Conformant Planners: Approximations vs. Representation

Son Thanh To, Vien Dang Tran, Khoi Hoang Nguyen, Tran Cao Son, Enrico Pontelli

Computer Science Department
New Mexico State University, Las Cruces, NM 88003
Conformant Planning Problem

- **Given**: planning problem \( P = \langle F, O, I, G \rangle \) where
  - \( F \) is a set of propositions
  - \( O \) is a set of operators
  - \( I \) is the initial state – often incomplete
  - \( G \) is the goal
- **Problem**: Computing a plan that achieves \( G \) from all possible initial states of the world satisfying \( I \)
Goal, Motivated Questions, and Facts

- **Goal**: develop state-of-the-art conformant planners
- **Motivated questions**:
  - How does the definition of a progression function influence the performance of a conformant planner?
  - How does the representation of belief states influence the performance of a conformant planner?
- **Motivated facts**:
  - \( \text{CpA}^\text{PH} \), an *approximation-based conformant planner*, uses an incomplete progression function & a compact belief state representation performs very well in its first implementation
  - \( \text{CpA}^\text{PH} \) differs from all of its counterparts when it was introduced
  - \( \text{CpA}^\text{PH} \) needs complete initial belief state in benchmark problems with disjunctive information about the initial state
Considerations in Conformant Planners

- How to encode a belief state? Many possibilities
  - OBDD
  - DNF
  - CNF
  - ...
  each might have its own desirable properties (e.g. minimal)

- How to progress? By a function $\Phi$
  - Given an action $a$ and a belief state $S$ in the corresponding representation, compute the belief state $U$ resulting from executing $a$ in $S$, written as $U = \Phi(a, S)$
  - Certain operations on a representation might lead to a formula which no longer satisfies the desirable properties and require some overhead after the computation (e.g., updating minimal CNF might not result in a minimal CNF)
Main Characteristics of CpA

- Approximation-based progression function
- Encoding of belief state enable easy computation of successor belief state
- Search for plan in the space of $3^n$ partial states instead of the space of $2^{2n}$ belief states as most other conformant planners (for problems with conjunction of literals as initial state)
- Maintain completeness through special reasoning technique
  - CpA incurs significant overhead in the computation of the representation of the initial belief state
  - CpA uses DNF-formulae to encode belief states and can potentially require a lot of memory
- CpA uses a combination of the cardinality and the number of satisfied subgoals heuristic as its heuristic function
Main Characteristics of DNF

- A middle-ground between approximation and complete reasoning
- Search for plan in the space of $2^{2n}$ belief states
- Use **minimal** DNF-formulae to represent belief states, also enable **easy** computation of successor belief state
- Progression function defined over minimal DNF-formulae
  - DNF incurs overhead for the transformation of successor belief state into minimal DNF-formulae
- DNF uses a combination of the cardinality, the number of satisfied subgoals, and the square distance to the goal heuristic as its heuristic function
Main Characteristics of CNF

- Search for plan in the space of $2^{2n}$ belief states
- Use **minimal** CNF-formulae to represent belief states, a departure of easy computation of successor belief state
- Progression function defined over minimal CNF-formulae
  - CNF also incurs overhead for the transformation of successor belief state into minimal CNF-formulae
- CNF uses the number of satisfied subgoals as its heuristic function
Simplification Techniques for Scalability and Performance

- Forward reachability: eliminating redundant actions and propositions
- Goal relevance: identifying necessary information in the initial belief state to guarantee completeness
- Goal splitting: divide-and-conquer using subgoals
- Oneof-combination: reducing the size of the initial belief state
- Oneof-relaxation: replacing mutual exclusive or by disjunctive or

**Overall Structure**

Input Problem PDDL → Static Analyzer → Simplified Problem AL → Planners CPA, DNF, CNF → Solution
If a problem $P$ contains a subgoal whose truth value cannot be negated by the actions used to reach the other goals, then the problem can be decomposed into a sequence of smaller problems.

- Improve scalability.
Simplification Techniques: oneof-combination

- If actions and propositions in different oneof's have no interaction then we do not need to consider all possible permutations of the oneof's.
- Reducing the size of the initial belief state
- Improve scalability
- Suitable for DNF and CpA
Simplification Techniques: \texttt{oneof}-relaxation

- If actions and propositions in an \texttt{oneof}-clause satisfy certain properties then an \texttt{oneof}-clause can be replaced by an \texttt{or}-clause.
- Increasing the size of the initial belief state.
- Improve scalability.
- Suitable for CNF.

\[
\text{Original Initial State} \quad \begin{cases} \text{ONEOF} \ (A_1, A_2) \\ \text{ONEOF} \ (B_1, B_2) \end{cases} \quad \equiv \quad \begin{cases} (A_1, B_1), \\ (A_1, B_2), \\ (A_2, B_1), \\ (A_2, B_2) \end{cases} \quad \Rightarrow \quad \begin{cases} \text{or}(A_1, A_2), \\ \text{or}(B_1, B_2) \end{cases} \\
\text{Initial State After Relaxation} \quad \begin{cases} \text{or}(A_1, A_2), \\ \text{or}(B_1, B_2) \end{cases}
\]
Conclusions

