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# Autonomy Protocols: From Human Behavioral Modeling to Correct-by-Construction, Scalable Control

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## Project Objective:

**Develop scalable, automated methods for the synthesis of autonomy control protocols with provable correctness guarantees, incorporating insights from models of human behavior.**

Novel empirical and mathematical insights on how humans manage complexity
- •guide architectural exploration for effective hierarchical decompositions
- •couple control and sensing/perception

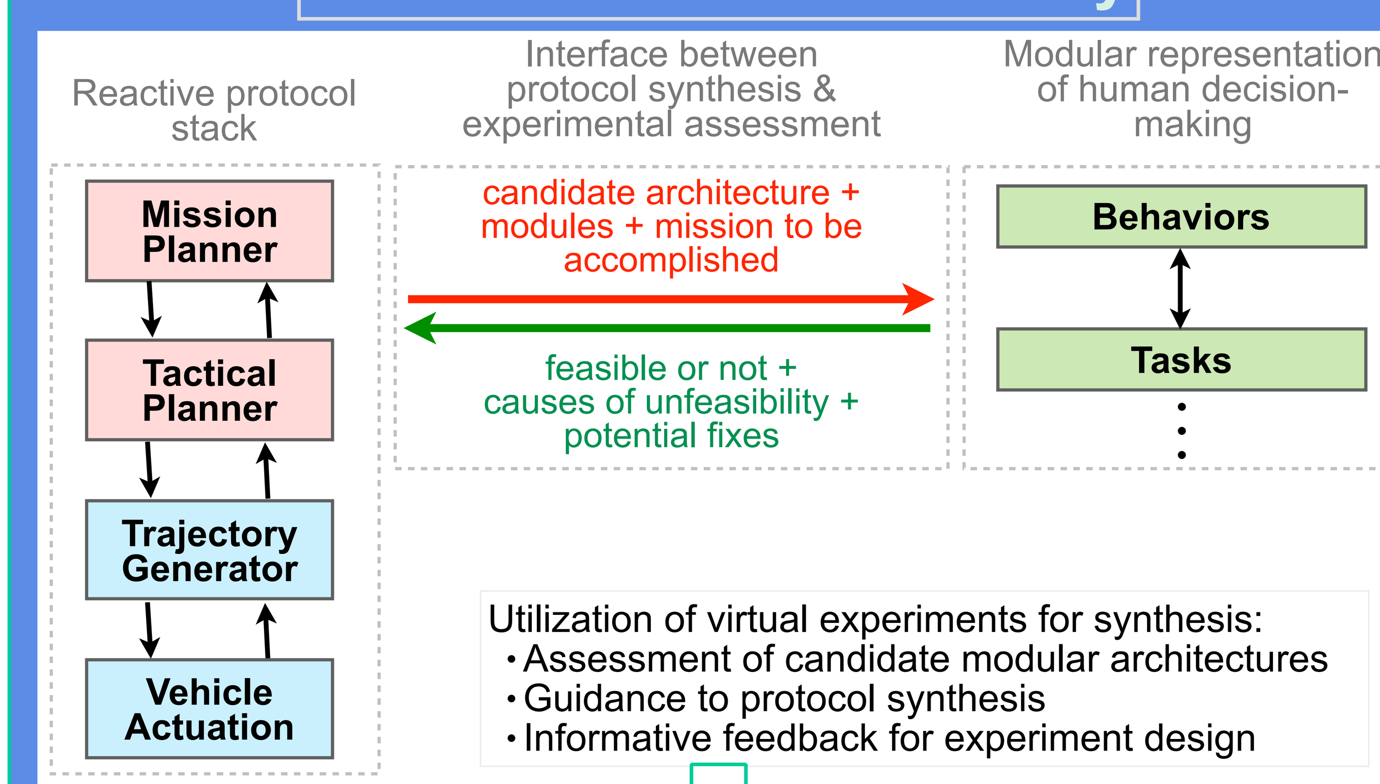
Decision-making hierarchies identified as "promising" by developing correct-by-synthesis protocols from
- •formal temporal logic specifications for verifiability
- •customized real-time solution algorithms for constrained Optimal Control Problems (**OCP**s)

