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Incremental Learning of Action Models as HMMs over Qualitative Trajectory Representations

Motivation and Goal

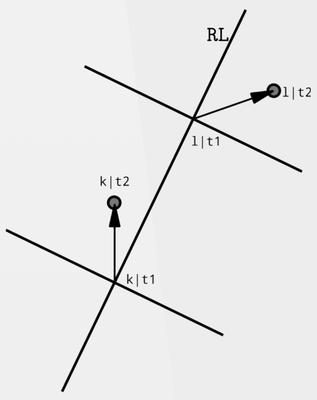
Acquiring representations or models of actions is important for many embodied intelligent systems that need to act in the world. Specifically for our purpose:

- **Action recognition** - classify action performances
- **Simulation** - forward model to project consequences
- **Clustering** - determine if two action instances belong to the same class
- **Online learning** - integrate new data incrementally and continuously

➡ Hidden Markov Model

Discretization Scheme – QTC

Discretization scheme to abstract away from raw positions and velocities. Qualitative Trajectory Calculus **QTC** [Weghe et. al.]



- Qualitative relations between moving point-objects k, l using position and direction
- 4-element state descriptor with ternary elements (-, 0, +)
- Relative to the reference line RL between object centers

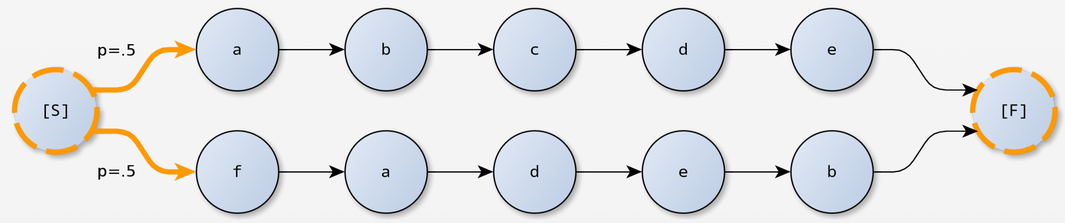
Incremental HMM Induction

We apply an incremental learning scheme utilizing the best first model merging framework [Omohundro]. The model building process is based on three basic operations:

- **Data integration -** integrates new observation sequences into existing (possibly empty) models**.**
- **State merging** - Consolidates the resulting models in a way which enables them to generalize over unseen sequences
- **Model evaluation** - Approximates how well a given model fits it's underlying dataset

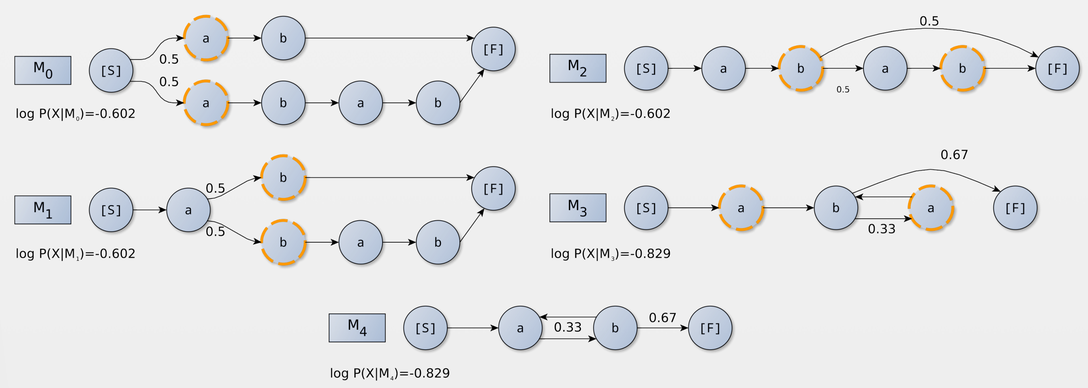
Data Integration

Formulate the new sequence which is to be integrated as maximum likelihood Markov Chain which exactly reproduces its underlying sequence and integrate it between start and end state of an existing (possibly empty) model.



State Merging

Consolidate the model in a way which allows it to generalize to yet unseen trajectories by intertwining paths corresponding to different action instances.



