



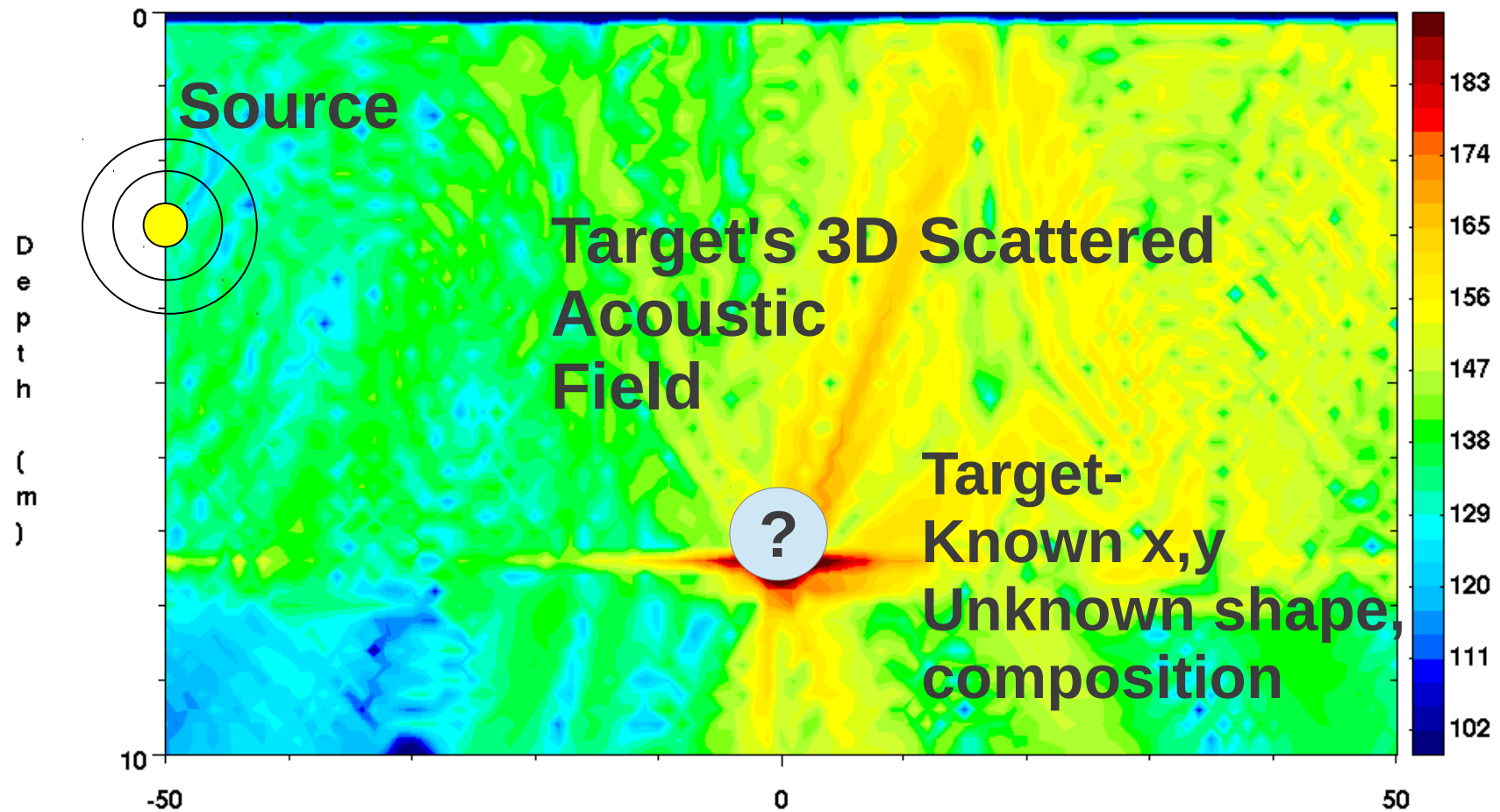
Using the MOOS-IvP with machine learning and AUV behaviors for target classification based on acoustic scattered fields

