Using the MOOS-IvP with machine learning and AUV behaviors for target classification based on acoustic scattered fields

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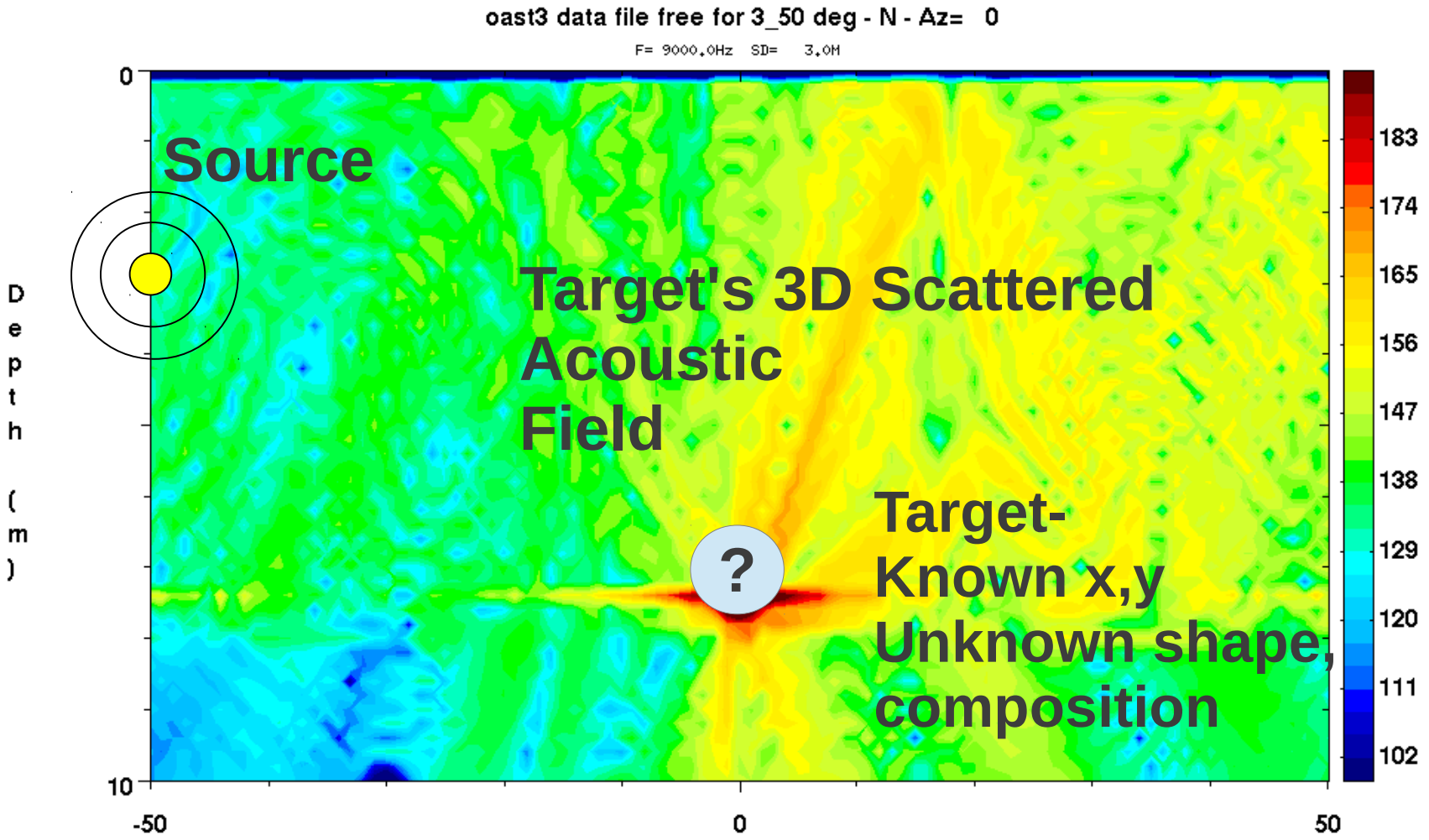
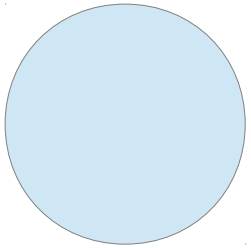
Problem Overview

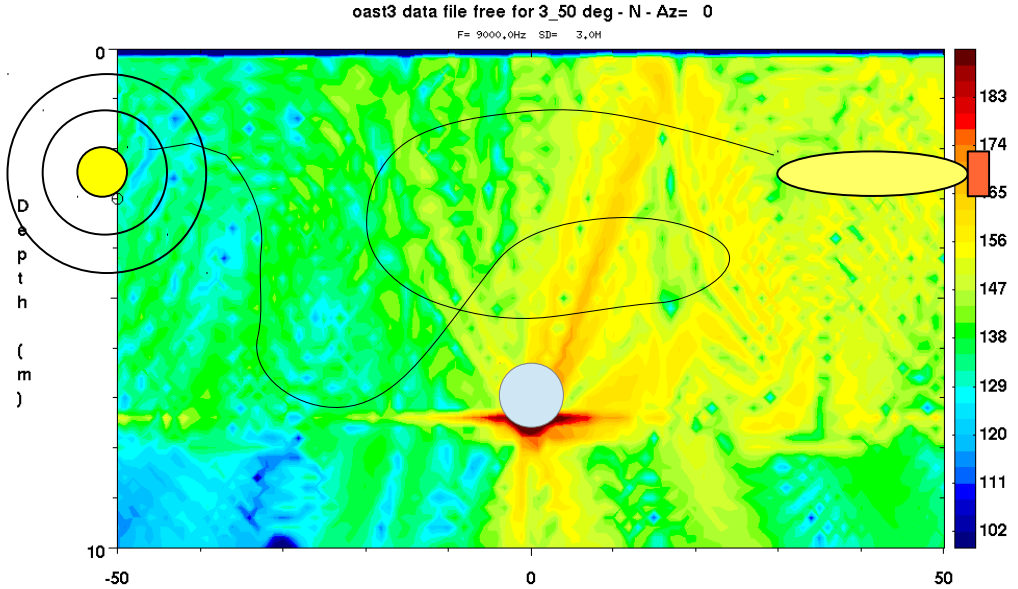


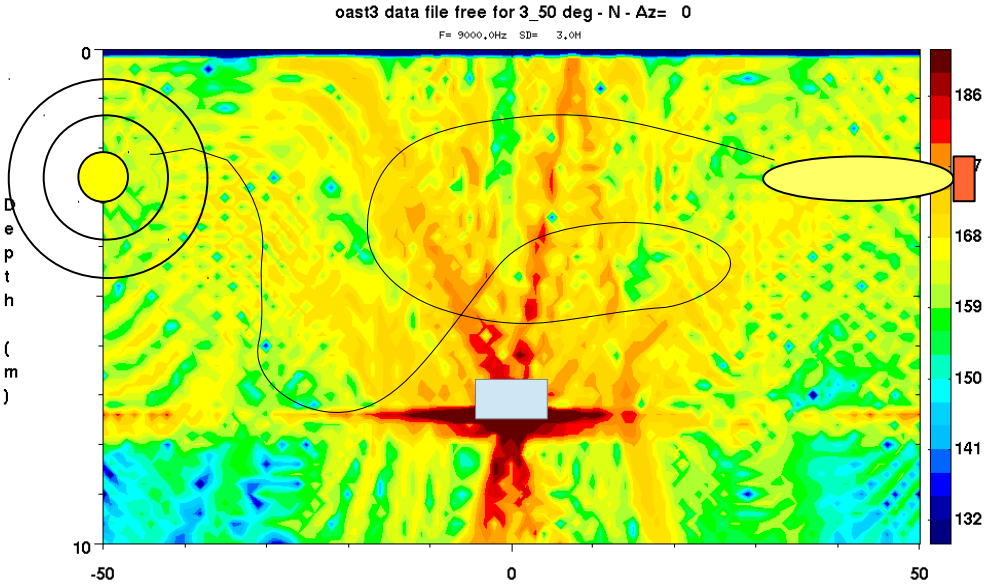
Goal: Use acoustic scattered field to learn things about target.

