auto**N**omous, self-Learning, **OPTI**mal and comp**L**ete **U**nderwater **S**ystems **NOPTILUS**

FP7-ICT-2009.6: Information and Communication Technologies

2nd Project Review

WP6 (Situation Understanding) Progress Report

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NOPTILUS

SEVENTH FRAMEWORK PROGRAMME

WP6: Situation Understanding

Event Recognition

- *observations*: abstract sensor readings, estimated state
- *events*: patterns in observation sequences

Models

- Probabilistic Context-Free Grammars (PCFGs)

Task 6.1: PCFG Parsing [Orfanoudakis]

- real-time, hierarchical parsing for on-line recognition

Task 6.2: PCFG Learning [Kofinas]

- off-line learning of PCFGs from past AUV mission logs

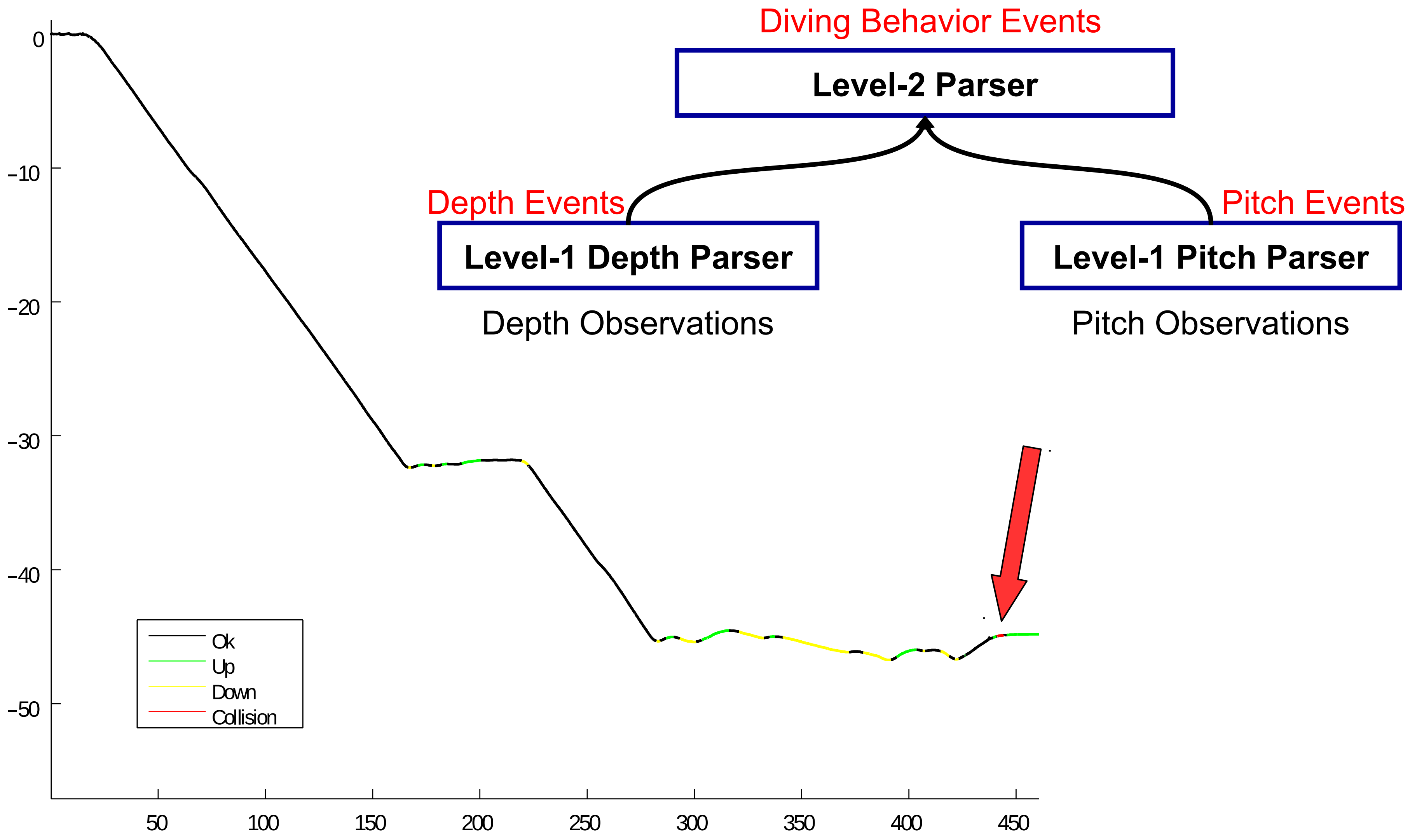
Task 6.3: Integration

- on-line event recognition using learned PCFGs

WP6 Summary from 1st Review

- **Preprocessing**
  - abstraction from raw data to observations
- **Event recognition**
  - *events*: diving behavior
  - *technology*: probabilistic context-free grammars
  - successful recognition on several past mission logs
  - demonstration of feasibility and potential
- **Software**
  - optimized parser for event recognition in Matlab

