line parsing

WP6 in AUV Missions

> **Off-line (before)**
>   - identify type of event
>   - identify related data
>   - collect normal data
>   - learn grammar(s)

> **On-line (during)**
>   - execute parser on-board
>   - recognize events
>   - report detection(s)

> **Off-line (after)**
>   - parse past mission logs
>   - event detection

> **Event**
>   - z-spin abnormalities
>   - z-angle/yaw sensor
>   - normal mission data
>   - rules and probabilities

> **Mission**
>   - use learned grammar
>   - detect abnormality
>   - reset AUV state, notify

> **Investigation**
>   - detect past occurrences
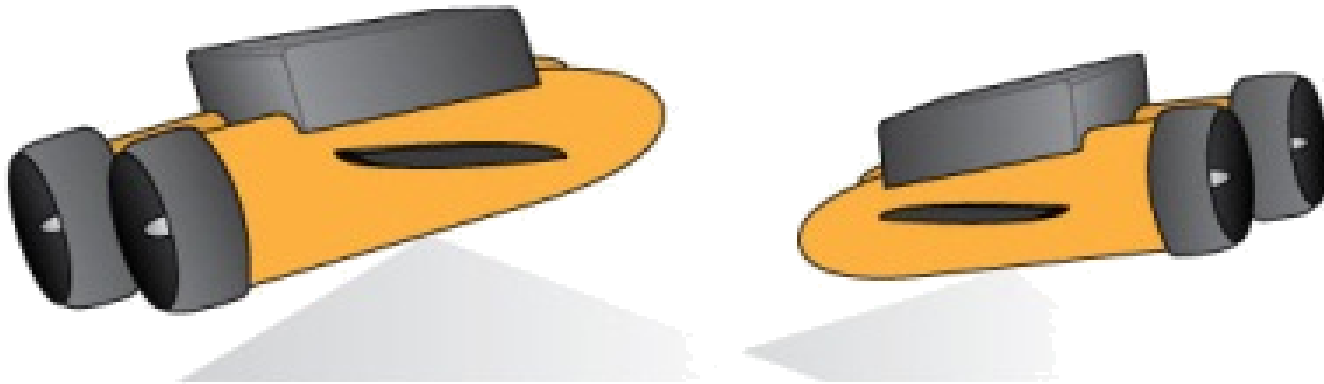>   - extract event statistics

WP6 Considerations

➢ **What is there**
- generic approach for high-level event recognition
- applicable to any desired data stream within DUNE
- reported events announced through IMC messages
- foundation: PCFGs, hierarchies, Bayesian learning, …
- potential for capturing hidden patterns in streams

➢ **What can be done**
- investigation of a wider range of AUV mission events
- focus on events that leave "signatures" in AUV sensors
- identification and selection of relevant data streams
- identification of joint patterns over data streams
- better integration of event recognition into decisions

Thank you!

NOPTILUS