Problem Overview



Sphere v. Cylinder Classification



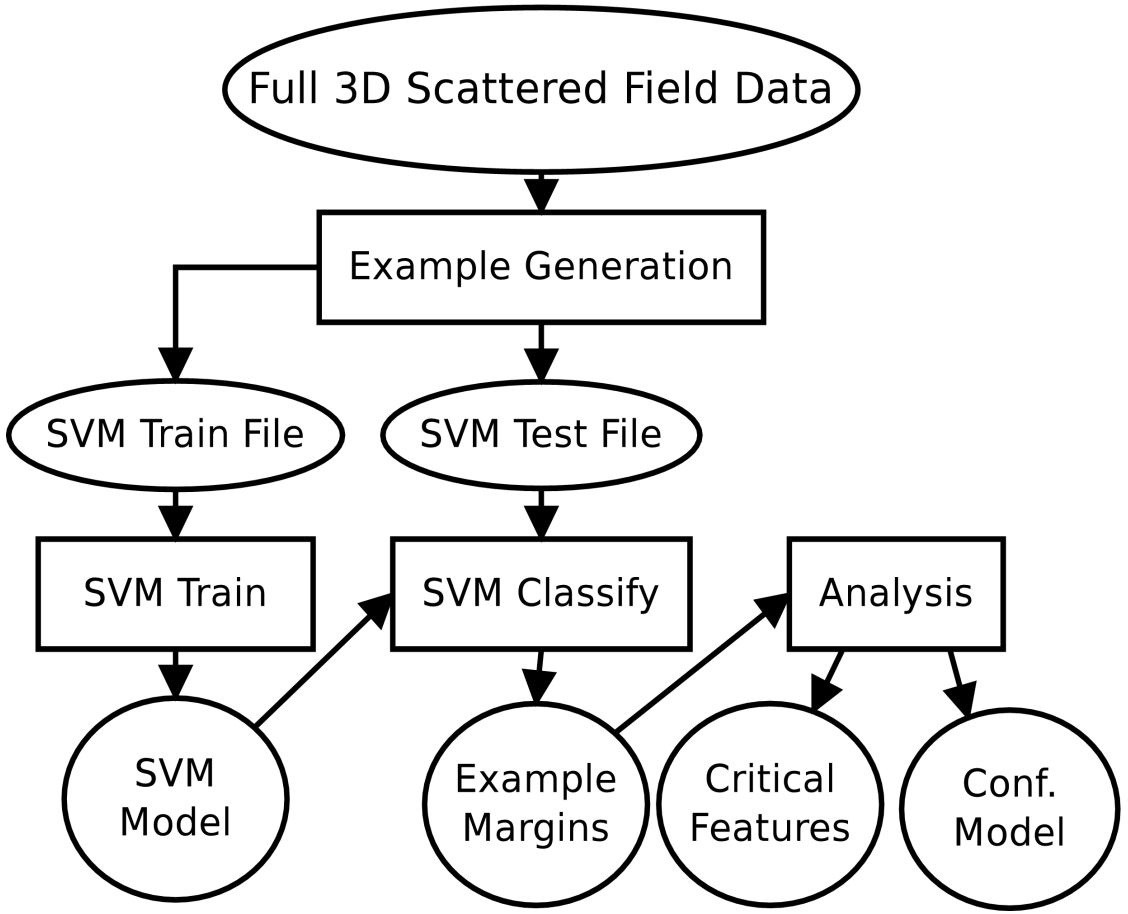


Classify Target geometry/composition using only AUV-sampled amplitude of the scattered field

Classification Methodology

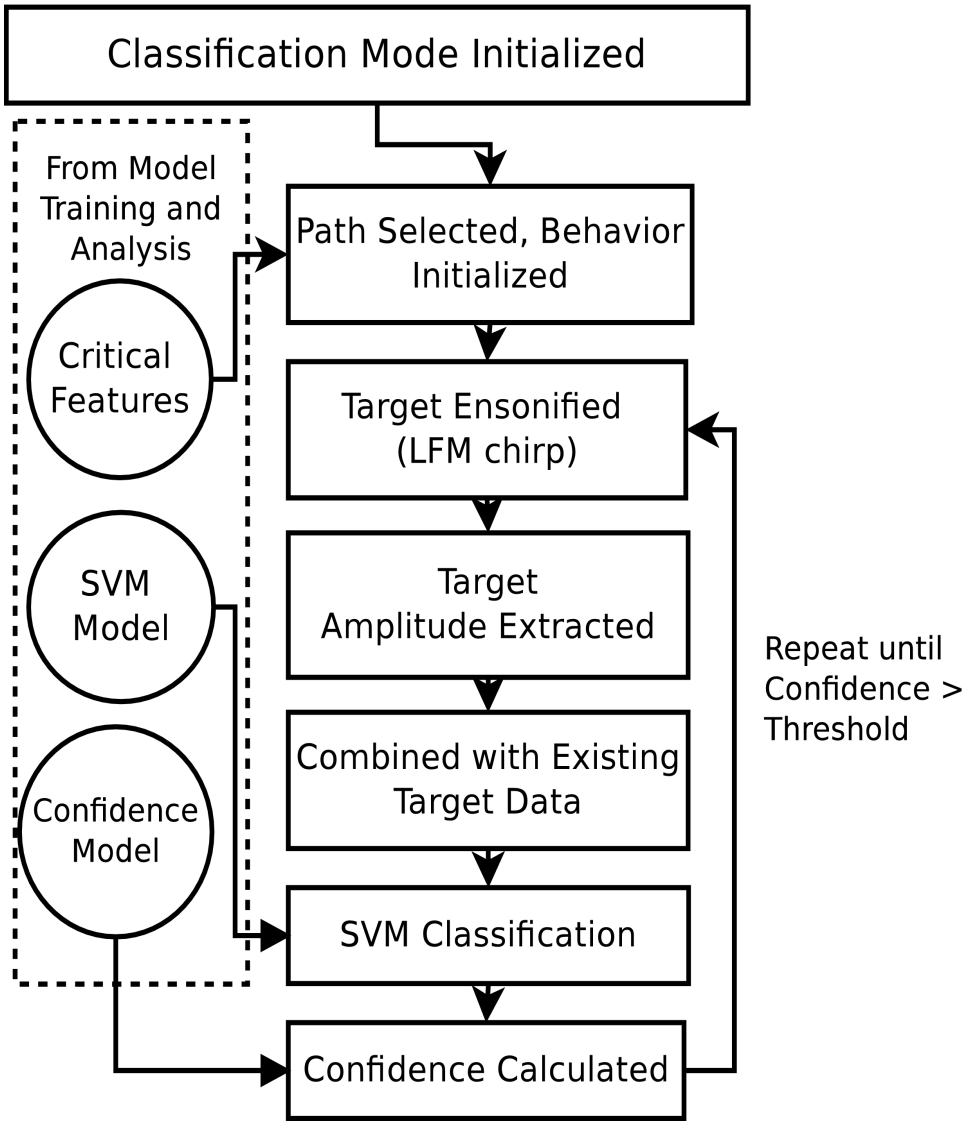
- Vehicle Behaviors, Signal Processing and Machine Learning used for target processing
- Support Vector Machines (SVMs) for actual classification
  - Acoustic amplitudes mapped to geometric feature space
- Two Parts:
  - Model Training and Analysis
  - Classification

Model Training and Analysis (Offline)



- Offline process (not run onboard)
- Input: 3D scattered field data (real or simulated)
- Output: SVM model, confidence model, critical waypoints for AUV behaviors

Classification (Onboard)

