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HUMAN-CENTERED ENGINEERING

Mixed-Initiative Machine for Instructed Computing (MIMIC)

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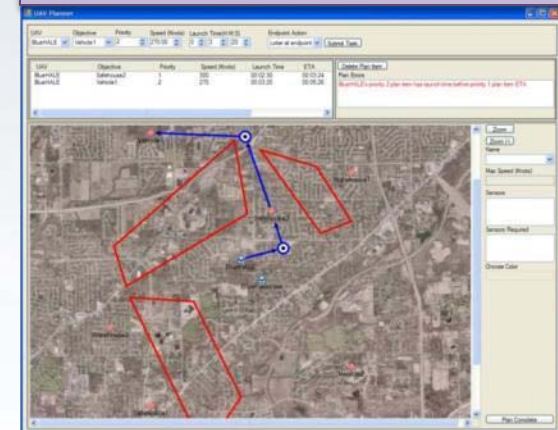
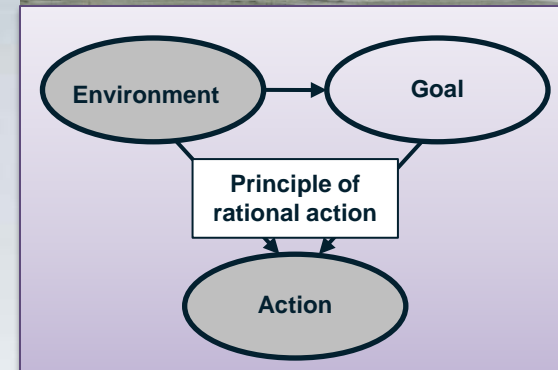
Challenges

- UASs as core capability for intelligence
- UAS mission planning relies on human decision-making
 - Cognitive capacity is limited
 - Cognitive processing is limited
 - Scalability issues for multi-UAS settings
- How do planners plan?
Objectives – Goals – Actions – Strategies
- How can we understand what planners do?
 - To train other planners...
 - To train automated agents (to support human decision-making)



Research Summary

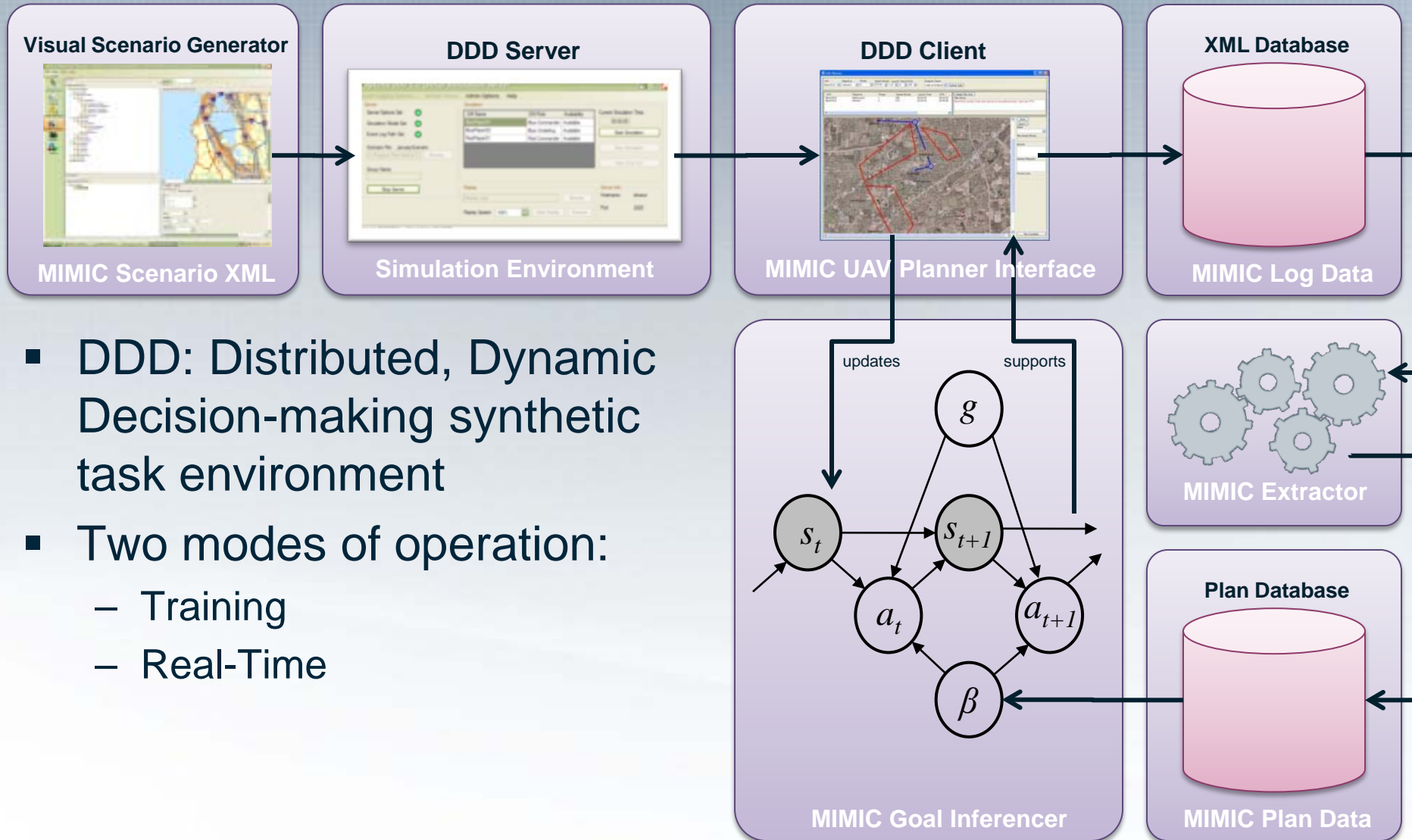
- MIMIC – Mixed-Initiative Machine for Instructed Computing
- MIMIC introduces a novel computational model that...
 - ... captures planning actions
 - ... infers planning goals
 - ... identifies planning strategies
- Experimental validation showed:
 - Successful model training protocol
 - Promising detection accuracy
 - Better than random prediction capability