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LAMSS

Problem Overview

oast3 data file free for 3_50 deg - N - Az= 0

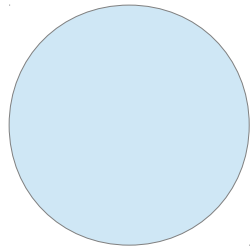
F= 9000.0Hz SD= 3.0M



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

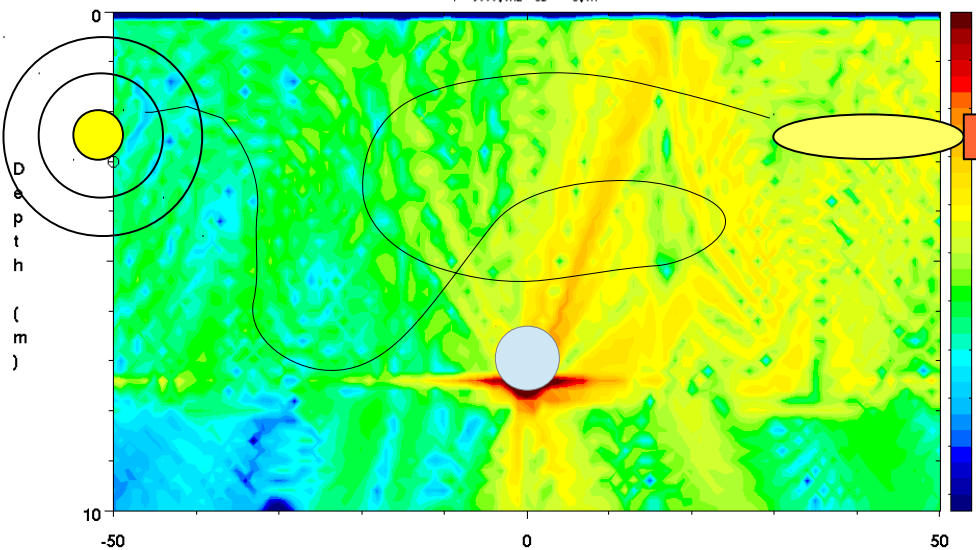


Problem Overview

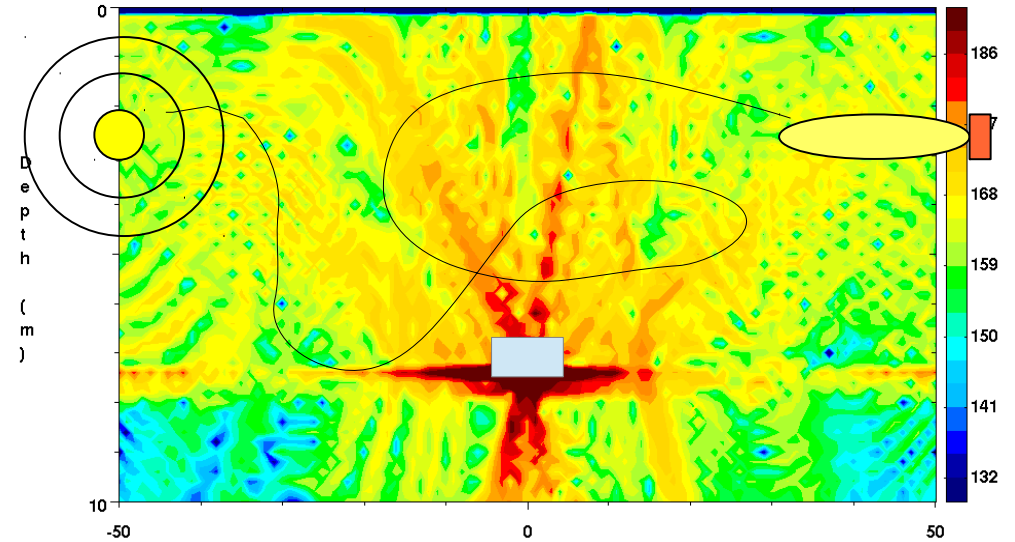


Sphere v. Cylinder Classification

oast3 data file free for 3_50 deg - N - Az= 0
F= 9000_0Hz SD= 3_0M



oast3 data file free for 3_50 deg - N - Az= 0
F= 9000_0Hz SD= 3_0M



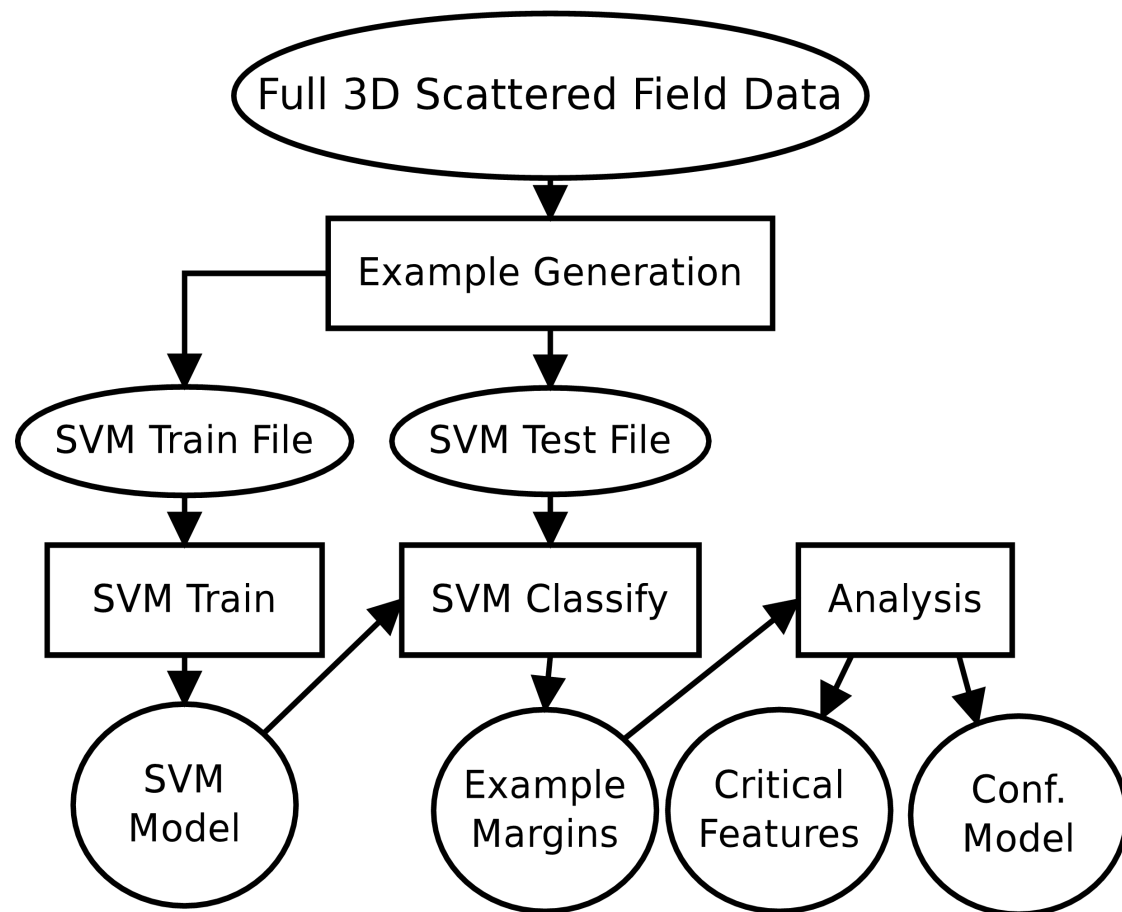
Classify Target geometry/composition using only AUV-sampled amplitude of the scattered field



Classification Methodology

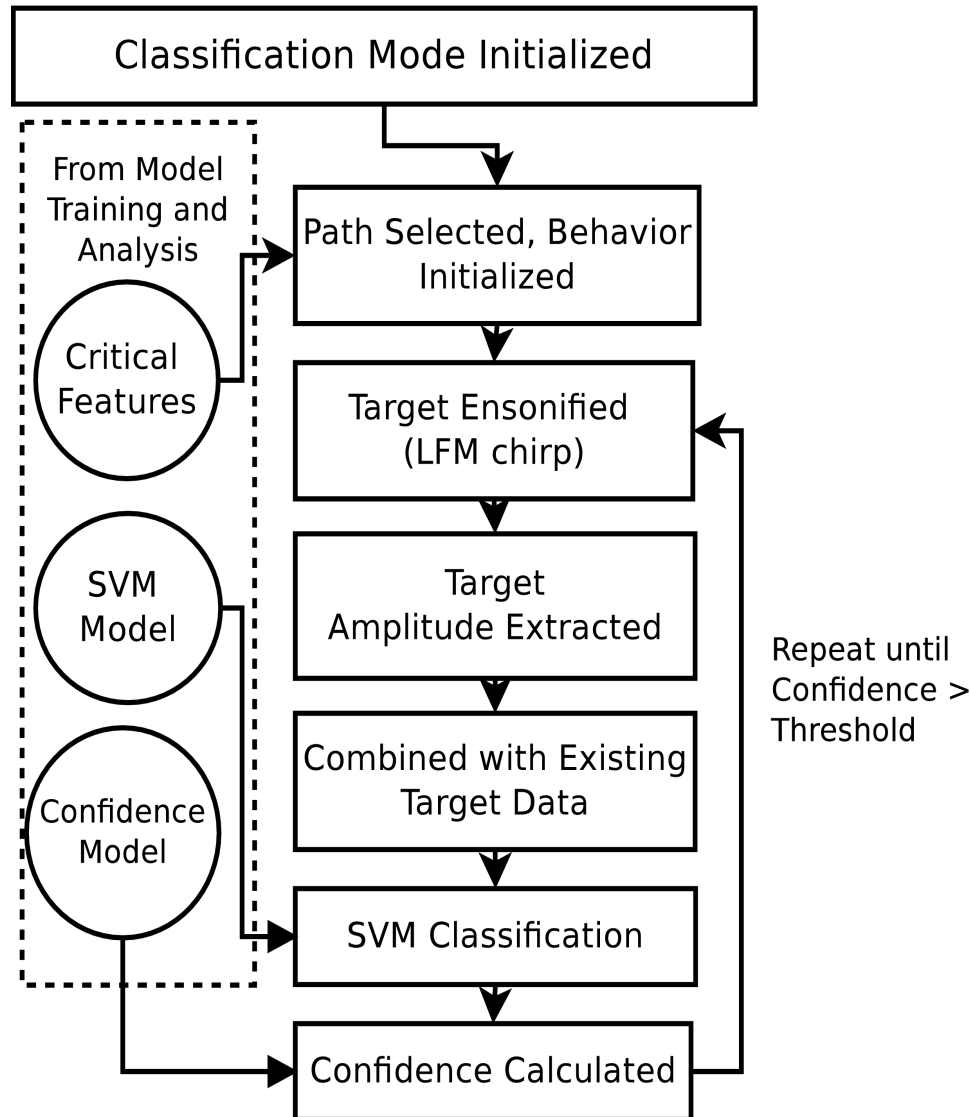
- Vehicle Behaviors, Signal Processing and Machine Learning used for target processing
- Support Vector Machines (SVMs) for actual classification
 - Acoustic amplitudes mapped to geometric feature space
- Two Parts:
 - Model Training and Analysis
 - Classification