- Presentation of three conformant planners: CpA, DNF, and CNF
- There exists no “one size fits all” representation for all domains
- The choice of belief state representation impacts
  - performance of conformant planner
  - choice of simplification techniques
  - algorithm for computing successor belief state
A Sample Run – CpA - Preprocessor

Translating from PDDL to Prolog

Prolog Representation of PDDL (segment)

```
trannew[1029]  ; clear
trannew[1030]  ; pwd
/home/trannew/CoG/TestCpA_H/coins
trannew[1031]  ; ./parser pr0i.pddl > trash
trannew[1032]  ; more pddl2pl.pl

:- use_module(library(lists)).
:- dynamic executable/2.
:- dynamic cpa_executable/2.
:- dynamic causes/3.
:- dynamic cpa_causes/3.

%%%% Objects %%%
cpa_elevator(cpa_e0).
cpa_elevator(cpa_e1).
cpa_floor(cpa_f0).
cpa_floor(cpa_f1).
cpa_pos(cpa_p0).
cpa_pos(cpa_p1).
cpa_coin(cpa_c0).
cpa_coin(cpa_c1).

%%%% Constants %%%

%%%% Types rules %%%

%%%% Predicates %%%
```
Calling the Preprocessor

```
% compiling /home/tranl/tsen/IPC08/TestCPA_H/coins/prob.pl...
% loading /local/sicstus-3.12.2/lib/sicstus-3.12.2/library/lists.po...
% module lists imported into user
% loaded /local/sicstus-3.12.2/lib/sicstus-3.12.2/library/lists.po in module lists, 0 msec 13696 bytes
% loading /local/sicstus-3.12.2/lib/sicstus-3.12.2/library/ordsets.po...
% module ordsets imported into user
% loaded /local/sicstus-3.12.2/lib/sicstus-3.12.2/library/ordsets.po in module ordsets, 0 msec 13912 bytes
NAME CLASH: remove_duplicates/2 is already imported into module user from module lists
Do you really want to override this definition with the one in user? (y, n, p, s, a, b, or ?) y
* [NewFluents] - singleton variables in user:create_independent_theories/3
* Approximate lines: 581-589, file: '/home/tranl/tsen/IPC08/TestCPA_H/coins/prob.pl'
* [NewFluents] - singleton variables in user:create_dependent_theories/3
* Approximate lines: 590-596, file: '/home/tranl/tsen/IPC08/TestCPA_H/coins/prob.pl'
* [NI] - singleton variables in user:compose_in/4
* Approximate lines: 946-953, file: '/home/tranl/tsen/IPC08/TestCPA_H/coins/prob.pl'
NAME CLASH: remove_duplicates/2 is already defined in module user
Do you really want to override this definition with the one in lists? (y, n, p, s, a, b, or ?) y
% compiled /home/tranl/tsen/IPC08/TestCPA_H/coins/prob.pl in module user, 200 ms
```

Connected to trannew.cs.nmsu.edu

3:trannew.cs.nmsu.edu - MyLinux - SSH Secure Shell

POSTER TEMPLATE BY: www.PosterPresentations.com
Output of the Preprocessor

First theory in AL

Goal Splitting
Calling the planner

Plan

```
% goal state

goal  cpa_have(cpa_c0);
trannew[1039]% ..../cpa
  cpa*  cpa+bfs+card* cpa+bfs+rgp* cpa.pddl2pl
  cpa** cpa+bfs+gc* cpa+dfs
trannew[1039]% ..../cpa+bfs+gc theory_names
0
```

Statistic

```
ll cpa_go_down(cpa_e0,cpa_f1,cpa_f0) cpa_go_up(cpa_e1,cpa_f0,cpa_f1) cpa_step_in
  (cpa_e0,cpa_f0,cpa_p0) cpa_go_up(cpa_e0,cpa_f0,cpa_f1) cpa_step_out(cpa_e0,cpa_f1,
  cpa_p0) cpa_collect(cpa_c0,cpa_f1,cpa_p0) cpa_move_right|cpa_f1,cpa_p0,cpa_pl)
  cpa_collect(cpa_c0,cpa_f1,cpa_pl) cpa_collect(cpa_c1,cpa_f1,cpa_pl) cpa_move_left
  (cpa_f1,cpa_pl,cpa_p0) cpa_collect(cpa_c1,cpa_f1,cpa_pl)
%
linear 12 0 1 2 3 4 5 6 7 8 9 10
STATISTICS
----------------------
Total time: 0.011 (sec)
  Reading: 0.002 (sec) [17.37 %]
  Preprocessing: 0.001 (sec) [9.63 %]
  Search: 0.008 (sec) [73.01 %]
Total states allocated: 0
Total cstate(s): 0
Total cstate(s) remaining in the queue: 0
trannew[1040]% 
```

Connected to trannew.cs.nmsu.edu  SSH2 - aes128-cbc - hmac-md5 - none 80x27