- **MIMIC enables:**
 - Real-time strategy and intent detection
 - Prediction of future operator actions
 - Human planning modeling
 - Increased planning complexity through automation-based support
- **MIMIC can support**
 - Collaborative multi-UAS mission planning
 - Multi-UAS real-time mission replanning
 - Assessment or evaluation of planning skills
 - Overall faster planning in more complex environments

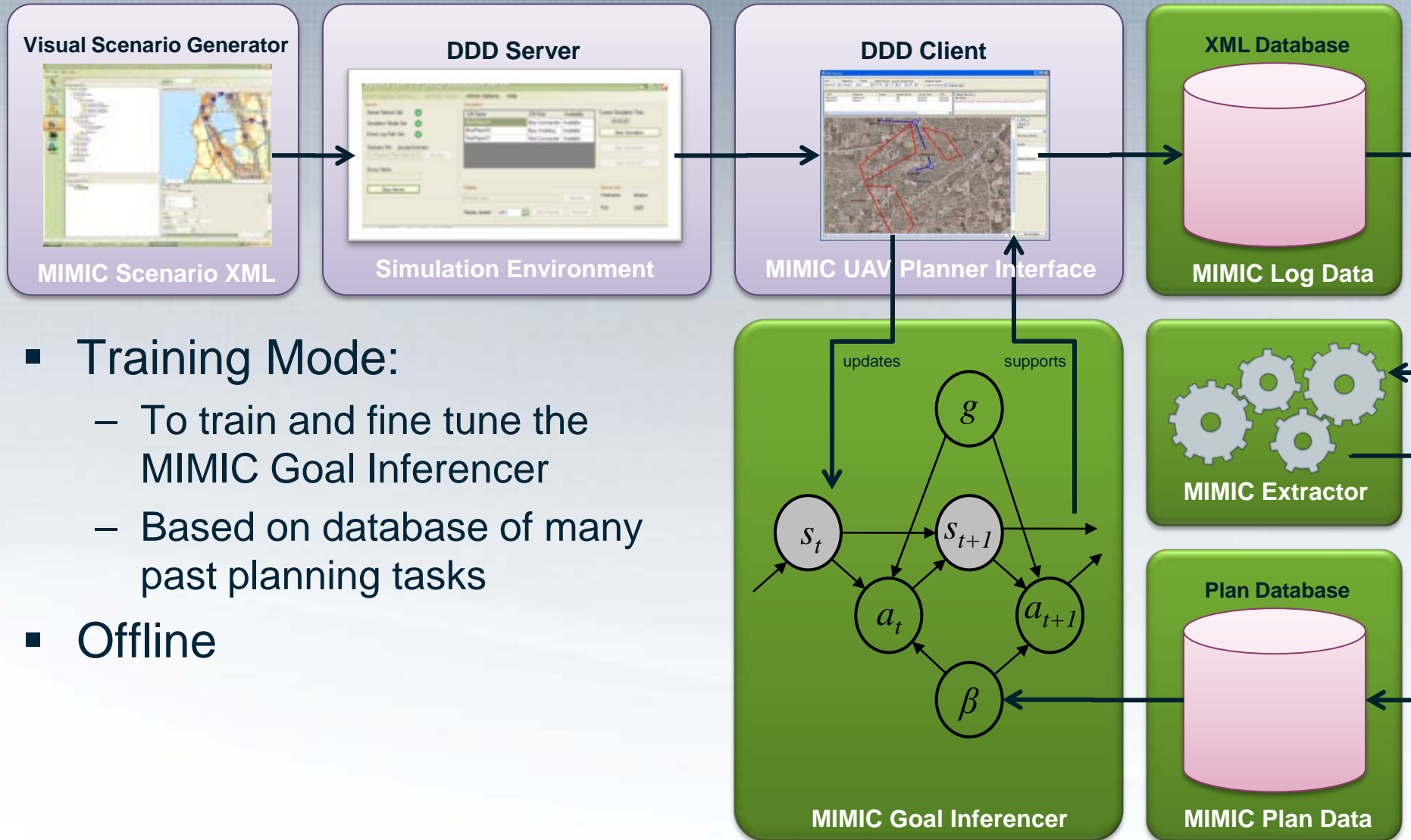


Approach



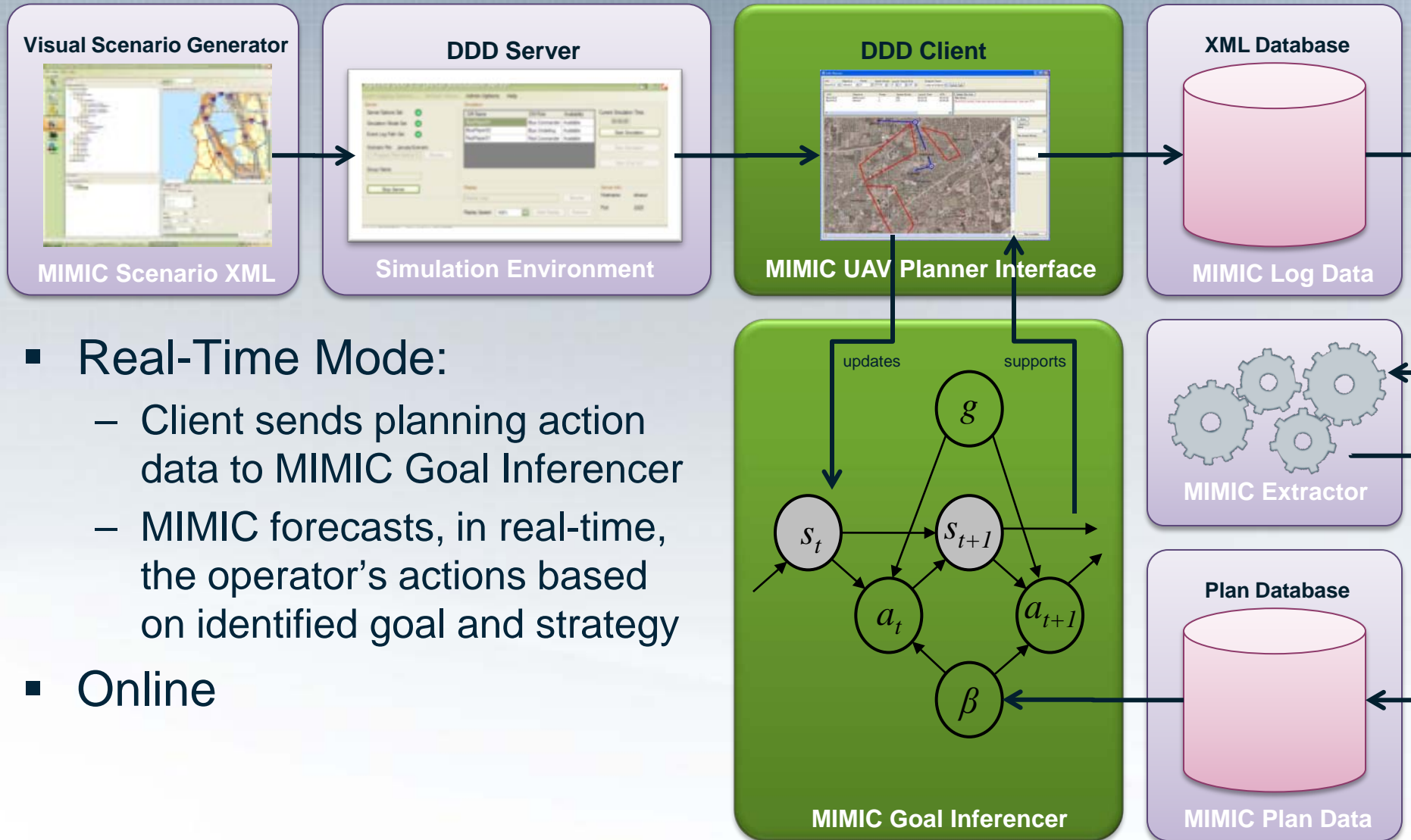
- DDD: Distributed, Dynamic Decision-making synthetic task environment
- Two modes of operation:
 - Training
 - Real-Time