## Key Observations:

- Human decision-making is observed to have a modular hierarchical decomposition
- Modular Inverse Reinforcement Learning (**RL**) provides a systematic way to model human behavior
- Temporal Logic (**TL**) based mission/tactical planning systematically ensures "correctness" of autonomy
- Real-time optimization based motion control can implement mission plans in the physical domain
- Online abstractions of constrained motion control via reachability sets provide inter-layer consistency

Merging these capabilities under a single synthesis framework can enable a leap in autonomy by
- •Significantly increasing the fidelity of models used in decision-making
- •Reducing the conservatism of the autonomy protocols without sacrificing tractability and correctness

## Human Decision Hierarchy




*How can insights from human behavior can be leveraged to manage complexity and uncertainty in autonomous decision-making?* ?

## Thrust-I: Modeling of human sensory-motor decisions and empirical assessment of the candidate decision-making architectures

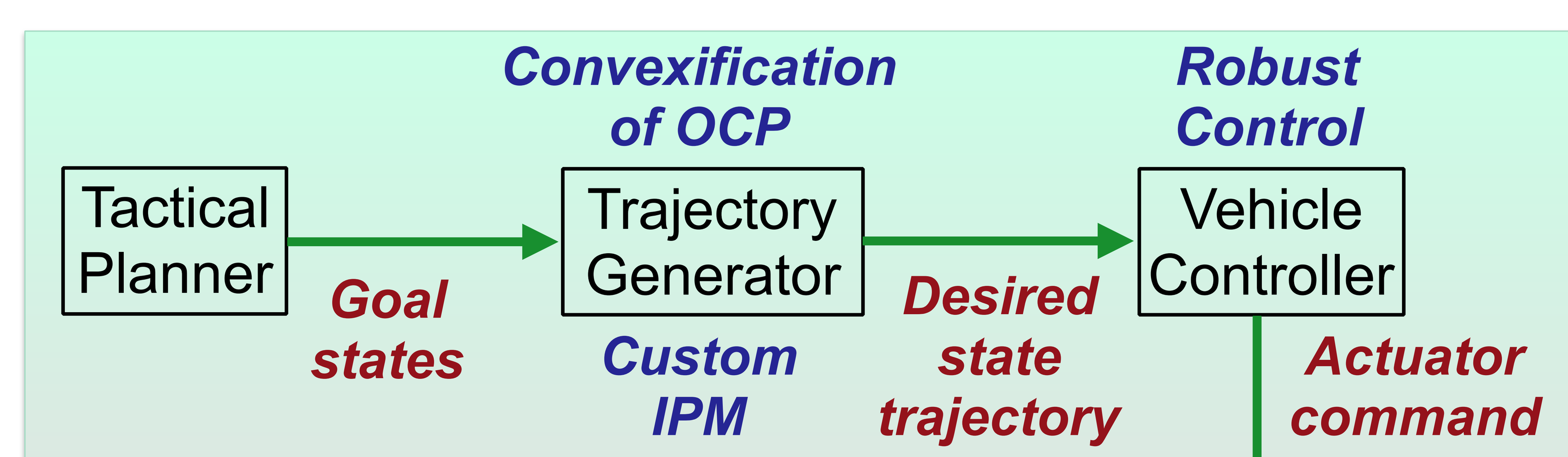
- How do humans decompose decision-making?
- How do we represent this decomposition?

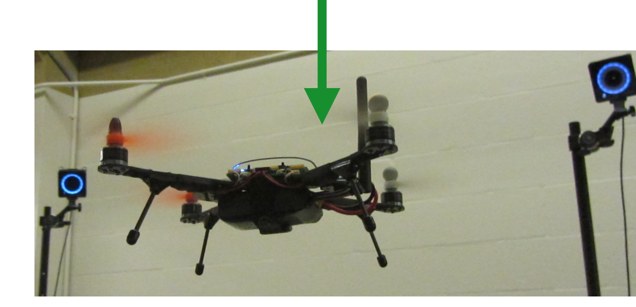

## Reliable custom IPM solvers enabling real-time convex optimization

| Method | SQP | IPM | Custom IPM |
|---|---|---|---|
| CPU time (m-secs) | 20,000 – 30,000 | 2,500 – 3,000 | 12 – 15 |
| Reliability | 75 – 80% | >99.9% | >99.9% |