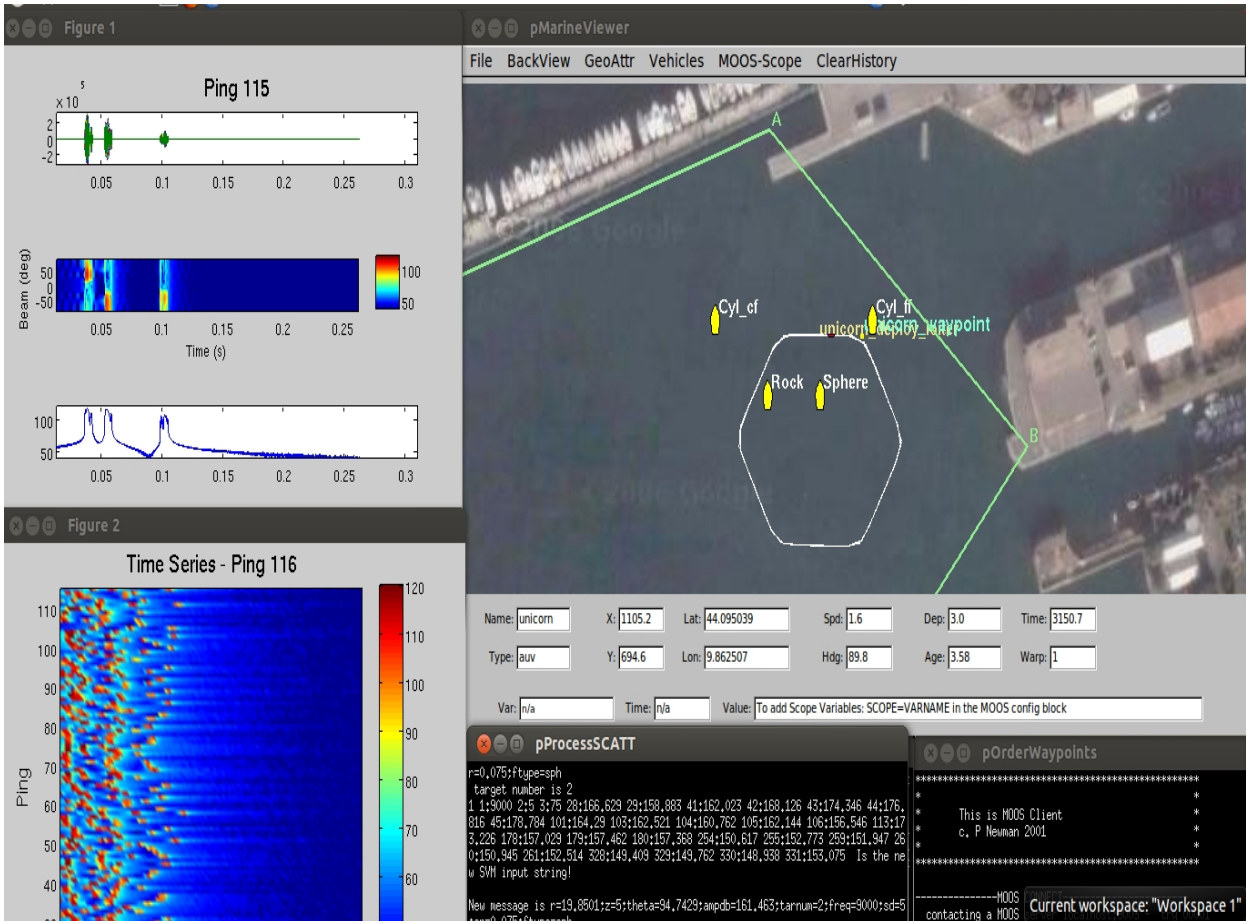


- Run on the vehicle
- Input: SVM model, confidence model, critical waypoints, target information
- Action: MOOS applications and behaviors, interfacing with third party tools (svm_light, Bellhop)
- Outputs: Classification and associated confidence
- Integrate this with MOOS-IvP

Experiment Setup- GOATS'14

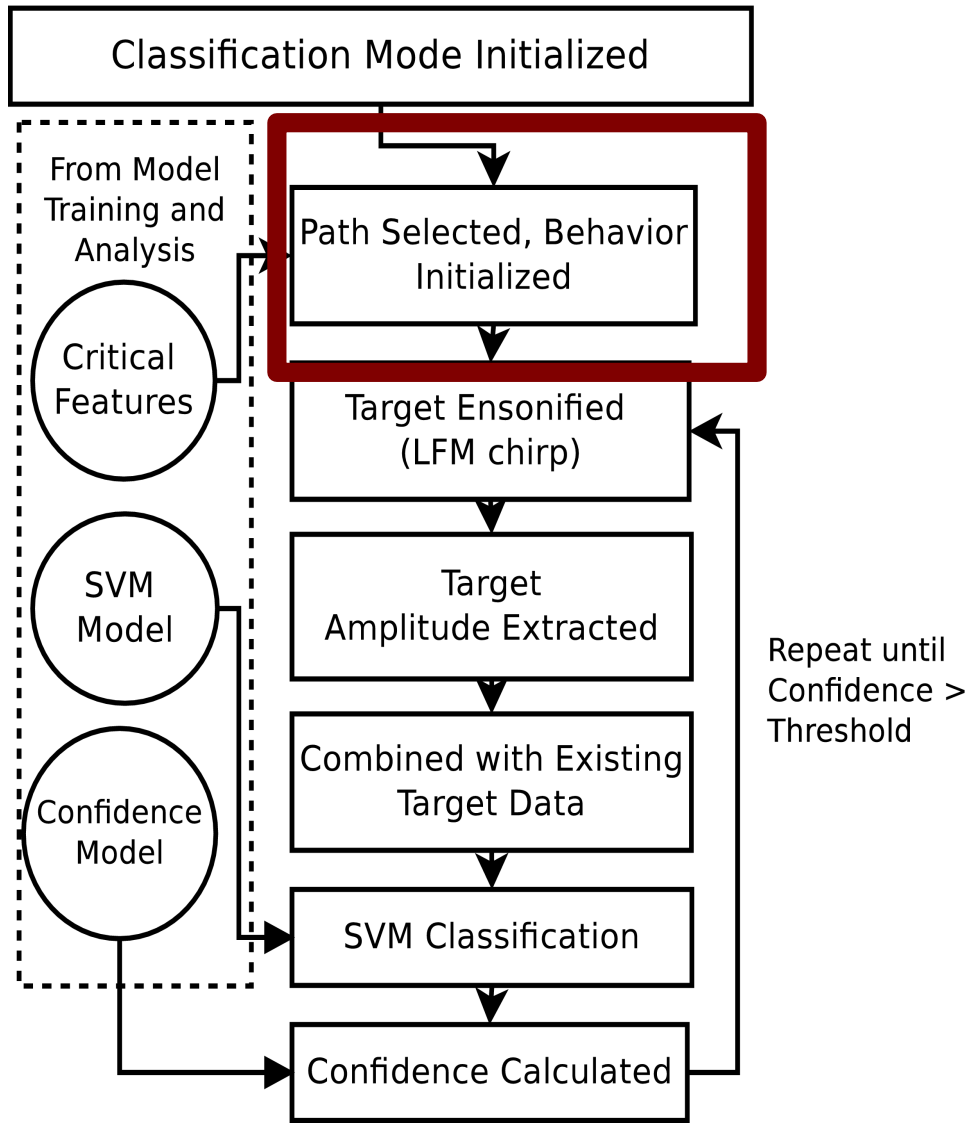
- CMRE (Harbor Environment)
  - 8-12 m water depth
- Classification Spherical v. Cylindrical Targets
- Source ~50-75m from target(s), 7-11kHz
- LAMSS AUV Unicorn
  - Bluefin 21” AUV
  - 16 element nose array
- Goals
  - Collect full acoustic data sets
  - Classify targets in real time on the vehicle

LAMSS MOOS-IvP Simulation Environment



- Vehicle and environment simulation
- High fidelity acoustic simulation
- Integrating classification processing chain with this

Classification- Vehicle Behaviors

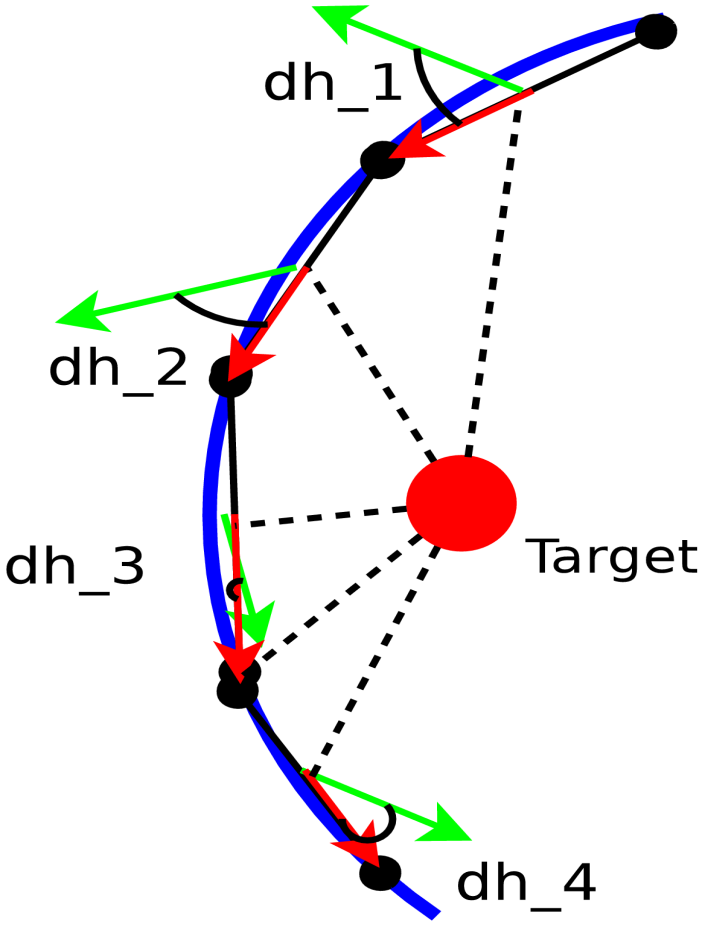


Behavior Concept

- Hit “Critical Waypoints” selected from test examples
  - Selected based on greatest classification confidence across all frequencies and target types
  - Order does not matter from a classification standpoint
- Criteria for a good path:
  - Path length
  - Obey vehicle turn radius and depth change constraints
  - Remain broadside to the target as much as possible to ensure best acoustic data