Model Evaluation

Evaluate the model according to a occam's razor like prior which favors simpler models and a sufficient statistics approximation how well the model fits its underlying dataset

$$P(M|X) = \lambda P(M) + (1-\lambda) P(X|M)$$

$$P(M) = e^{-|M|}$$

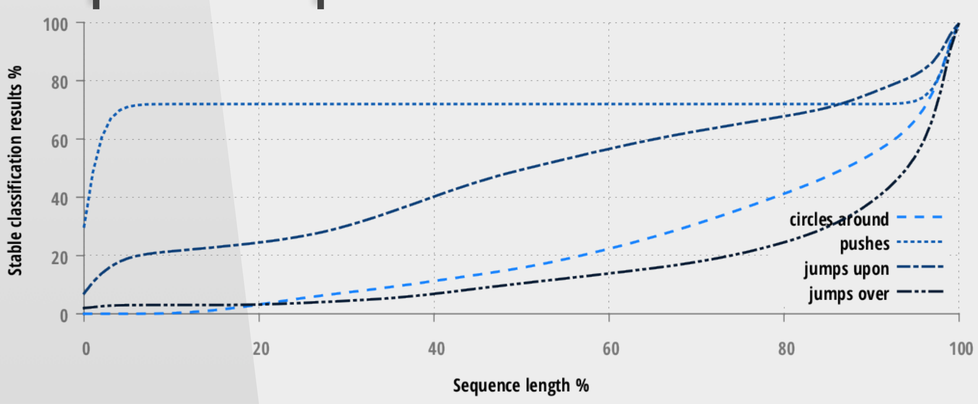
$$P(X|M) \approx \prod_{q \in Q} \left(\prod_{q' \in Q} p(q \to q')^{c(q \to q')} \prod_{\sigma \in \Sigma} p(q \uparrow \sigma)^{c(q \uparrow \sigma)} \right)$$

Results

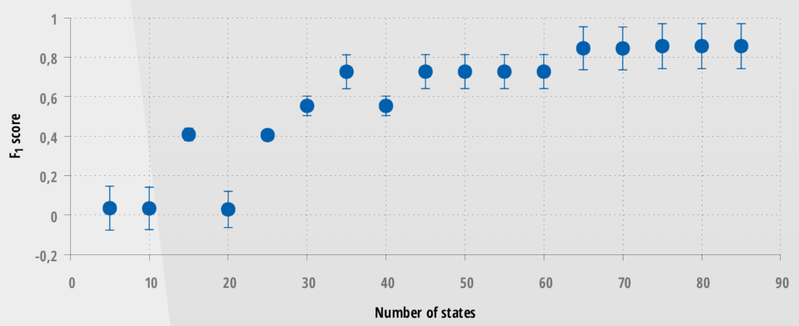
Batch vs. Online

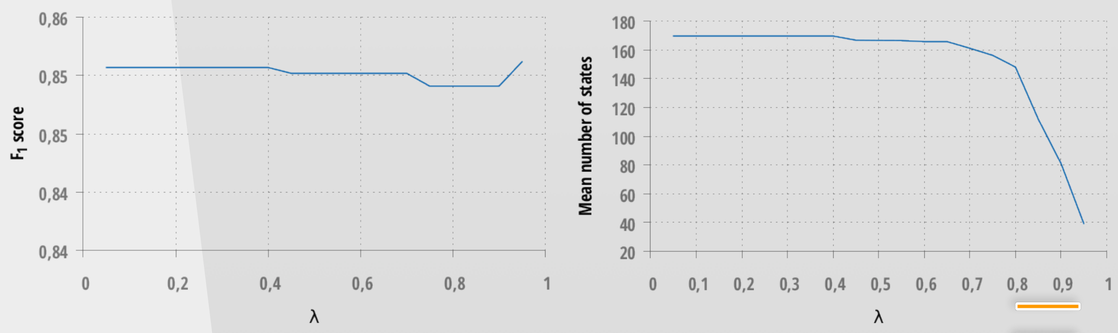
	F_1	precision	recall	σ
Batch	0.86	0.82	0.90	0.11
Incremental	0.86	0.82	0.90	0.12

Incomplete Sequences



Parameter Stability





[1]Weghe et al. (2005) · A Qualitative Trajectory Calculus and the Composition of it's Relations.
[2]Omohundro (1992) · Best-first Model Merging for Dynamic Learning and Recognition.