Hybrid Execution Models of Parameterised Actions for Explainable and Diagnosable Robot Action Execution

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Overall Objective

Increase the interpretability of robot action execution so that execution failures can be analysed - important for users so that they understand the reasons for failures, but also for robots so that they can learn from failures more effectively.

Execution Model Representation [1]

- **Execution model** represents execution-specific action knowledge
- Formally defined as $M = (R, F)$ with $R$ relational and $F$ continuous
- **Qualitative action modes** represented by a collection of relational models: $R = (R_1, \ldots, R_n)$
- Optional action constraints incorporated as inputs to $F$
- Execution parameters sampled from $F$ and verified by $R$

Relational success model $R$:
- Extracted from a predefined set of qualitative attributes
- Models semantic execution-specific knowledge
- Learned from successful execution examples

Success prediction model $F$:
- Represented by a Gaussian Process regression model [2]
- Predicts execution success given action parameters
- Learned from positive and negative execution examples

Model Generalisation Over Object Classes [3]

- **Objective**: Generalise model $M_\theta$ learned for class $o$ to another class $\tilde{o}$
- **An object ontology and generalisation trials** guide generalisation
- **Class generalisation preferences** represented in a suitability graph
- **Suitabilities** $P(\tilde{o}|\tilde{S}, S)$ defined by a distribution of the form

  $$P(\tilde{o}|\tilde{S}, S) = \sigma(\tilde{o}|o)P(S|\tilde{S}, o)P(\tilde{S}|o, S)$$

- Class $o^*$ selected for generalisation maximises the suitability over the related objects $\tilde{C}_o$:

  $$o^* = \arg \max_{\tilde{o}} P(\tilde{o}|\tilde{S}, S = 1)$$

Object similarity $\sigma(\tilde{o}|o)$:
- Guides generalisation based on relations in an ontology
- Calculated using the Wu-Palmer similarity measure [4]

Success probability $P(S|\tilde{o}, o)$:
- Represented by a Beta distribution $Beta(\alpha(o), \beta(o))$ [5]
- Posterior updated based on the generalisation outcomes

Execution Failure Diagnosis [6]

- **Failure diagnosis found as a violation of the relations in $R$**
- Violation enables finding an alternative set of corrective parameters

Violation search:
- Failed parameters perturbed until violations are found
- Perturbation done using sampling from a diagonal Gaussian

Experience correction:
- Failed parameters sampled away from region of violation
- Sampling done from a Gamma distribution

Violation search parameters and the relations in $R$ affect diagnosability

Future Work

- Automatic or lifelong learning of relations for increasing the diagnosis quality
- Extending the diagnosis framework to deal with failures propagated over time

References


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