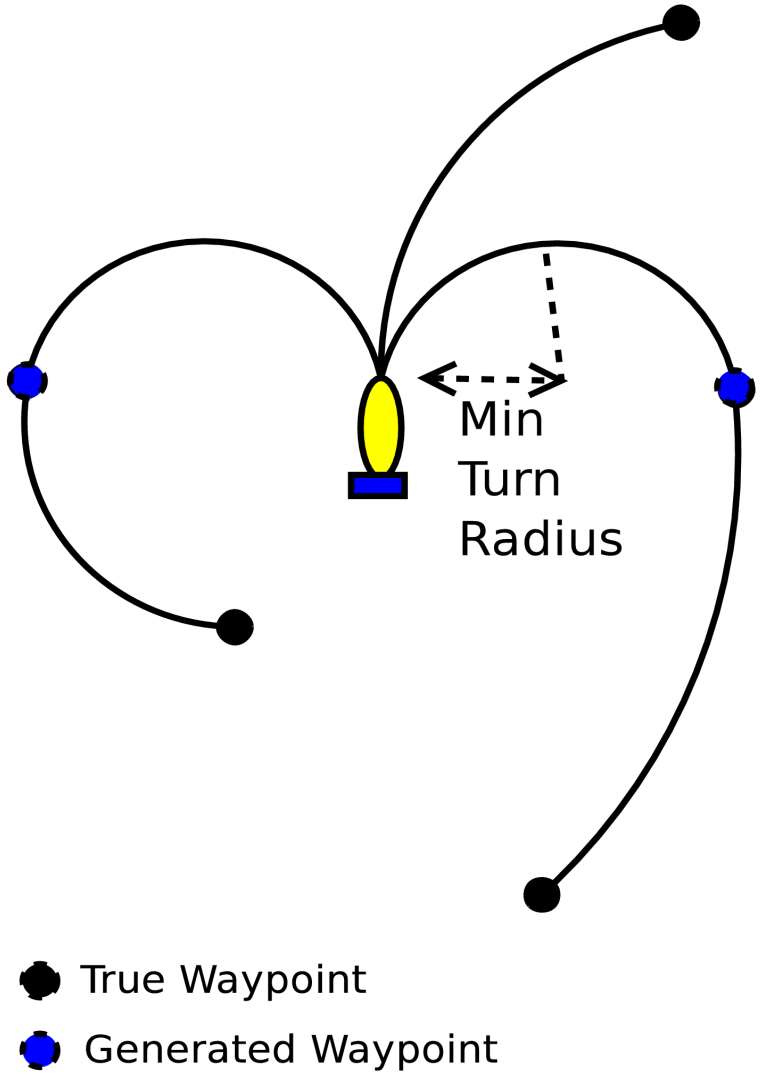
“Broadsideness”

- Keep vehicle's array perpendicular to target
- Gives best acoustic data
- Metric: weighted sum of angle differences from broadside
- broadside_cost = (cos(dh_1) + cos(dh_2) + cos(dh_3) + cos(dh_4) + 4)*arcLen/4

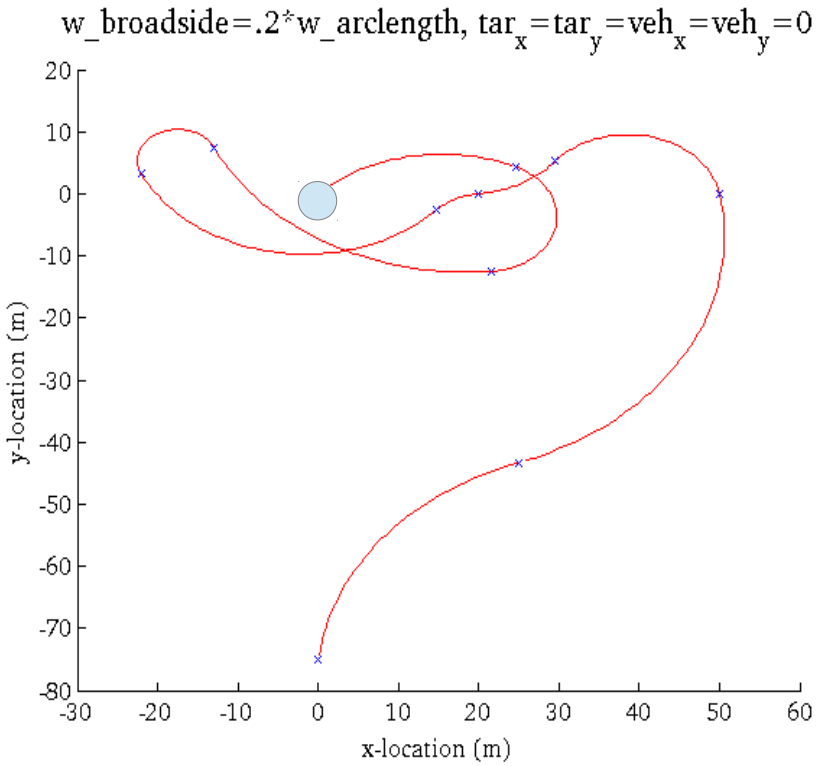


Arc Path Planner – pOrderWaypoints

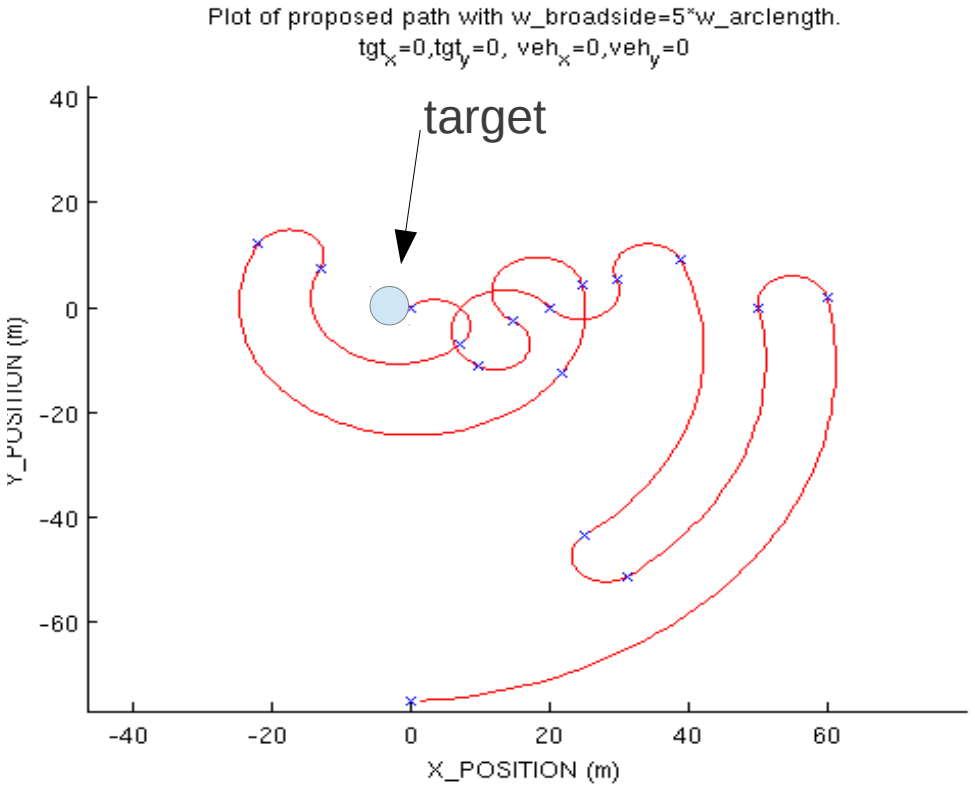
- Calculates when DEPLOY_MISSION= Pathfollow
- Orders waypoints using a* search
- Uses circular segments between waypoints.
- Obeys turning radius constraint and max pitch angle/depth change
- Cost includes weighted combination of “Broadsideness”, depth change and arc length
- Publishes ORDERED_WAYPOINTS message, CLASSIFY_TARGET flag
- Alternate formulation uses lines instead of arcs



Arc Path Planner - Paths



Broadside weighting << arclength weighting



Broadside weighting >> arclength weighting

Waypoint Manager- pManageWaypoints

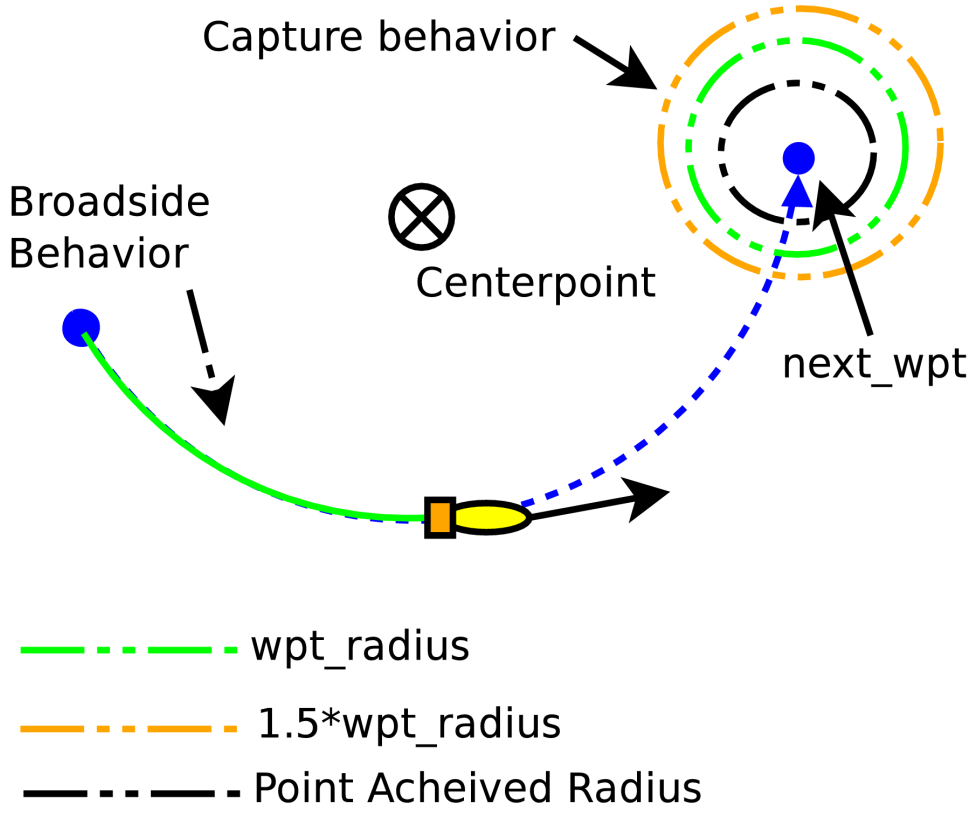
- Takes in ORDERED_WAYPOINTS
- Outputs PATH_UPDATE
  - Passes points one-at-a-time to bhv_pathfollow
  - This allows for path planning updates (including any future online implementations)
  - separate depth and x,y behavior commands
  - x,y behavior info includes center of arc prescribed by pOrderWaypoints