Approach



- **Training Mode:**
 - To train and fine tune the MIMIC Goal Inferencer
 - Based on database of many past planning tasks
- **Offline**

Approach



- **Real-Time Mode:**
 - Client sends planning action data to MIMIC Goal Inferencer
 - MIMIC forecasts, in real-time, the operator's actions based on identified goal and strategy
- **Online**

Experiments

	Experiment 1	Experiment 2	Experiment 3
Objective	MIMIC setup and training	MIMIC evaluation	MIMIC prediction
Goal	To identify typical operator planning priorities, in order to define MIMIC's features; and gather planning data in order to train the MIMIC model.	To gather planning data and priority ratings to compare MIMIC's output to operators' assessments of priorities and goals.	To predict, in real-time, what an operator's next actions will be, and compare the MIMIC prediction to the actual operator action.
Participants	42 students aged 18-69 (avg 30yo ± 12.5)	20 students aged 18-47 (avg 27yo ± 8.3)	20 students aged 18-54 (avg 26yo ± 9.3)
IVs	<ul style="list-style-type: none"> Planning time (as a proxy for time pressure): short (3 min) vs. long (6 min) Scenario complexity: low (10 targets, few ROEs) vs. medium (20 t., few ROEs) vs. high (20 t., many ROEs) 		
DVs	<ul style="list-style-type: none"> System interaction Post-hoc constraints and priorities identification 	<ul style="list-style-type: none"> System interaction Quasi-real-time subjective identification of priorities by operators 	<ul style="list-style-type: none"> System interaction
Analysis	<ul style="list-style-type: none"> A list of typical planning priorities which will be used as features in the MIMIC machine learner. A large amount of system interaction data which will be used to train MIMIC. 	<ul style="list-style-type: none"> A comparison between MIMIC-identified and operator-identified priorities. 	<ul style="list-style-type: none"> An assessment of MIMIC's prediction ability.

MIMIC UAV Planner Interface

- 2 UAVs
 - HALE
 - FireScout
- 10 to 20 targets
- Weather zones
- ROE constraints

The screenshot displays the MIMIC UAV Planner interface. At the top, there is a 'MANUAL' section with a table for configuring a task. Below this is a table listing the mission tasks. The main area features a satellite map with flight paths for BlueHALE (blue) and BlueFireScout (green). Red polygons on the map represent weather zones or ROE constraints. On the right side, there is a 'Plan Errors' panel with red text indicating speed and priority issues. Below the map, there are controls for zooming, naming, and setting max speed, along with a 'Plan Complete' button.