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

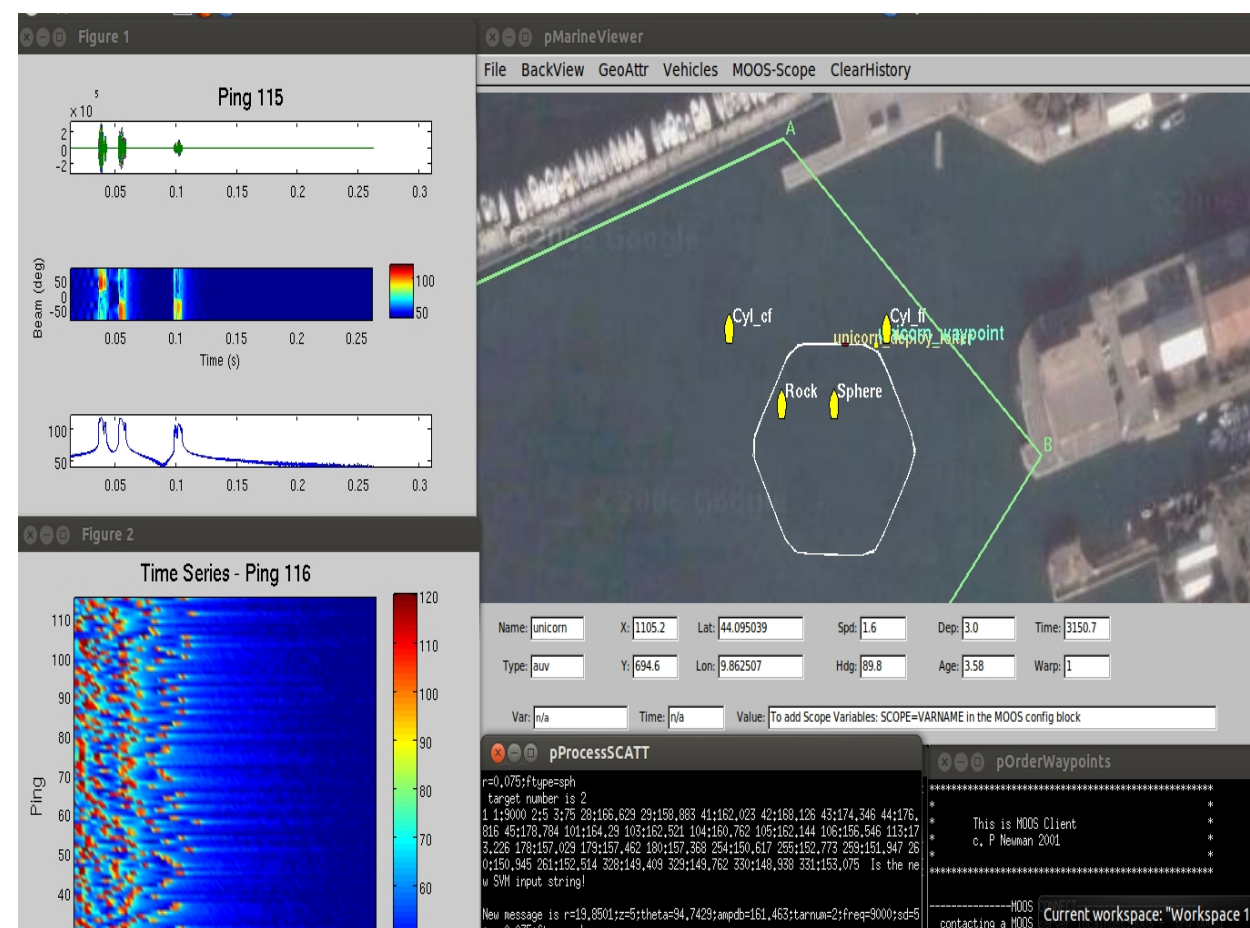
Experiment Setup- GOATS'14

- 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

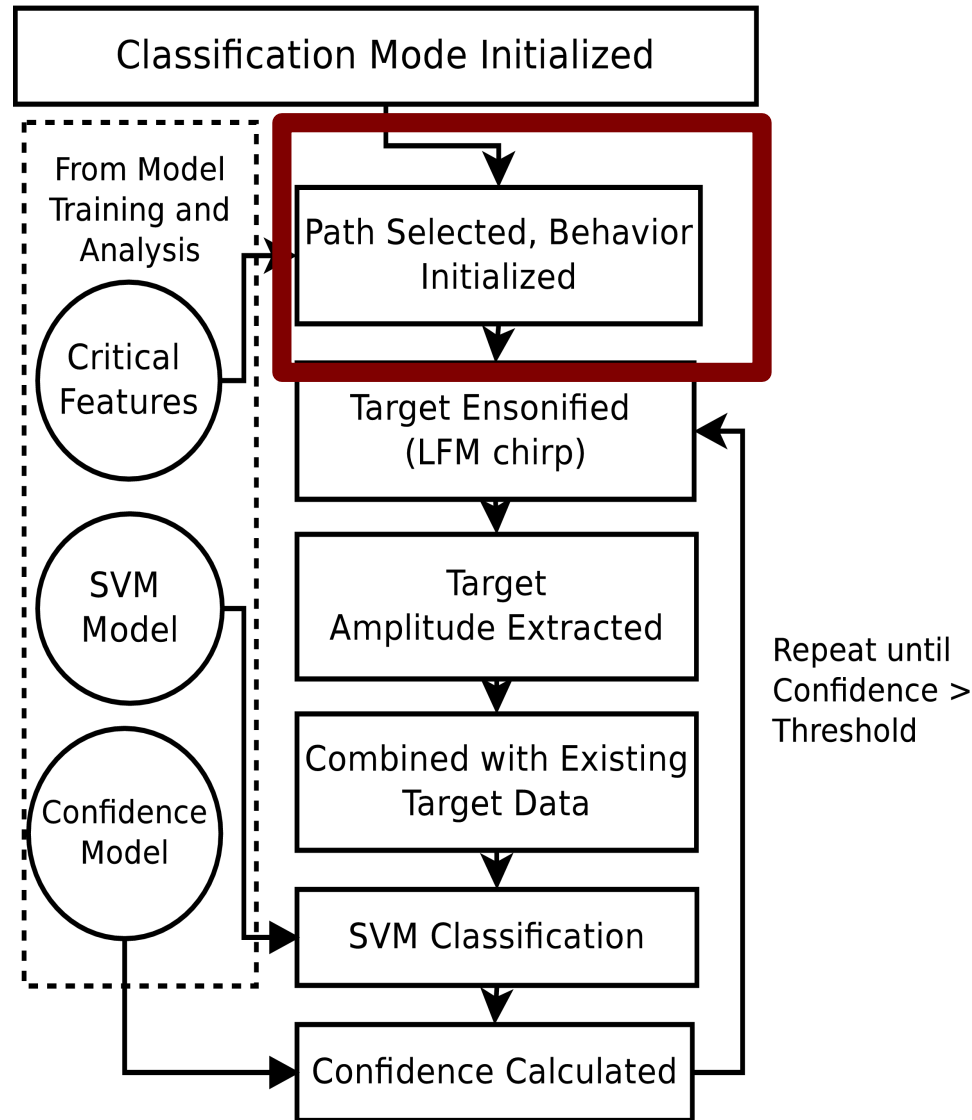


LAMSS MOOS-IvP Simulation Environment

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



Classification- Vehicle Behaviors



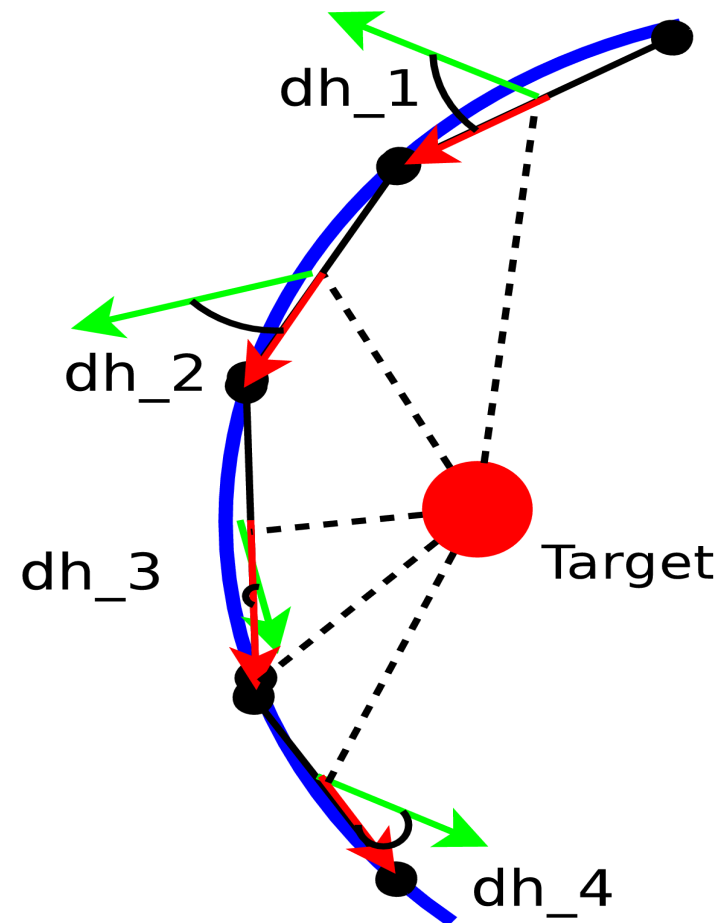


