Decision Diagrams As Plans: Answering Observation-Grounded Queries

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Overview

Given:
A query about the situation in the world, whose answer is 'Yes' or 'No'.

A world model with knowledge about objects in the world and situations that may occur.

Find:
A branching observation plan that resolves the query with minimal worst-case execution cost.

Main Ideas

Represent world models, queries, and plans using ordered reduced binary decision diagrams.

Compute an output-conditioned product of the world model and the query.

Apply variations of Rudell's sifting algorithm to improve the variable ordering, indirectly optimizing execution cost.

Example Queries

Query 0
Are there any paintings on exhibit?
\[ \exists x:\text{painting}(x) \]

Query 1
Is Warhol's Marilyn Diptych on exhibit in location 15?
\[ \text{marilyn-diptych}(\text{loc15}) \]

Query 2
Is Marilyn on exhibit in some L-shaped room?
\[ \forall x: \text{marilyn-diptych}(x) \Rightarrow \neg \text{ell-shaped}(x) \]

Query 3
Is any art by Yinka Shonibare on display?
\[ \exists x: \text{yinka-shonibare}(x) \]

Query 4
Marilyn in location 15 and Yinka anywhere at all?
\[ \exists x: \text{marilyn-diptych}(x) \land \text{yinka-shonibare}(x) \land \text{loc15}(x) \]

Query 5
Are the sculptures in corner or non-L-shaped rooms?
\[ \forall x: \text{sculpture}(x) \Rightarrow (\neg \text{ell-shaped}(x) \lor \text{corner}(x)) \]

Query 6
Any sculptures in non-L-shaped rooms?
\[ \exists x: \text{sculpture}(x) \land \neg \text{ell-shaped}(x) \]

Algorithms

Generate and evaluate swaps within the BDD variable ordering.
Alg. 1: Rudell's algorithm [Rudell, ICCAD 1993], reducing the BDD size.
Alg. 2: Rudell's algorithm but with execution cost.
Alg. 3: Shift entire blocks of variables tied to a single location.
Alg. 4: Alg. 3, then Alg. 1 within blocks.
Alg. 5: Alg. 1 within blocks, then Alg. 3.
Repeat until timeout or convergence.

Computed Plans

Two plans for Query 1, optimized for different starting locations.

Efficient plans for Queries 3, 4, and 5 respectively.

Evaluation

This material is based upon work supported by the National Science Foundation under grants IIS-1659514, IIS-1849249, and IIS-1849291.
Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

Acknowledgement

Computer Science and Engineering
Texas A&M University