**Introduction**

The Aim: Designing and implementing a system which can autonomously learn behaviours of the objects in the environment and the interactions among them to be able to use these objects in automated planning (Elsen & Sarar-Talay, 2012).

A suitable testbed for this aim: The Incredible Machine (TIM) computer game

- Various objects, tools and machines with different types of interactions
- Both a planning problem (solving puzzles) and a learning problem (behaviours of and interactions among the objects)

**Learning Interactions From Examples**

- **Input (Tutorials):**
  - $E$: a sequence of events on objects
  - $F$: orientational features
  - $R$: relations among the objects
  - $K$: a knowledge base
  - spatial information
  - temporal information
  - spatio-temporal information

- **Output:**
  - Finite state machines (FSM): LOCM + change of orientation
  - Conditional connections among these FSMs: interactions among objects

**System Overview:**

- A sequence of events $E$ + orientational features $F$ + relations among objects $R$ + a knowledge base $K$ + spatial information + temporal information = spatio-temporal information

**An Example Tutorial**

- $E_1$: push_down(ball, switch)
- $E_2$: start(motor)
- $E_3$: spin(cre, conveyorbelt)
- $E_4$: slide(cre, conveyorbelt)
- $E_5$: slide_left(ball)
- $E_6$:竺ament(cre, conveyorbelt)
- $E_7$: light(light1, flashlight)
- $E_8$: front_left(motor)
- $E_9$: hit(ball, toasta)
- $E_{10}$: activate(resumecontroller)
- $E_{11}$: make_toast(motor)
- $E_{12}$: blow(appliance, toaster)
- $E_{13}$: lower(base)
- $E_{14}$: start(motor, mandrilmotor)

**Phase-1: Creating FSMs Reflecting Behaviors**

LOCM (Cresswell et al., 2009) is used to group objects with respect to their types and model their behaviors with FSMs:

- Each argument of the same type of action contains objects of the same sort (e.g., motor and motor in $E_2$ and $E_3$)
- Each event causes a transition for each object in its arguments (continuity of transitions such as $E_2$ and $E_3$ on ball)

A modification to address change of behaviors due to different orientations:

**Phase-2: Modeling Interactions Through Relations**

**Using a Knowledge Base**

- A knowledge base modeling directly observable relations

**Using Spatial Locality of Objects**

- Input: minimum bounding RMB(s) of objects

**Using Temporal Locality of Events**

- Input: starting time of events

**Spatio-Temporal Reasoning**

Spatial and temporal approaches have pros and cons. In human-level learning, both spatial and temporal information is used to integrate spatial information into temporal approach.

**Experimental Evaluation**

**Planning Experiments:**

- 12 TIM puzzles
  - Success rate: ratio of correctly chosen actions place, flip, connect with bolt and connect with rope (91.8%) for knowledge-based approach, 83.6% for spatio-temporal approach

**References**