Behavior Concept

- 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

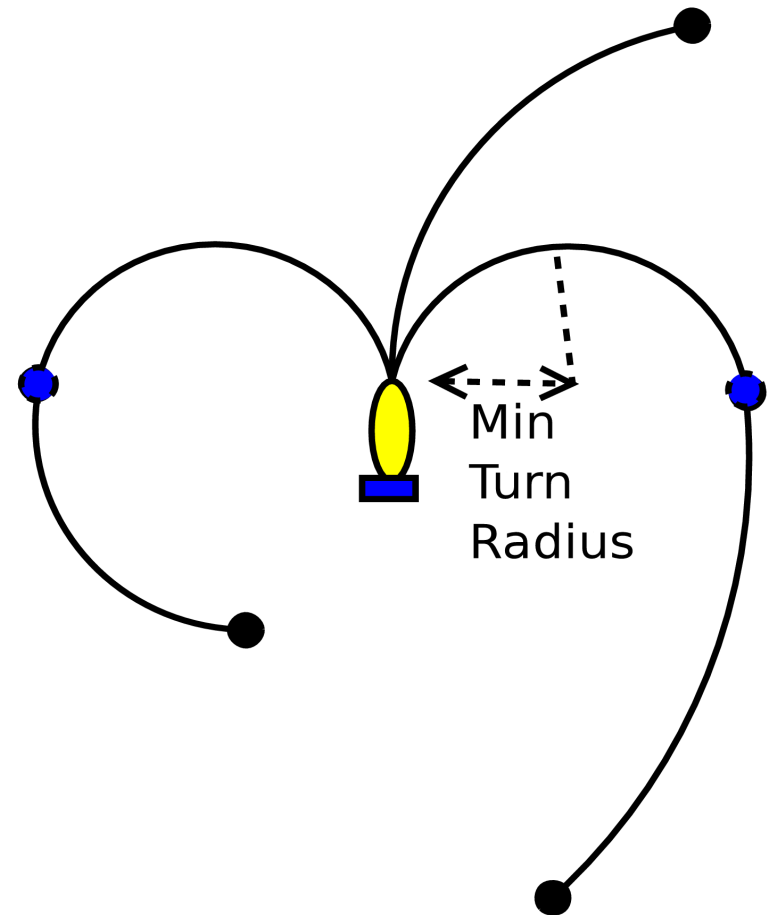
“Broadsideness”

- Keep vehicle's array perpendicular to target
- Gives best acoustic data
- Metric: weighted sum of angle differences from broadside
- $\text{broadside_cost} = (\cos(\text{dh}_1) + \cos(\text{dh}_2) + \cos(\text{dh}_3) + \cos(\text{dh}_4) + 4) * \text{arcLen} / 4$