Translating Paths with IvP

- Arc Pathfollow behavior
  - Runs when MODE == PATHFOLLOW
  - Updates with PATH_UPDATE
  - Hit waypoint while broadside to a centerpoint
  - Updates desired heading (course)
- Depth behavior
  - PATH_UPDATE messages include depth
  - Simple depth behavior handles depth changes (commands prompted w/ each new waypoint)

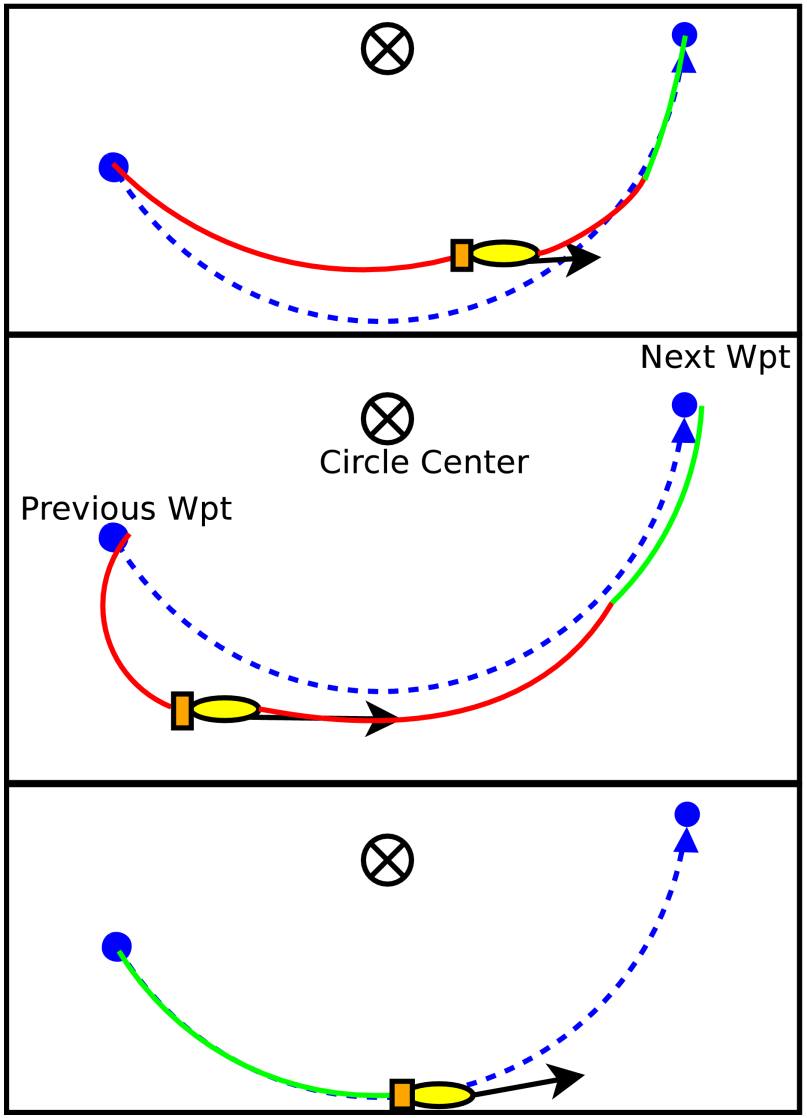
Arc Pathfollow

- Heading
  - In general: desired heading is tangent to the arc (always circles the centerpoint)
  - Two regimes:
    - Broadside (far from next_wpt)
    - Capture (near to next_wpt)
- Speed
  - Whatever is sent in updates (or in initialization)



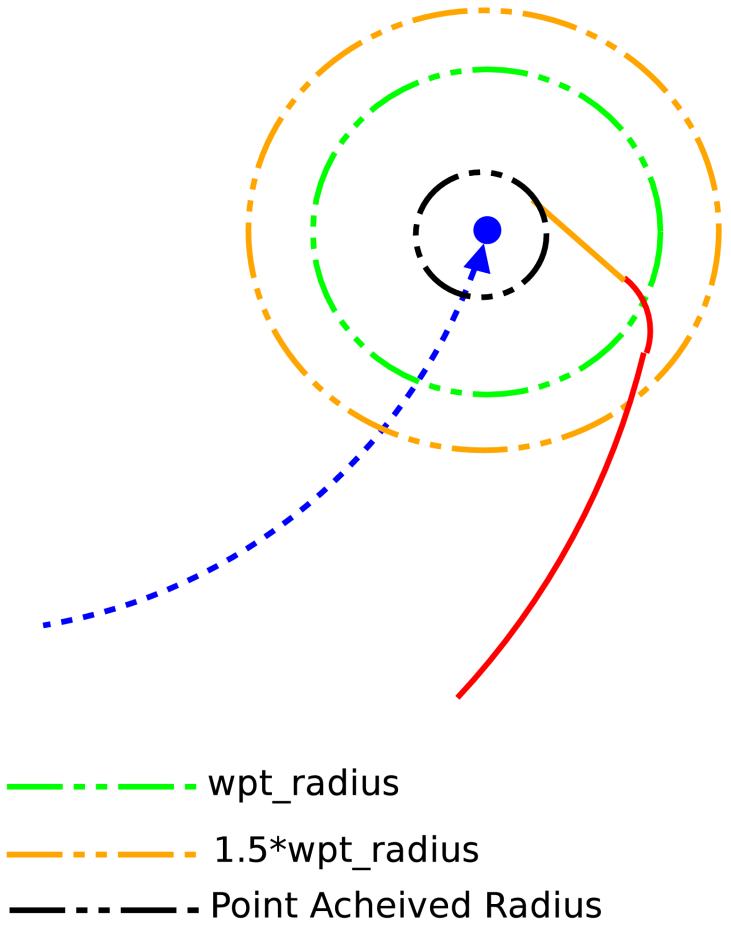
Arc Pathfollow

- Broadside
  - Desired heading is heading broadside to centerpoint
  - Maintains heading_broadside when on that radius
  - Adjusts heading to return to broadside_radius if it gets off