Diving Behavior Event Recognition



Diving Behavior Events

Level-2 Parser

Depth Events

Pitch Events

Level-1 Depth Parser

Level-1 Pitch Parser

Depth Observations

Pitch Observations

WP6 Plans from 1st Review

- **Software** 2 Done!
  - optimized parser for real-time event recognition in Dune
- **Event recognition** rethink!
  - *new events*: getting caught in net, vehicle faults, …
- **Rethinking events**
  - normal vs. abnormal AUV operation 1 Done!
  - *idea*: instead of looking for the abnormal and rare, …
  - … why not look after the normal and frequent?
- **Structured prediction**
  - automatic construction of grammars 3 ongoing!
  - learning rules and probabilities from past missions

WP6: Event Recognition

Rethinking Events

External Events

- **Intention**
  - recognize events which are “external” to the AUV
- **Observations**
  - salinity sensor measurements
  - temperature sensor measurements
  - other external (processed) readings from other WPs
- **Events**
  - crossing borders of areas with different salinity
  - unusual variations in temperature
- **Importance**
  - salinity affects ranging measurements
  - temperature may relate to the presence of a current

Normal/Abnormal Events

Considerations

- what is an interesting event? what do we care about?
- 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 look after the normal and frequent?
- easier to define normal as opposed to abnormal

Normal Operation

- typical patterns in motion and measurements (PCFG!)

Abnormal Operation

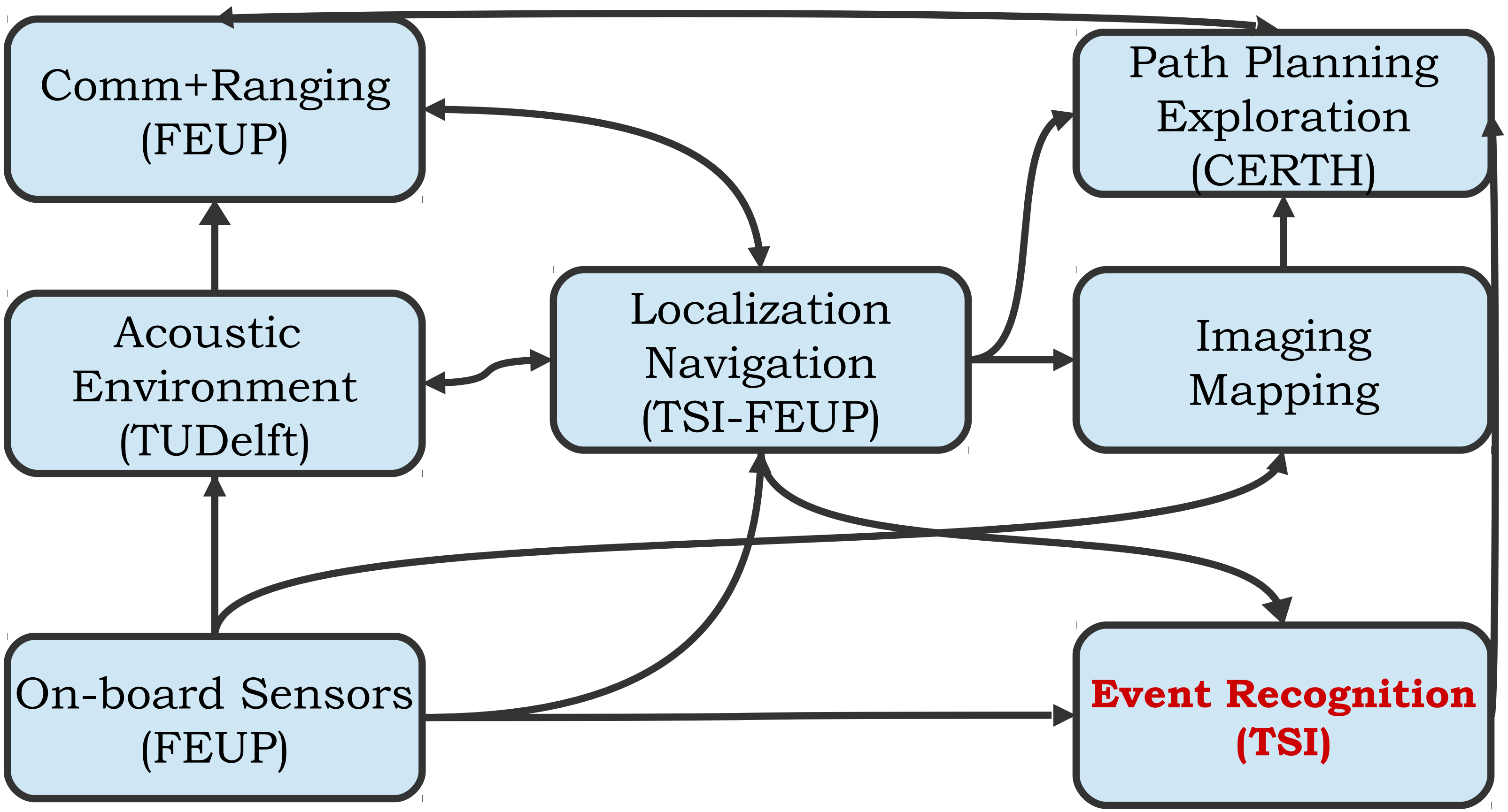
- any pattern that does not occur in normal operation