Arc Path Planner – pOrderWaypoints

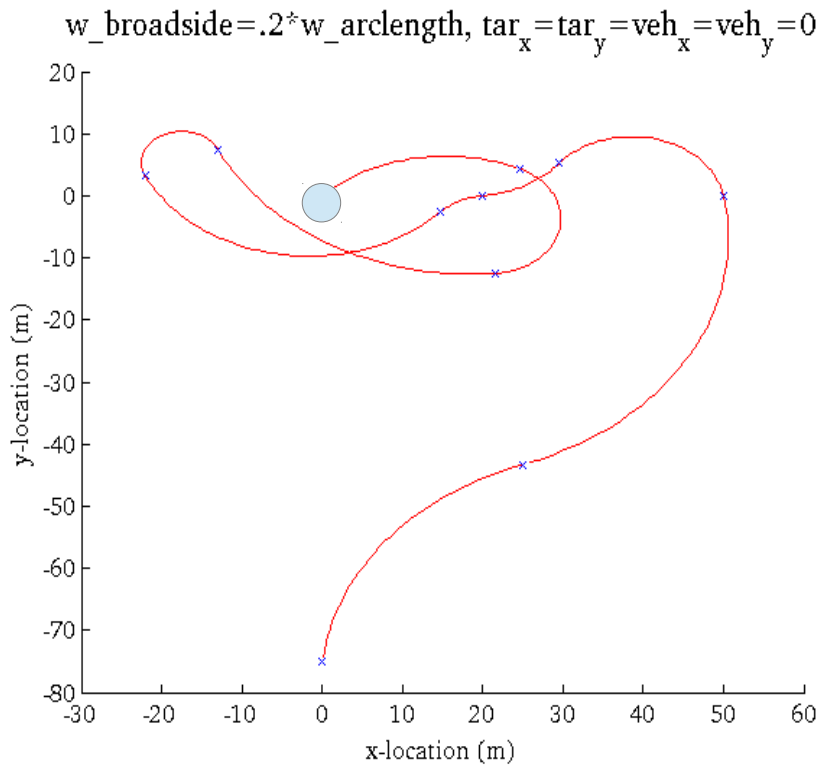
- Calculates when DEPLOY_MISSION= Pathfollow
- Orders waypoints using a* search
- Uses circular segments between waypoints.
- Obeys turning radius constraint and max pitch angle/depth change
- Cost includes weighted combination of “Broadsideness”, depth change and arc length
- Publishes ORDERED_WAYPOINTS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



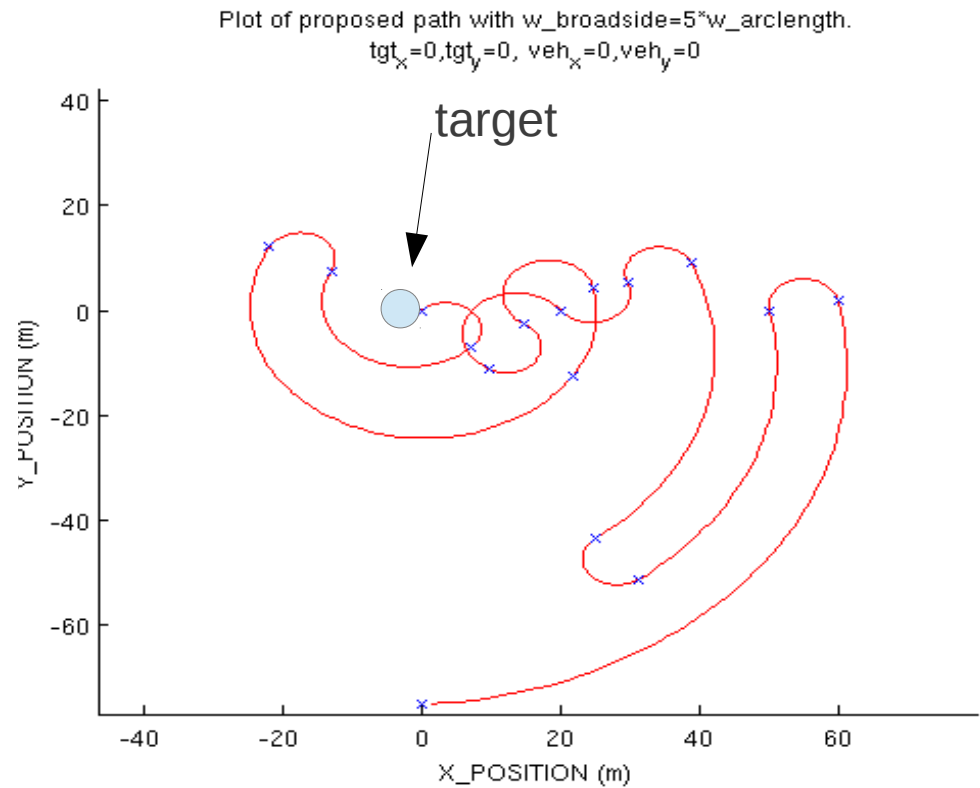
- True Waypoint
- Generated Waypoint



Arc Path Planner - Paths



Broadside weighting \ll
arclength weighting



Broadside weighting \gg
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)

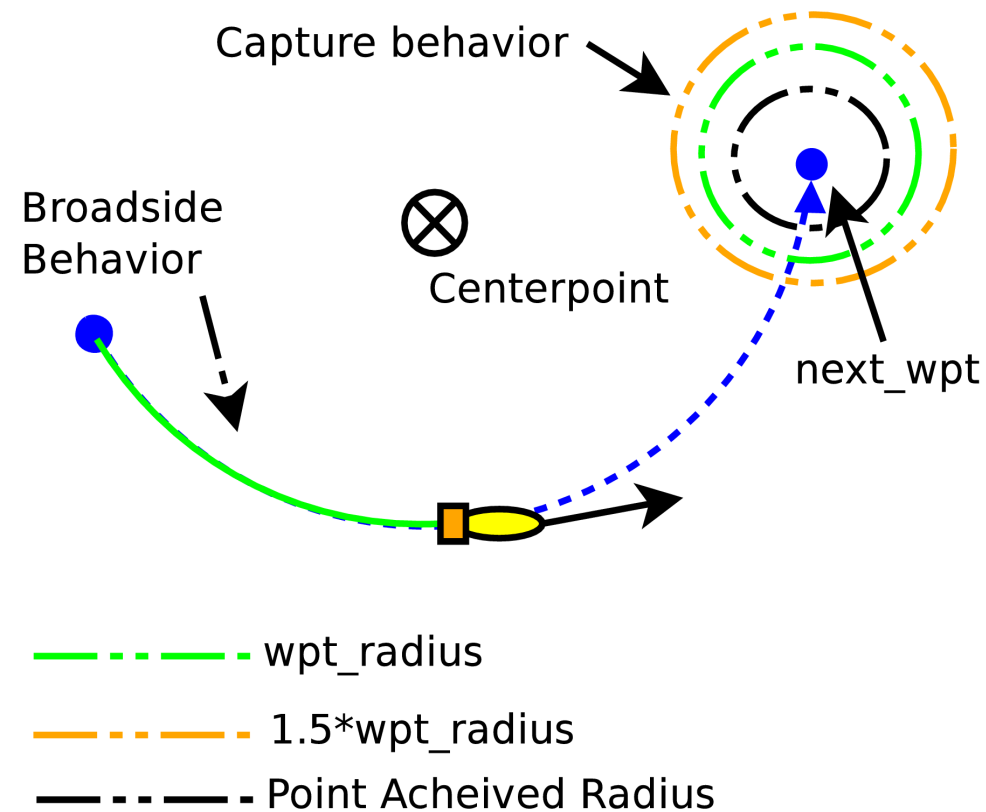
Arc Pathfollow

- 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)