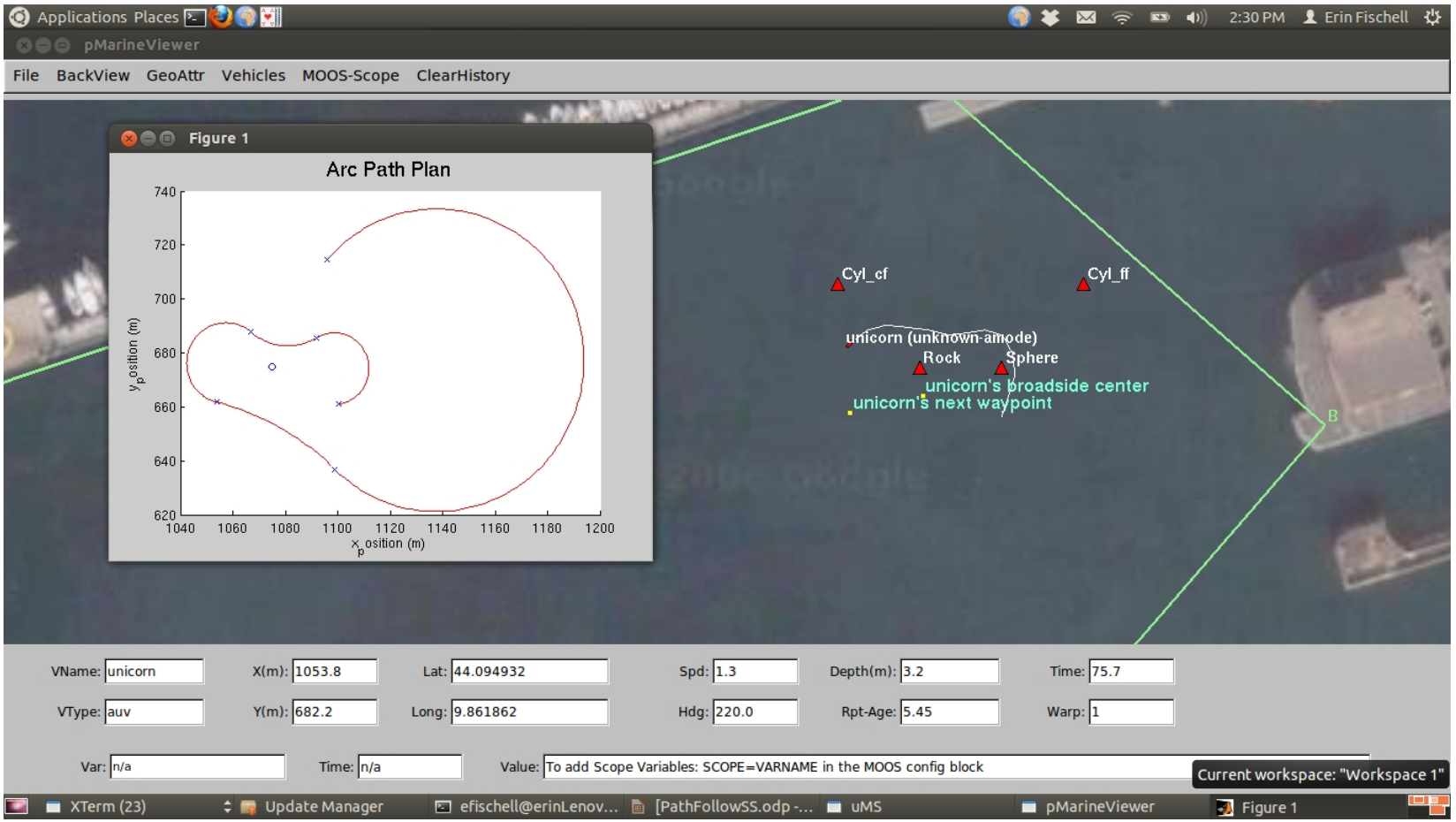


Arc Pathfollow

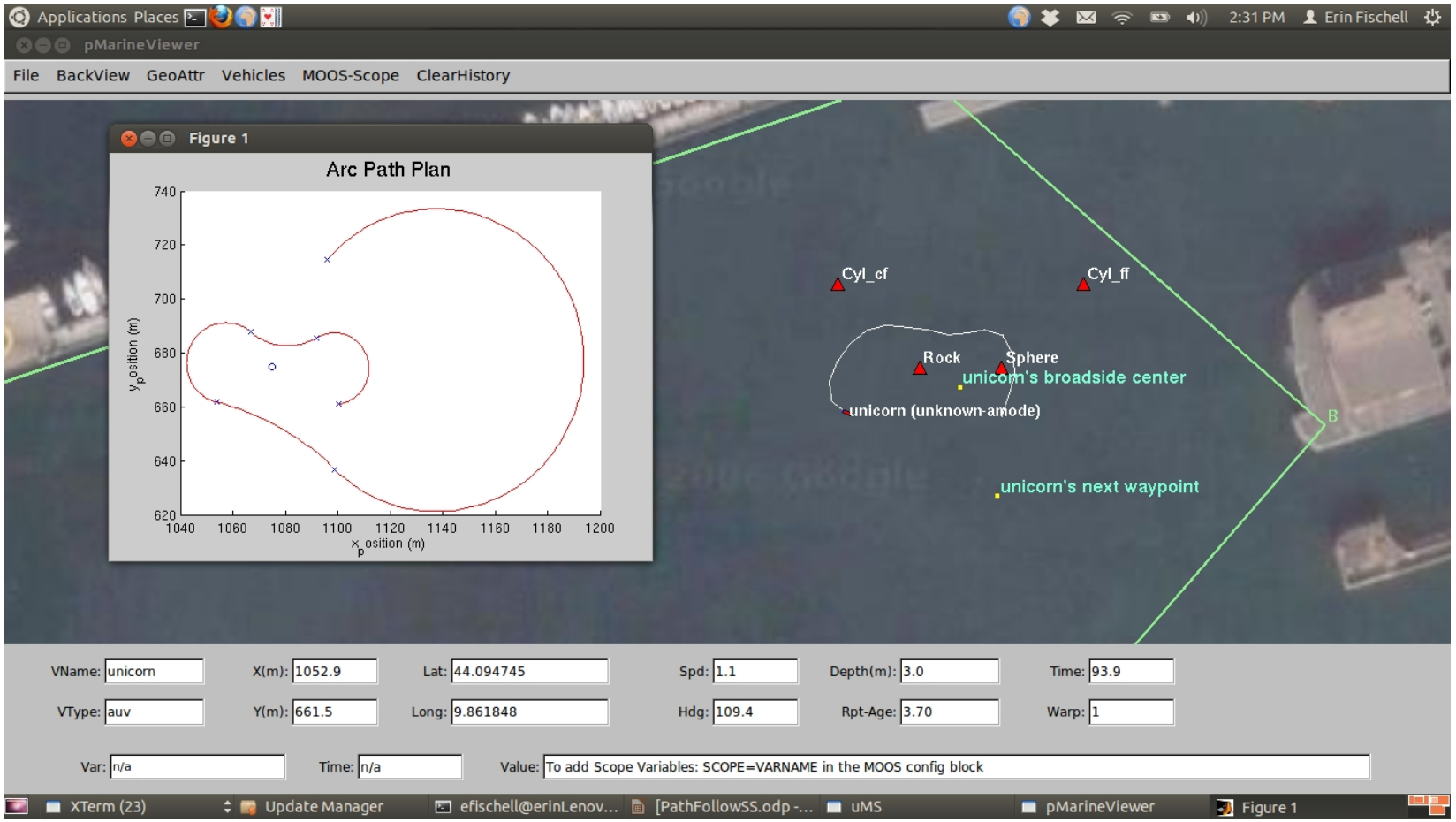
- Capture -
  - r <= wpt_radius, full weight on heading to the next_wpt
  - r <1.5*wpt_radius, linear interpolation between broadside and waypoint headings
  - r<radius, the waypoint is “hit”, move on to next waypoint (pManageWaypoints)