WP6 Task 6.1: PCFG Parsing

Optimized parser implementation in Dune

Noptilus Dune Code Architecture

NOPTILUS



Comm+Ranging (FEUP)

Path Planning Exploration (CERTH)

Acoustic Environment (TUDelft)

Localization Navigation (TSI-FEUP)

Imaging Mapping

On-board Sensors (FEUP)

Event Recognition (TSI)

TSI Dune Code Repository

- **Github**
  - **`https://github.com/vosk/dune/`**
  - fork of the main LSTS-Dune repository
  - C++ software architecture (and simulator) for AUVs
  - eventually, will be integrated into the main repository
- **Development (ongoing)**
  - WP3: Cooperative Localization
    - partial and fully cooperative localization schemes
    - simulation of acoustic range measurements
  - WP6: Event Recognition
    - real-time CYK parser engine for any given PCFG
    - messaging for communicating observations and events

Implementation Challenges

Complexity

- thousands of lines of code
- additions of new features
- debugging new functionality
- compatibility with updates/upgrades

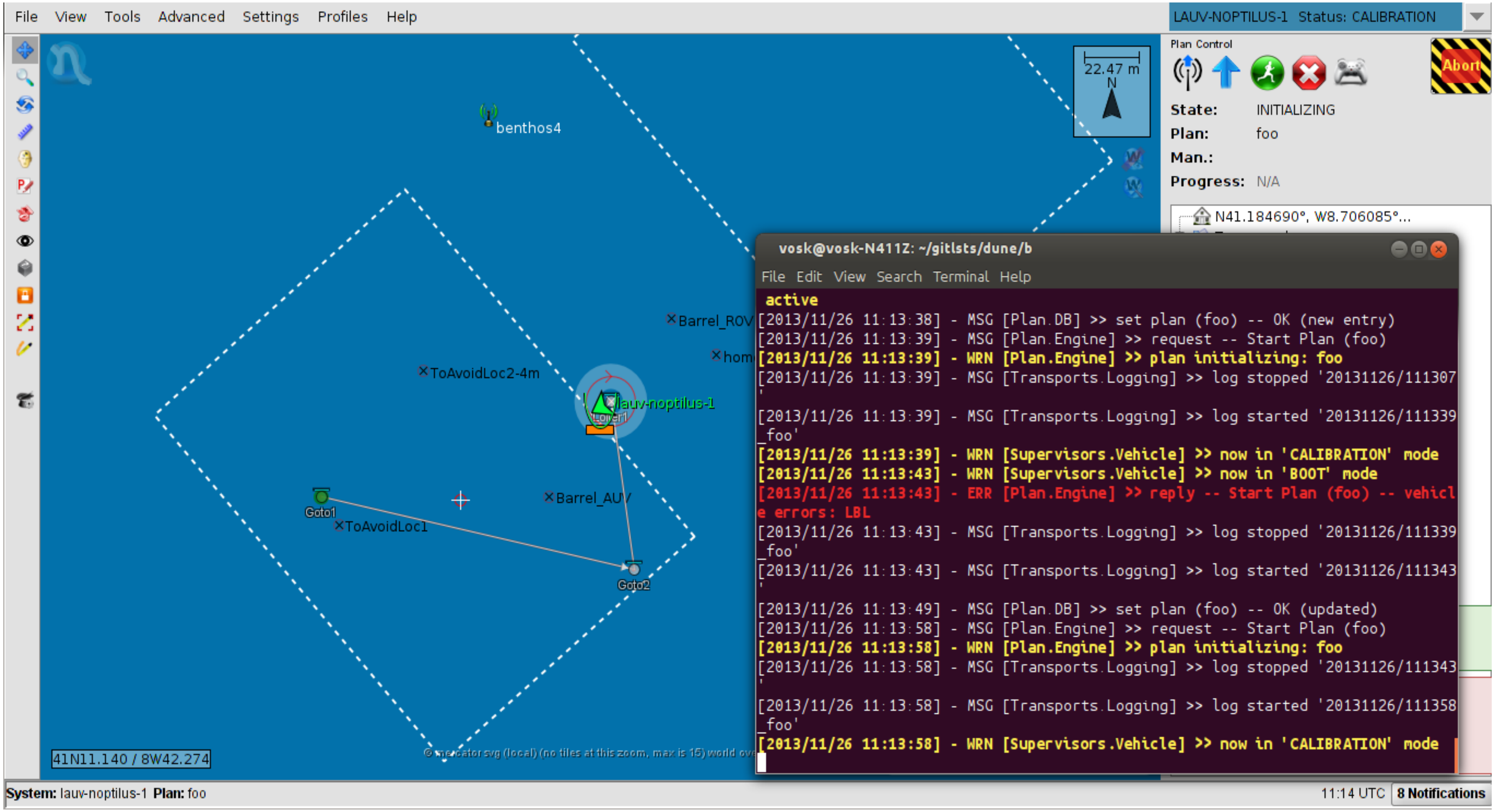
Optimization

- execution on a limited embedded platform
- real-time synchronization of observations
- hard to assess real-time performance

Simulation

- accuracy of acoustic model and measurements
- accuracy of acoustic environment model

Dune+Neptus Environment



File View Tools Advanced Settings Profiles Help
LAUV-NOPTILUS-1 Status: CALIBRATION
Plan Control
Abort
22.47 m
N
benthos4
Barrel_ROV
hom
ToAvoidLoc2-4m
lauv-noptilus-1
Loiter1
Barrel_AUV
Goto1
ToAvoidLoc1
Goto2
41N11.140 / 8W42.274
N41.184690°, W8.706085°...
vosk@vosk-N411Z: ~/gitlsts/dune/b