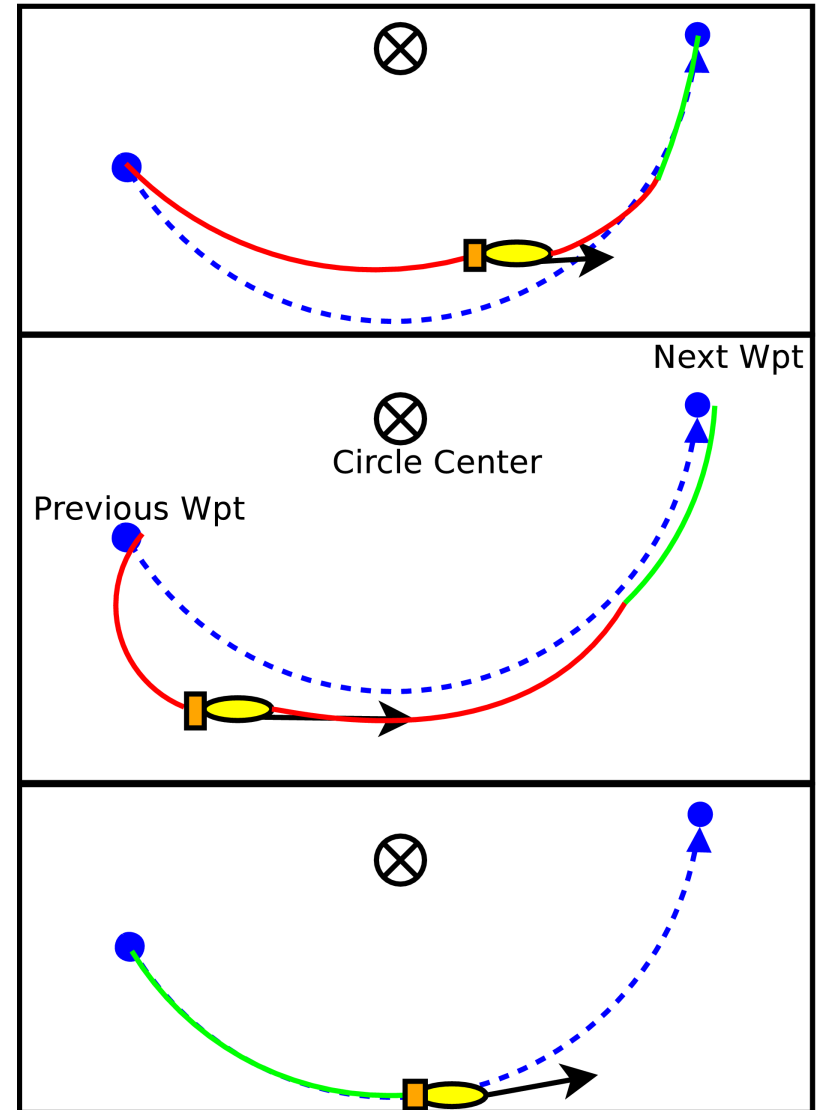
- Speed

- Whatever is sent in updates (or in initialization)



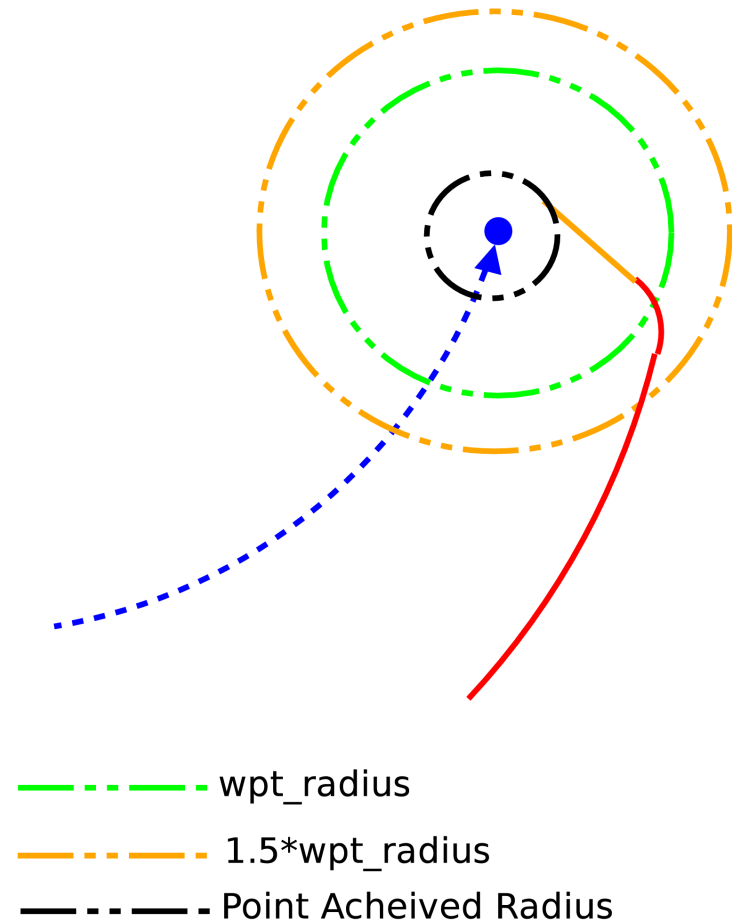
Arc Pathfollow

- 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 -
 - $r \leq wpt_radius$, 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

Applications Places pMarineViewer

File BackView GeoAttr Vehicles MOOS-Scope ClearHistory

Figure 1

Arc Path Plan

The graph shows a red path starting at approximately (1055, 665), moving to (1065, 685), then to (1085, 685), then to (1100, 665), then to (1115, 640), then to (1140, 625), then to (1180, 625), then to (1200, 680), then to (1140, 730), then to (1100, 715), then to (1085, 685), then to (1065, 665), and finally back to (1055, 665). There are several 'x' markers along the path and a blue circle at approximately (1075, 675).

Cyl_cf Cyl_ff

unicorn (unknown-mode)

Rock Sphere

unicorn's broadside center

unicorn's next waypoint

B

VName: unicorn X(m): 1053.8 Lat: 44.094932 Spd: 1.3 Depth(m): 3.2 Time: 75.7

VType: auv Y(m): 682.2 Long: 9.861862 Hdg: 220.0 Rpt-Age: 5.45 Warp: 1

Var: n/a Time: n/a Value: To add Scope Variables: SCOPE=VARNAME in the MOOS config block

Current workspace: "Workspace 1"

XTerm (23) Update Manager efischell@erinLenov... [PathFollowSS.odp ...] uMS pMarineViewer Figure 1



Arc Pathfollow

Applications Places | pMarineViewer

File BackView GeoAttr Vehicles MOOS-Scope ClearHistory

Figure 1

Arc Path Plan

The graph shows a red path in a 2D coordinate system. The x-axis is labeled 'X_position (m)' and ranges from 1040 to 1200. The y-axis is labeled 'Y_position (m)' and ranges from 620 to 740. The path starts at approximately (1050, 660), moves to (1060, 680), then to (1080, 685), then to (1100, 660), then to (1110, 640), then to (1140, 630), then to (1180, 630), then to (1200, 660), then to (1180, 700), then to (1140, 730), then to (1100, 710), then to (1080, 685), then to (1060, 680), then to (1050, 660). There are several 'x' markers along the path and a blue circle at approximately (1075, 675).