UAV	Objective	Priority	Speed (Knots)	Launch Time(H:M:S)	Endpoint Action
BlueHALE	Safehouse1	1	1.00	0 0 0	Loiter at endpoint

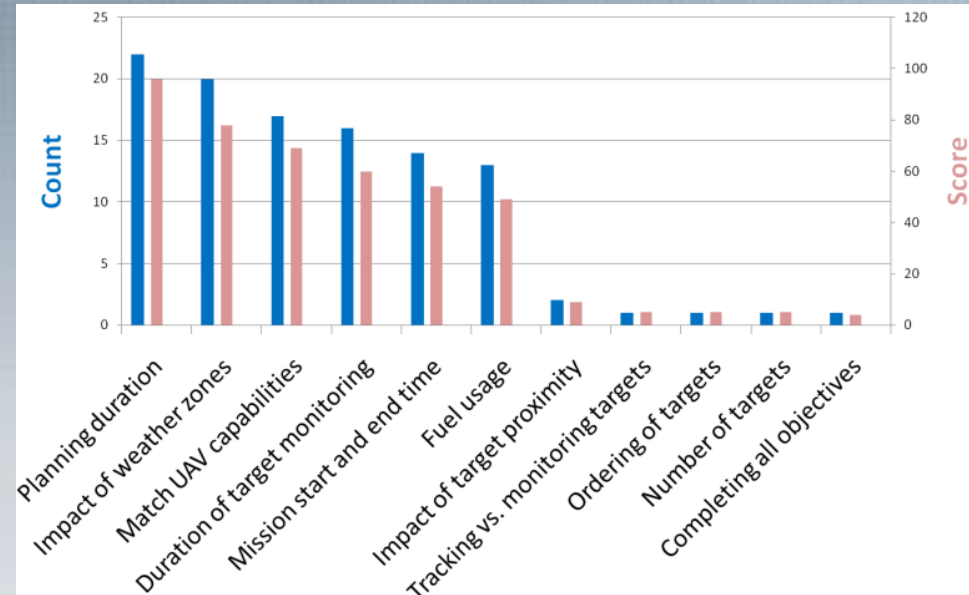
UAV	Objective	Priority	Speed (Knots)	Launch Time	ETA
BlueFireScout	Safehouse2	1	1	00:00:00	02:44:44
BlueFireScout	Warehouse1	2	1	00:00:00	08:32:16
BlueHALE	Safehouse1	1	1	00:00:00	15:27:45

Plan Errors

- BlueFireScout's speed is less than min of 2.00 knots.
- BlueFireScout's speed is less than min of 2.00 knots.
- BlueHALE's speed is less than min of 2.00 knots.
- BlueFireScout's priority 2 plan item has launch time before n

Results – Experiment 1

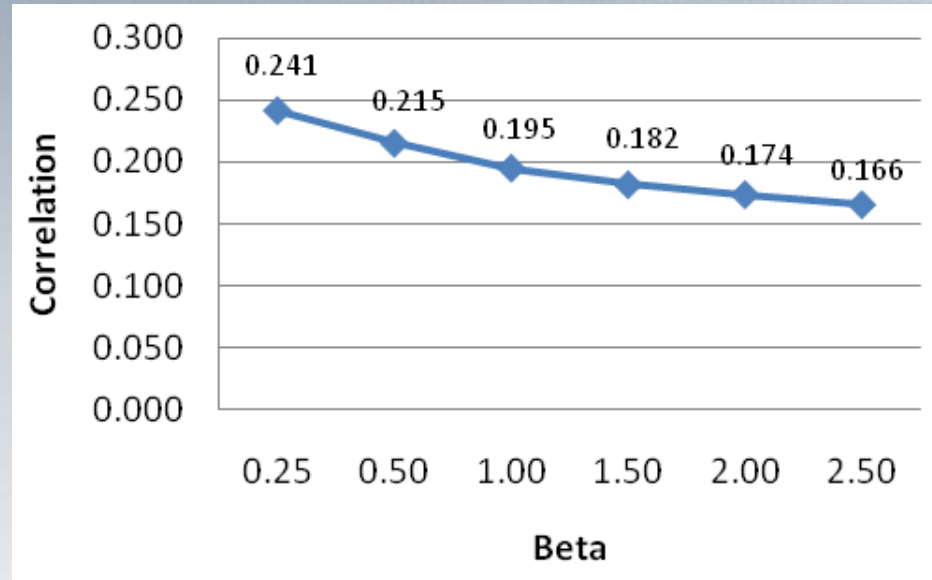
- **Measure:**
 - Identify planning priorities
- **Finding:**
 - 6 main planning constraints / priorities emerged