File Edit View Search Terminal Help
11:14 UTC
8 Notifications

State: INITIALIZING
Plan: foo
Man.:
Progress: N/A

System: lauv-noptilus-1 Plan: foo

```
active
[2013/11/26 11:13:38] - MSG [Plan.DB] >> set plan (foo) -- OK (new entry)
[2013/11/26 11:13:39] - MSG [Plan.Engine] >> request -- Start Plan (foo)
[2013/11/26 11:13:39] - WRN [Plan.Engine] >> plan initializing: foo
[2013/11/26 11:13:39] - MSG [Transports.Logging] >> log stopped '20131126/111307
'

[2013/11/26 11:13:39] - MSG [Transports.Logging] >> log started '20131126/111339
_foo'
[2013/11/26 11:13:39] - WRN [Supervisors.Vehicle] >> now in 'CALIBRATION' mode
[2013/11/26 11:13:43] - WRN [Supervisors.Vehicle] >> now in 'BOOT' mode
[2013/11/26 11:13:43] - ERR [Plan.Engine] >> reply -- Start Plan (foo) -- vehicl
e errors: LBL
[2013/11/26 11:13:43] - MSG [Transports.Logging] >> log stopped '20131126/111339
_foo'
[2013/11/26 11:13:43] - MSG [Transports.Logging] >> log started '20131126/111343
'

[2013/11/26 11:13:49] - MSG [Plan.DB] >> set plan (foo) -- OK (updated)
[2013/11/26 11:13:58] - MSG [Plan.Engine] >> request -- Start Plan (foo)
[2013/11/26 11:13:58] - WRN [Plan.Engine] >> plan initializing: foo
[2013/11/26 11:13:58] - MSG [Transports.Logging] >> log stopped '20131126/111343
'

[2013/11/26 11:13:58] - MSG [Transports.Logging] >> log started '20131126/111358
_foo'
[2013/11/26 11:13:58] - WRN [Supervisors.Vehicle] >> now in 'CALIBRATION' mode
```

WP6 Task 6.2: PCFG Learning

Learning the structure of a grammar

Learning Approaches

- existing work mostly in natural language processing
- no single algorithm can learn any arbitrary grammar!