The map view shows a satellite image of a coastal area. A green path is overlaid on the image, starting from a point labeled 'B' and moving towards the left. Several waypoints and obstacles are marked: 'Cyl_cf' (red triangle), 'Cyl_ff' (red triangle), 'Rock' (red triangle), 'Sphere' (red triangle), 'unicorn's broadside center' (green square), 'unicorn (unknown-amode)' (red square), and 'unicorn's next waypoint' (green square). A point 'B' is marked with a red letter.

VName: X(m): Lat: Spd: Depth(m): Time:

VType: Y(m): Long: Hdg: Rpt-Age: Warp:

Var: Time: Value:

XTerm (23) | Update Manager | efischell@erinLenov... | [PathFollowSS.odp ...] | uMS | pMarineViewer | Figure 1



Arc Pathfollow

Applications Places pMarineViewer

File BackView GeoAttr Vehicles MOOS-Scope ClearHistory

Figure 1

Arc Path Plan

The graph shows a red path on a coordinate system where the x-axis is labeled 'X_position (m)' and the y-axis is labeled 'Y_position (m)'. The x-axis ranges from 1040 to 1200, and the y-axis ranges from 620 to 740. The path starts at approximately (1050, 660), moves to (1060, 660), then to (1070, 680), (1080, 680), (1090, 710), (1100, 710), (1110, 730), (1120, 730), (1130, 710), (1140, 710), (1150, 680), (1160, 680), (1170, 660), (1180, 660), (1190, 640), (1200, 640), (1190, 620), (1180, 620), (1170, 640), (1160, 640), (1150, 660), (1140, 660), (1130, 680), (1120, 680), (1110, 710), (1100, 710), (1090, 680), (1080, 680), (1070, 660), (1060, 660), and returns to (1050, 660). There are several 'x' markers along the path and one blue circle at approximately (1075, 675).

The satellite map view shows a path (white line) and several waypoints (red triangles): Cyl_cf, Cyl_ff, Rock, unicorn's broadside center, and unicorn (unknown-amode). A green square marks 'unicorn's next waypoint'. A green line labeled 'B' is also visible.

VName: X(m): Lat: Spd: Depth(m): Time:

VType: Y(m): Long: Hdg: Rpt-Age: Warp:

Var: Time: Value:

XTerm (23) Update Manager efischell@erinLenov... [PathFollowSS.odp ...] uMS pMarineViewer Figure 1



Arc Pathfollow

Applications Places | pMarineViewer

File BackView GeoAttr Vehicles MOOS-Scope ClearHistory

Figure 1

Arc Path Plan

unicorn (unknown-atype)
unicorn's next waypoint

Cyl_cf Cyl_ff

Rock unicorn's broadside center

B

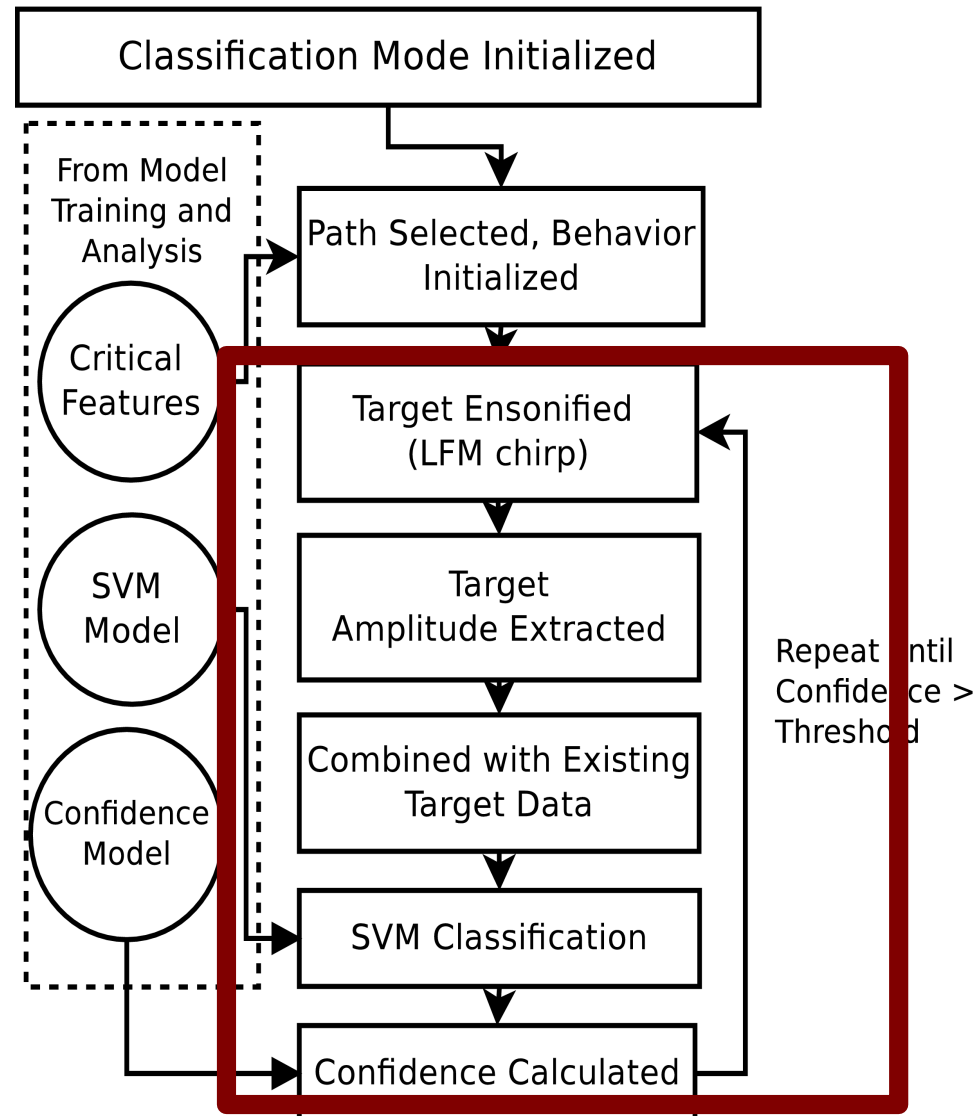
VName: X(m): Lat: Spd: Depth(m): Time:

VType: Y(m): Long: Hdg: Rpt-Age: Warp:

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XTerm (23) | Update Manager | efischell@erinLenov... | [PathFollowSS.odp ...] | uMS | pMarineViewer | Figure 1