## Thrust-III: Reliable run-time computational engines for motion planning and abstraction

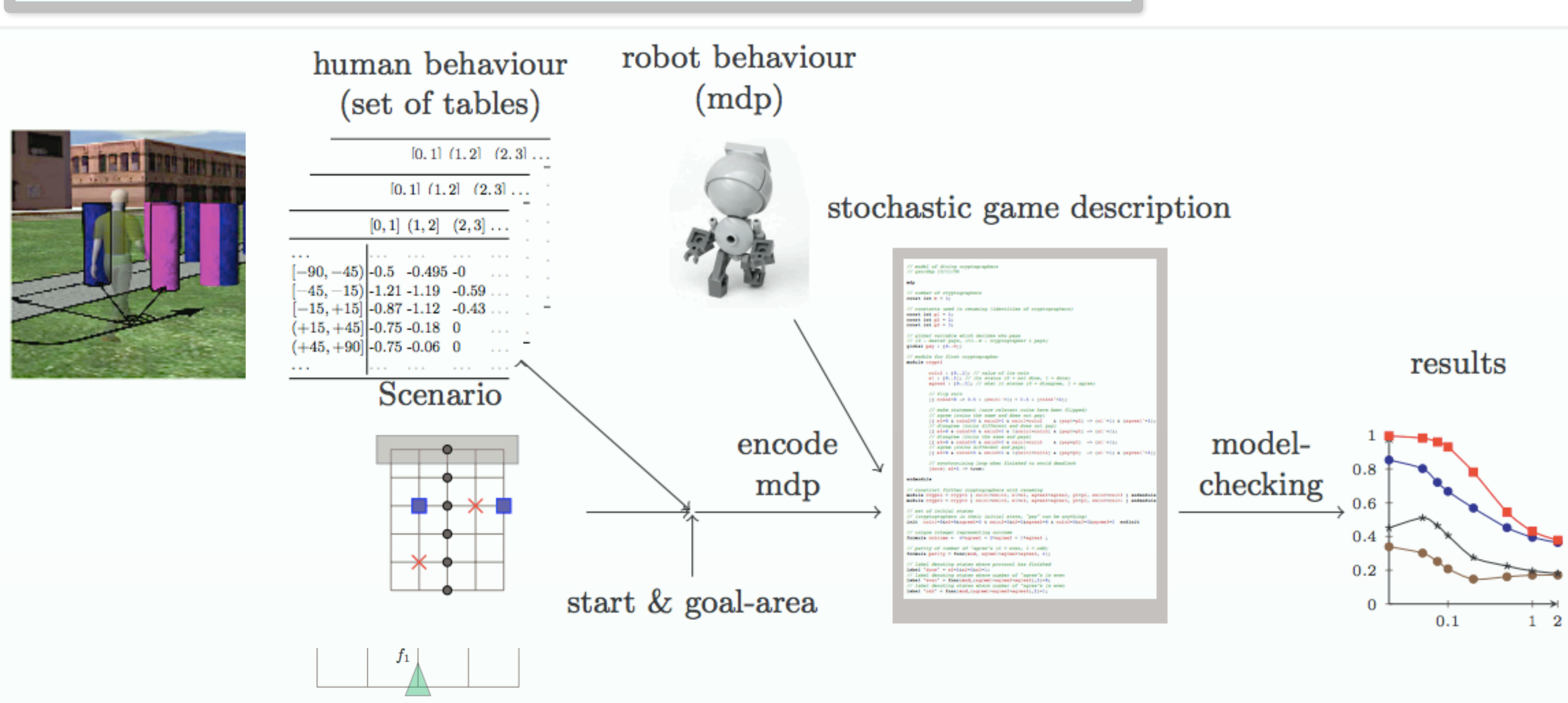
- How can we incorporate uncertainty and constraints?
- How can this process be abstracted?
- How can the computations be done in real-time?



## Thrust-II: Integrating architectural insights into decision-making

- How can synthesis problems be generated?
  - Models and constraints
  - Specifications and information flow
- How can we ensure inter-layer consistency?





## Broader Impact

- Autonomy is a capability with stand-alone applications such as UAVs
- Also embedded into numerous other instantiations of cyber-physical system

We target:
- the gap between current autonomy capabilities and the levels at which they can impact our use of resources
- the lack of systematic design methodologies toward highly capable and scalable autonomy protocols