➢Using annotated examples

- annotated strings and/or syntactic trees are required
- *problem*: infeasible to annotate lots of data!

➢Using positive and negative examples

- near-miss negative data are required
- *problem*: near-misses can hardly be defined!

➢Using positive examples

- algorithms specialized for certain grammar classes
- typically assume few symbols and few examples

Our Approach

- **Ongoing investigation**
  - review of existing approaches and their assumptions
  - implementation of promising learning algorithms
  - adaptation to the characteristics of our problem
  - experiments on examples from real AUV data
  - focus on handling large sets of positive training strings
- **Current promising learning algorithm**
  - learn with basic chunk and merge operations
  - use iterative bi-clustering to decide the best chunk
  - at each iteration, check for possible merge operations
  - repeat until the training corpus is full reduced
  - rule probabilities can be extracted during the process

Grammar Learning Example (1)

	a	b	c
a	6	0	4
b	0	6	0
c	0	4	0

Corpus:

$a^n c b^n$

- acb
- aacbb
- aaacbbb
- aaaacbbbb

Rules:

- N0 → ac

	a	b	N0
a	3	0	3
b	0	6	0
N0	0	4	0

Corpus:

- N0 b
- a N0 bb
- aa N0 bbb
- aaa N0 bbbb

Rules:

- N0 → ac
- N1 → N0 b

Grammar Learning Example (2)

	a	b	N1
a	3	0	3
b	0	3	0
N1	0	3	0

Corpus:

- N1
- a N1 b
- aa N1 bb
- aaa N1 bbb

Rules:

- N0 → ac
- N1 → N0 b
- N2 → a N1

	a	b	N2
a	1	0	2
b	0	3	0
N2	0	3	0

Corpus:

- N1
- N2 b
- a N2 bb
- aa N2 bbb

Rules:

- N0 → ac
- N1 → N0 b
- N2 → a N1
- N3 → N2 b

Grammar Learning Example (3)

	a	b	N3
a	1	0	2
b	0	1	0
N3	0	2	0

Corpus:

- N1
- N3
- a N3 b
- aa N3 bb

Rules:

- N0 → ac
- N1 → N0 b
- N2 → a N1
- N3 → N2 b
- N4 → a N3

	a	b	N4
a	0	0	1
b	0	1	0
N4	0	2	0

Corpus:

- N1
- N3
- N4 b
- a N4 bb

Rules:

- N0 → ac
- N1 → N0 b
- N2 → a N1
- N3 → N2 b
- N4 → a N3
- N5 → N4 b

Grammar Learning Example (4)

	a	b	N4
a	0	0	1
b	0	1	0
N4	0	2	0

Corpus:

- N1
- N3
- N4 b
- a N4 bb

Rules:

- N0 → ac
- N1 → N0 b
- N2 → a N1
- N3 → N2 b
- N4 → a N3
- N5 → N4 b

Corpus:

- N1
- N3
- N3
- N3

Rules:

$a^n c b^n$

- S → N1
- S → N3
- N0 → ac
- N1 → N0 b
- N2 → a N1
- N2 → a N3
- N3 → N2 b

WP6 Progress and Plans

What's there? What's next?

WP6 Incremental Progress

- **Events**
  - normal vs. abnormal events in AUV operation
- **Task 6.1: PCFG Parsing**
  - implementation/development on cloned Dune repository
  - optimized parser for real-time event recognition in Dune
  - required messaging modifications in IMC
- **Task 6.2: PCFG Learning**
  - learning (structured prediction) of grammars
  - learning using positive data only from past missions

WP6 Plans

- **Task 6.1: Software**
  - integration of parser in the main Dune repository
  - on-board testing and debugging
- **Task 6.2: Structured prediction**
  - efficient implementation of grammar learning algorithm
  - learning experiments on data from past missions
  - testing on similar mission logs
  - testing on synthetic abnormalities
- **Events**
  - identification of normal/abnormal external events
  - focus on specific measurements for parsing
  - (hierarchical) grammar learning on selected inputs

WP6 Integration/Contribution

- **Off-line (before)**
  - identify type of event
  - identify related data
  - collect normal data
  - learn grammar(s)
- **On-line (during)**
  - execute parser onboard
  - recognize abnormal
  - signal detection(s)
- **Off-line (after)**
  - parse past mission logs
  - feature detection

- **Event**
  - propeller free-winding
  - current, control, gyro
  - normal mission data
  - rules and probabilities
- **Mission**
  - use learned grammar
  - detect abnormality
  - reset controller
- **Investigation**
  - detect past occurrences
  - extract event statistics

Thank you!