Classification- Processing Chain

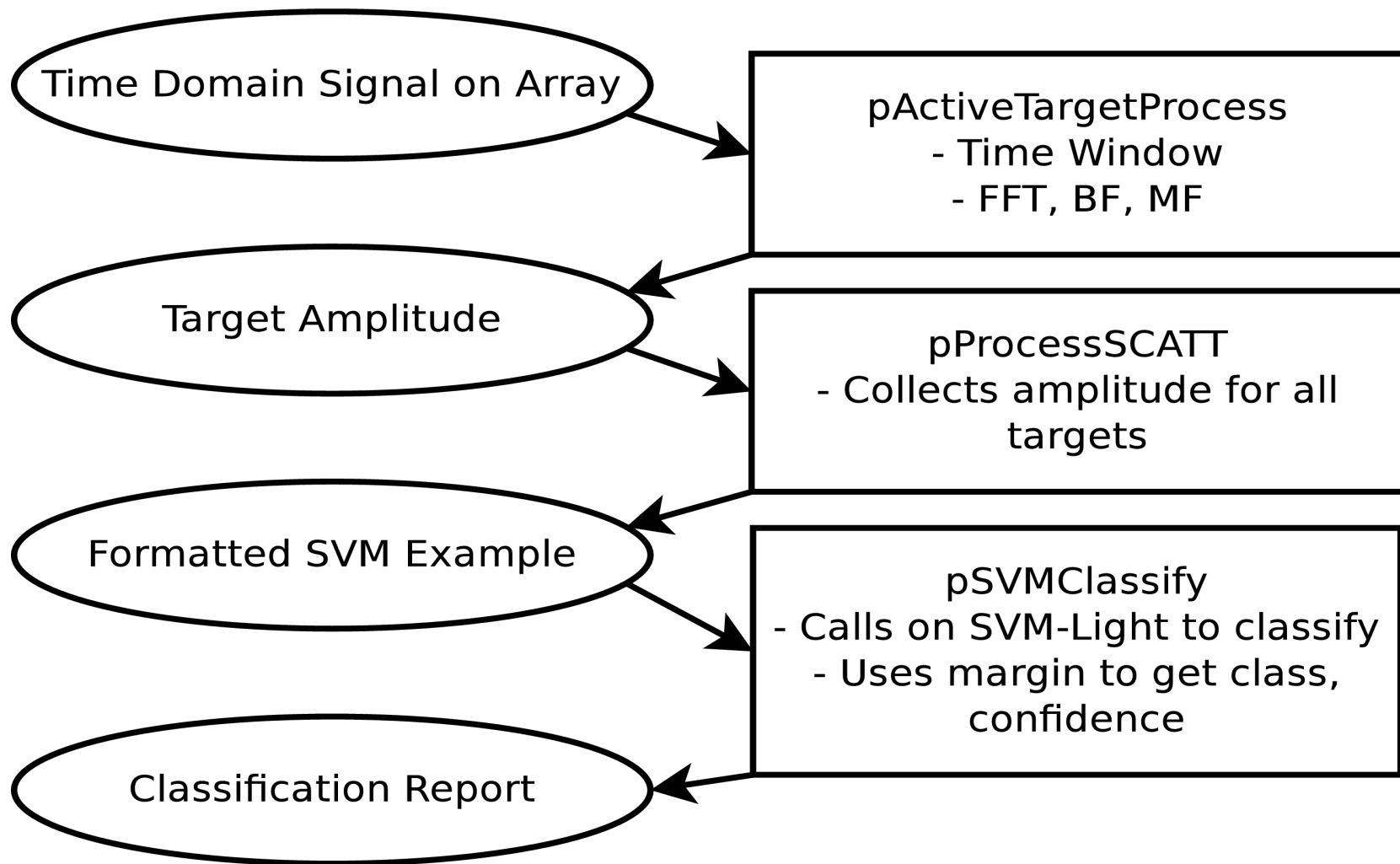




Classification Processing Chain

- 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

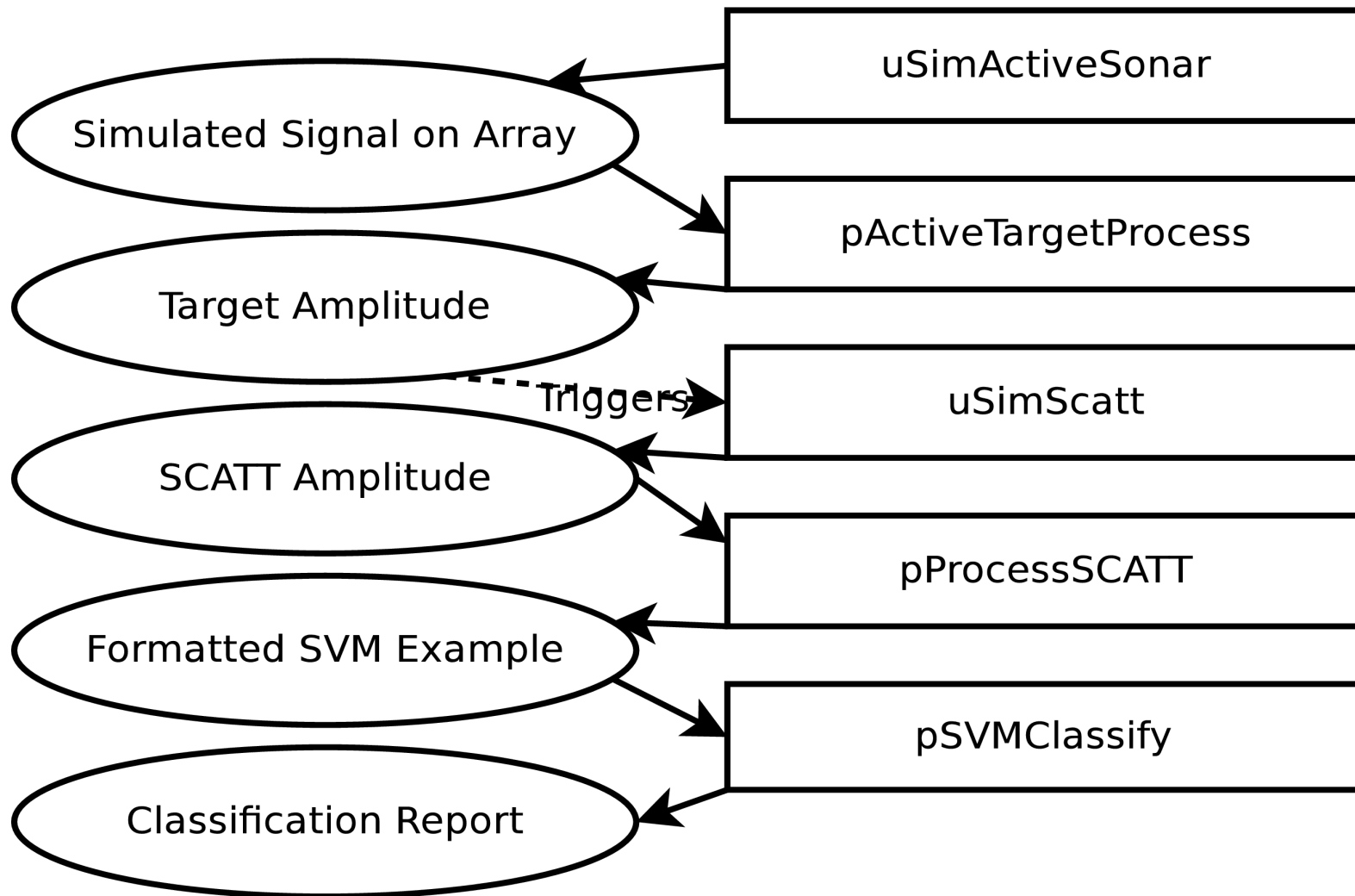




Simulation Tools

- 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



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Questions?