	Constraint	Priority	Description & Tradeoffs
1	Planning duration	Managing time pressure	Planning time is limited: the operator must trade off the complexity and accuracy of planning against completing the plan before the deadline.
2	Impact of weather zones	Avoiding weather zones	Going around weather zones might take more time than going through them. The operator must consider this trade-off in the route planning.
3	Match UAS capability	Using covertness capability	The covertness capability is not shared by all UASs; hence the operator must consider the impact of routing a covert UAS to one target on its availability to cover other targets.
4	Duration of monitoring	Routing to closer targets	The operator may assign UASs to the targets closest to them to afford more monitoring time. Doing so may involve tradeoffs with covertness or entry into dangerous weather zones.
5	Mission start and end time	Altering UAS speed	Increasing UAS speed allows for a shorter mission time, but consumes more fuel. The operator must consider this trade-off.
6	Fuel usage	Saving fuel	Saving fuel trades off against speed, flight time, weather zone avoidance.

Results – Experiment 2

- **Measure:**
 - Correlation between MIMIC-identified and operator-identified priorities
- **Finding:**
 - MIMIC achieved significant correlations with the participant rating data

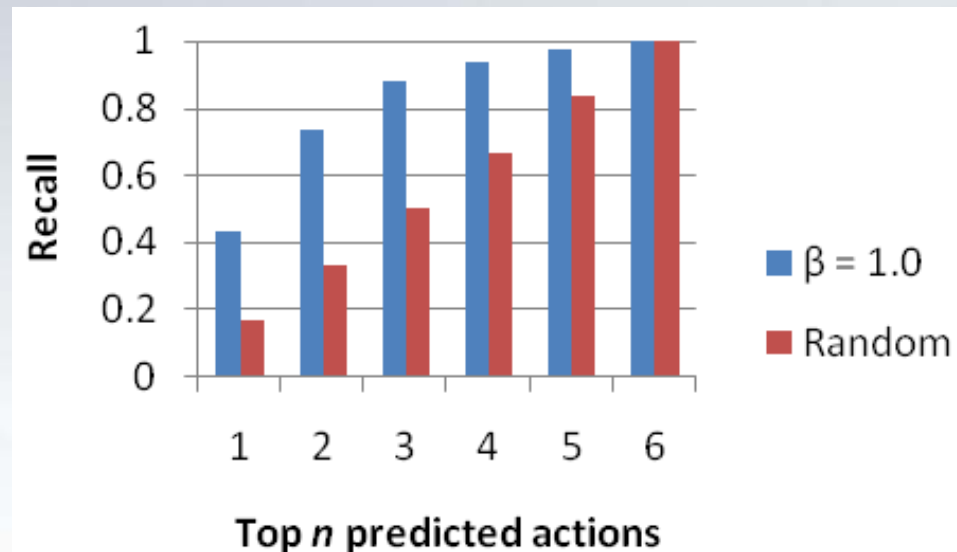


Results – Experiment 3

- **Measure:**
 - MIMIC’s prediction of an operator’s next action
- **Findings:**
 - The single goal MIMIC model is able to recover the human-coded actions at a rate far greater than chance.
 - The MIMIC model of goal-based rational planning is sufficient to predict many of the next actions of human planners in UAS mission planning scenarios.

Predictive accuracy of the single goal model with parameter $\beta = 1.0$ for different numbers of predicted actions.

	Top n predicted actions					
n	1	2	3	4	5	6
Precision	.449	.352	.263	.197	.147	.137
Recall	.434	.734	.879	.940	.976	1.0
F-score	.430	.458	.391	.316	.251	.239



Future research

- Automated support
 - Suggestions of actions
 - Auto-completion of actions
- Research goal:
 - Apply to other UAS domains
 - Cargo UASs
 - Extraction missions

The screenshot displays the UAV Planner interface. At the top, there are controls for 'MANUAL' mode, including dropdowns for UAV (BlueHALE), Objective (Safehouse1), Priority (1), Speed (Knots) (1.00), and Launch Time (H:M:S) (0:0:0). An 'Endpoint Action' dropdown is set to 'Loiter at endpoint'. A 'Submit Task' button is visible.