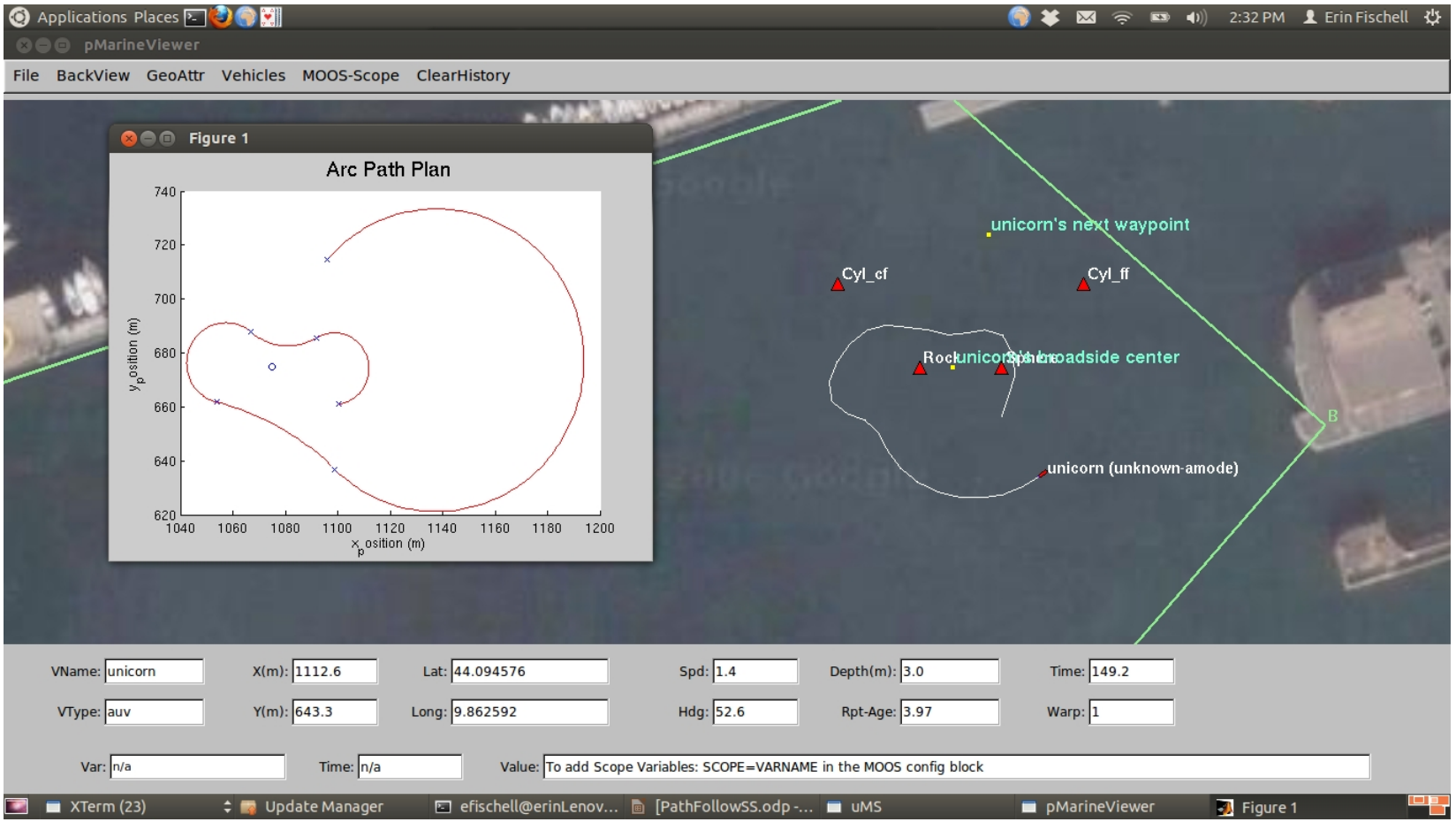
Arc Pathfollow



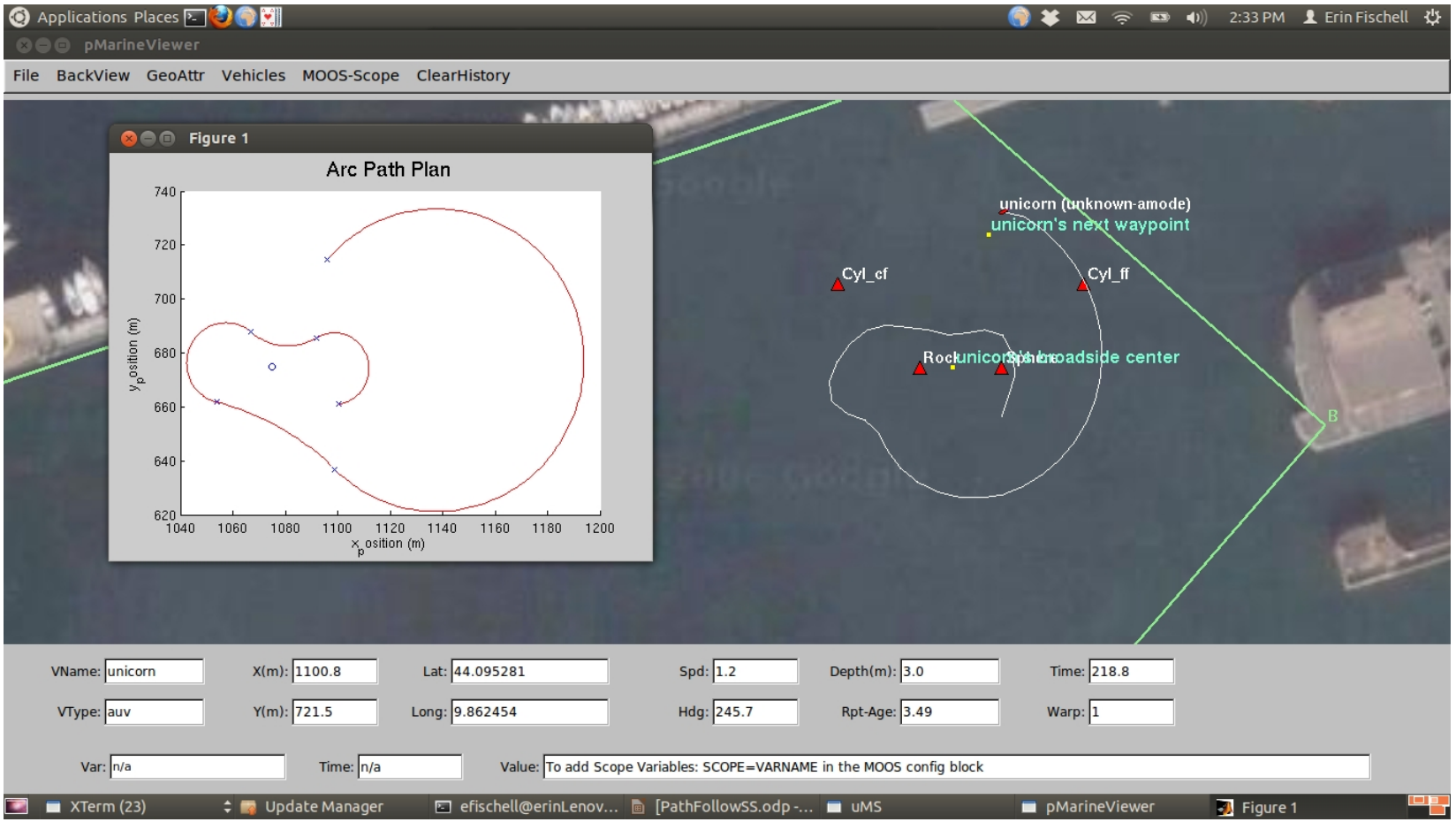
Arc Pathfollow



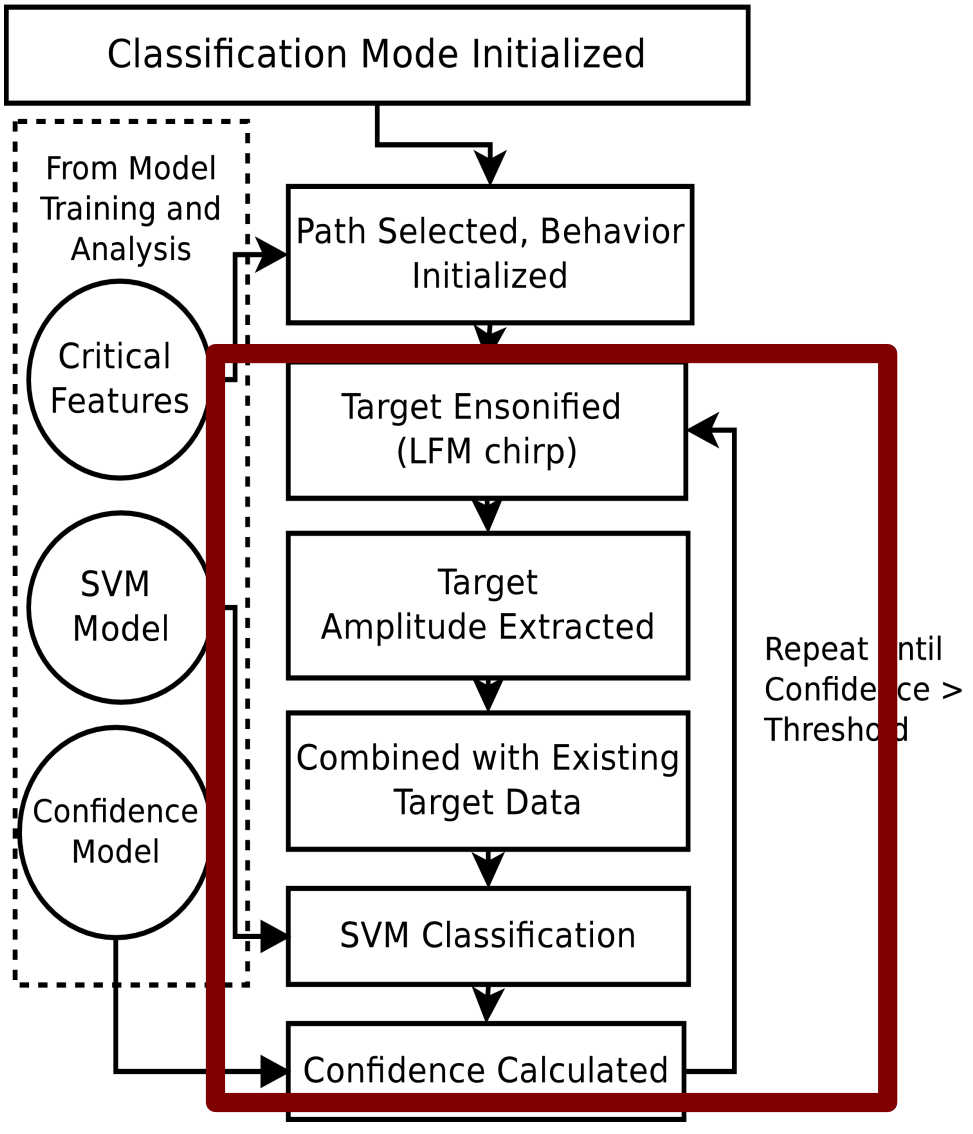
Arc Pathfollow



Arc Pathfollow



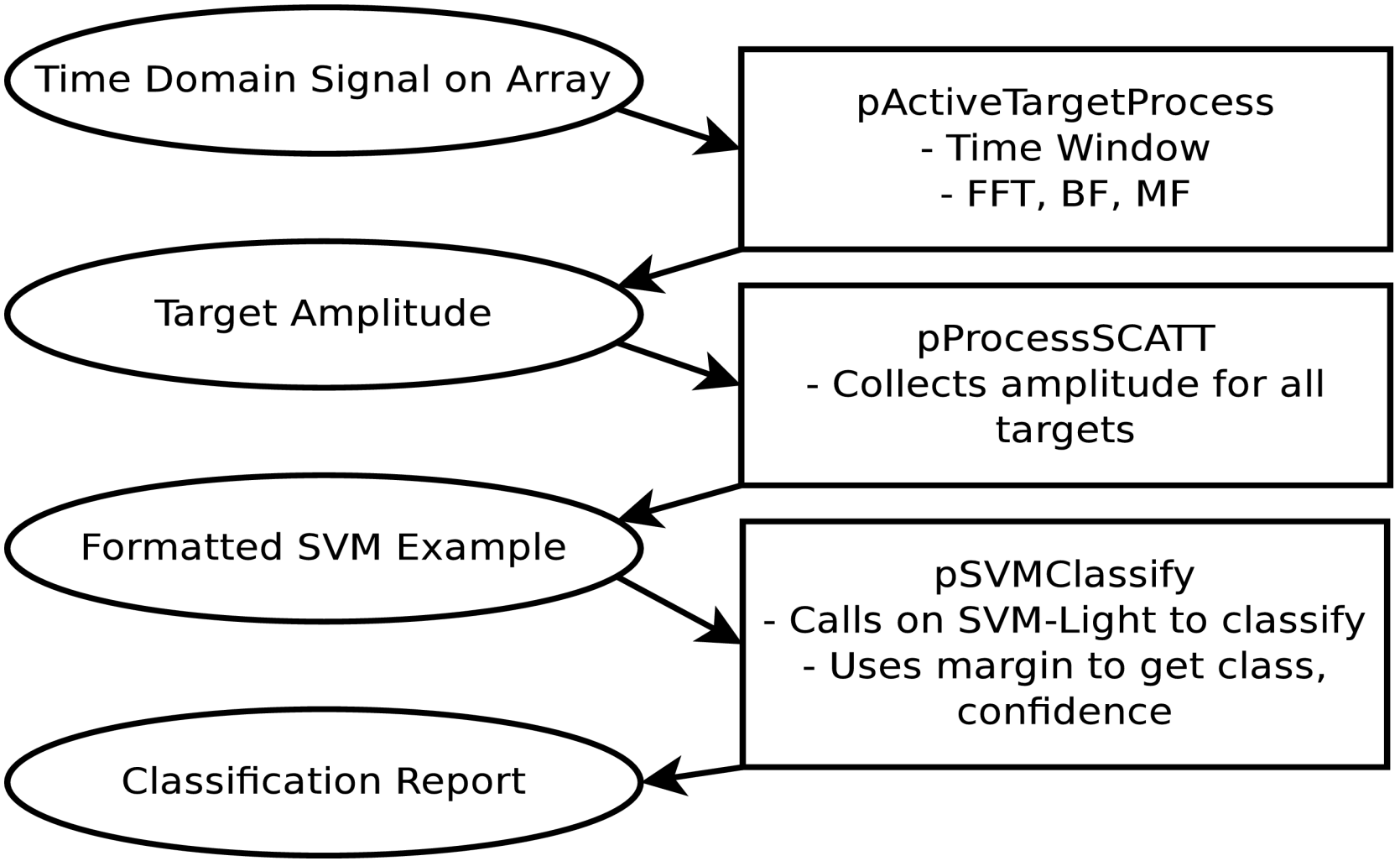
Classification- Processing Chain



Classification Processing Chain

- Runs when CLASSIFY_TARGET is published by pOrderWaypoints
- Parallel simulation and real time processing chains
  - Allows testing of behaviors and classification in simulation environment
  - Identical interface to simulation and runtime data

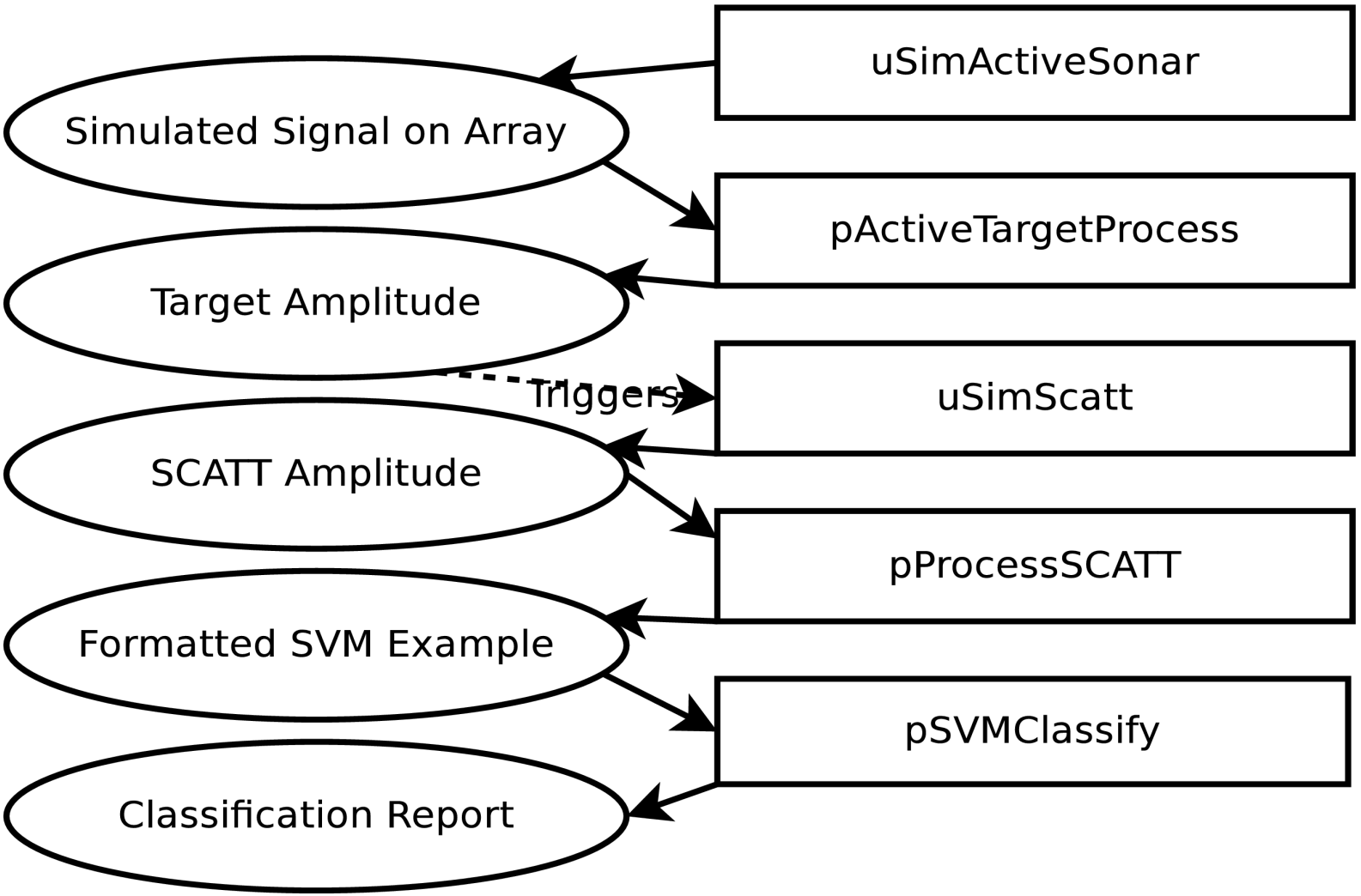
Classification Processing Chain: Real Time



Simulation Tools

- Bellhop
  - Ray tracing acoustic simulator
- uSimActiveSonar
  - Calls on Bellhop
  - Constructs time series on simulated array
- OASES SCATT
  - High fidelity target scattering model
  - Includes bottom scattering
- uSimSCATT
  - Uses SCATT model to output amplitude for current vehicle position for particular target

Classification Processing Chain: Simulated Data



Putting it all together

- Developed broadside pathfollow behaviors for sampling acoustic fields (hit key waypoints while staying broadside to target)
- Integrated classification processing chain with moos-ivp simulation environment
- Real time classification of targets (real or simulated) onboard a (real or simulated) vehicle

Moving Forward

- GOATS'14 Experiment
- Further development of sampling behaviors
- Cleaning up the offline processes
  - Full integration of SCATT with moos-ivp simulation environment
  - Model generation on the fly with new SCATT models

Acknowledgements

- This material is based upon work supported by the National Science Foundation Graduate Research Fellowship under Grant No. 0645960, and by ONR Grant No. N00014-08-1-0011

- Thanks to LAMSS: A. Balasuriya, M. Benjamin, S. Fried, S. Danesh, I. Katz, S. Petillo, T. Schneider, A. Yaari

- Thanks also to my advisor, Henrik Schmidt

Questions?