Below these controls is a table listing mission items:

UAV	Objective	Priority	Speed (Knots)	Launch Time	ETA
BlueFirescout	Safehouse2	1	1	00:00:00	02:44:44
BlueFirescout	Warehouse1	2	1	00:00:00	08:32:16
BlueHALE	Safehouse1	1	1	00:00:00	15:27:45

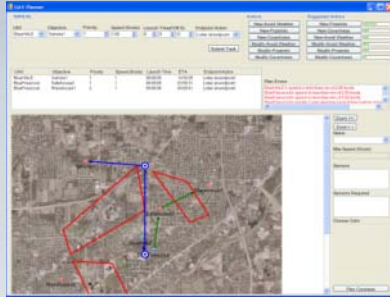
To the right of the table are 'Actions' and 'Suggested Actions' buttons, including 'New-Avoid Weather', 'New-Proximity', 'New-Covertness', 'Modifu-Avoid Weather', 'Modifu-Proximity', and 'Modifu-Covertness'. A 'Plan Errors' section shows several error messages in red text, such as 'BlueFirescout's speed is less than min of 2.00 knots'.

The main map area shows a top-down view of a terrain with various mission points marked: Safehouse1, Warehouse2, BlueHALE, BlueFirescout, Safehouse2, Warehouse1, Vehicle1, and Vehicle2. Red lines outline mission paths, and blue and green lines indicate flight paths for the UAVs.

On the right side of the map, there is a 'Zoom' panel with 'Zoom In' and 'Zoom Out' buttons, a 'Name' dropdown, 'Max Speed (Knots)' input, 'Sensors' and 'Sensors Required' text areas, and a 'Choose Color' dropdown. A 'Plan Complete' button is at the bottom right.

MIMIC Summary

Codify and improve the multi-UAS mission planning task for human operators by creating UAS teams that can recognize and adapt to operator goals and actions.

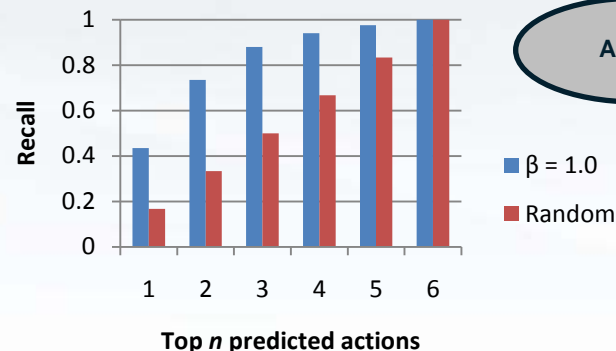
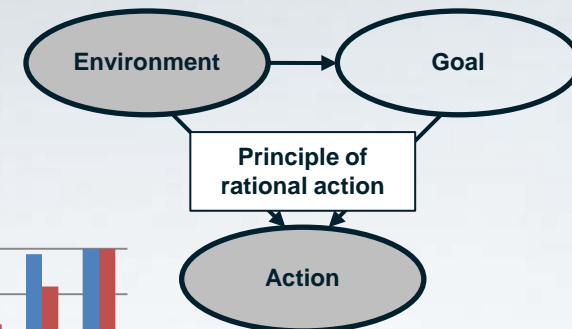


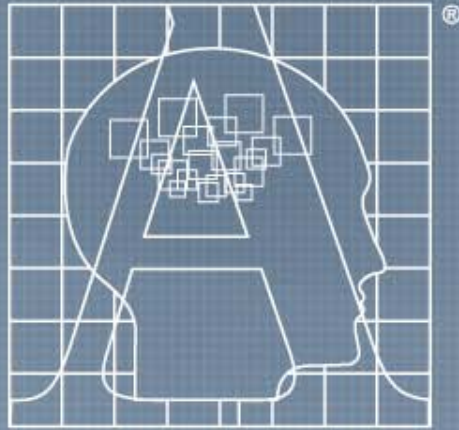
Approach

- Analyze in detail the domain of interest, including **human operator behaviors and goals**.
- Tailor the model representations to the **features of the domain** and the operator's goals.
- **Train the machine learner on human operator behavior** and fit the model's parameters and prior probabilities to experimental data.
- **Specify the causal relation between participants' planning goals and planning actions** as a Markov Decision Process (MDP).
- Leverage **Bayesian inference to invert the causal relation between goals and actions**, using observed action sequences to infer the most probable goals that gave rise to these actions.

Capabilities Provided

- Identifies UAS **mission planning strategies**
- **Elucidates common planning priorities** in simulated UAS mission planning
- **Models human UAS mission planners** as approximately rational planners
- **Characterizes operator intent in real-time** based on observed interaction with the planning interface
- **Forecasts future actions** of UAS mission planners
- Provides **real-time suggestion of planning actions** to accomplish operator intent





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