Game Applications of HTN Planning with State Variables

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Introduction and Outline

- I’ve done lots of research in two areas
  - AI planning
  - games and game theory
- But mostly as separate topics
  - Many incompatibilities, difficult to combine

- But:
  - Workshop last year on AI and games
  - Most of the participants were doing research on video games
  - A lot of them were using planning algorithms

- I’ll talk about
  - Incompatibilities
  - Ways to fix some of them
# Planning Versus Games

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- Lots of incompatibilities
  - Some easy to fix, some more difficult
Using Planning in Games

- *Approximate* some part of the game as a planning problem
  - Develop a *special-purpose* planner for that problem
  - Use it as a subroutine

- I’ll discuss some examples that involve HTN planning
  - But first, a description of how HTN planning works
HTN Planning

• Motivation
  » For some planning problems, we may already have ideas for how to look for solutions

• Example: travel to a destination that's far away:
  » Brute-force search:
    • Many ways to combine vehicles and routes
  » Experienced human: small number of “recipes”
    • e.g., flying:
      1. buy ticket from local airport to remote airport
      2. travel to local airport
      3. fly to remote airport
      4. travel to final destination
  » HTN planners use such recipes to generate the search space

• Ingredients
  » states, tasks, operators, methods, planning algorithm
States and Tasks

- **State**: description of the current situation
  - I’m at home, I have €20, there’s a park 8 km away

- **Task**: description of an activity to perform
  - Travel to the park

- **Two kinds of tasks**
  - *Primitive* task: a task that corresponds to a basic action
  - *Compound* task: a task that is composed of other simpler tasks
Operators

- Operators: parameterized descriptions of what the basic actions do

  » *walk* from location $x$ to location $y$
    - Precond: agent is at $x$
    - Effects: agent is at $y$
  
  » *call taxi* to location $x$
    - Precond: (none)
    - Effects: taxi is at $x$
  
  » *ride taxi* from location $x$ to location $y$
    - Precond: agent and taxi are at $x$
    - Effects: agent and taxi at $y$, agent owes $1.50 + \frac{1}{2} \text{distance}(x,y)$
  
  » *pay driver*
    - Precond: agent owes amount of money $r$, agent has money $m \geq r$
    - Effects: agent owes nothing, agent has money $m - r$

- Actions: operators with arguments
Methods

- Method: parameterized description of a possible way to perform a compound task by performing a collection of subtasks
- There may be more than one method for the same task

- **travel by foot** from $x$ to $y$
  - Task: travel from $x$ to $y$
  - Precond: agent is at $x$, distance to $y$ is $\leq 4$ km
  - Subtasks: walk from $x$ to $y$

- **travel by taxi** from $x$ to $y$
  - Task: travel from $x$ to $y$
  - Precond: agent is at $x$, agent has money $\geq 1.5 + \frac{1}{2} \text{distance}(x,y)$
  - Subtasks: call taxi to $x$,
    ride taxi from $x$ to $y$,
    pay driver
Simple Travel-Planning Problem

- Left-to-right backtracking search (SHOP)

### Travel by Taxi

**Precond:**
- ✔️ I’m at home
- ✔️ I have ≥ €5.50

**Effects:**
- I owe nothing
- Taxi is at the park

### Travel by Foot

**Precond:**
- ✔️ I’m at home
- ✗ home to park ≤ 4 km

**Effects:**
- Backtrack

### Initial state

- I’m at home
- I have €20
- home to park is 8 km

### Final state

- I’m at the park
- I have €14.50
- home to park is 8 km
- I owe nothing
- Taxi is at the park
SHOP and SHOP2

- SHOP and SHOP2:
  - HTN planning systems
  - SHOP2 an award in the AIPS-2002 Planning Competition

- Freeware, open source
  - Downloaded more than 20,000 times
  - Used in many hundreds of projects worldwide
    - Government labs, industry, academia
Bridge

- Ideal: game-tree search (all lines of play) to compute expected utilities
- Don’t know what cards other players have
  - Many moves they might be able to make
    - worst case about $6 \times 10^{44}$ leaf nodes
    - average case about $10^{24}$ leaf nodes
- About 1½ minutes available

*Not enough time – need smaller tree*

- **Bridge Baron**
  - 1997 world champion of computer bridge
- Special-purpose HTN planner that generates game trees
  - Branches $\Leftrightarrow$ standard bridge card plays (finesse, ruff, cash out, …)
  - Much smaller game tree: can search it and compute expected utilities
- **Why it worked:**
  - Special-purpose planner to generate trees rather than linear plans
  - Lots of work to make the HTN methods as complete as possible
Special-purpose HTN planner for planning at the squad level
- Method and operator syntax similar to SHOP’s and SHOP2’s
- Quickly generates a linear plan that would work if nothing interferes
- Replan several times per second as the world changes

Why it worked:
- Very different objective from a bridge tournament
- Don’t want to look for the best possible play
- Need actions that appear believable and consistent to human users
- Need them very quickly
These incompatibilities are easy to fix

» Instead of logical propositions, use state variables

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Propositions Versus State Variables

Classical representation:
- State: set of propositions
  - Actions add/delete them

PDDL is based on this

Propositions as state variables:
- Unstack:\(unstack(x,y)\)
  - Precond: \(on(x,y), clear(x), handempty\)
  - Effects: \(\neg on(x,y), \neg clear(x), clear(y), holding(x), \neg handempty\)

State-variable representation:
- State: variable bindings
  - Actions change the values

Same expressive power

More compatible with conventional computer programming

Reason is largely historical
- AI planning evolved out of AI theorem proving
Pyhop

- A simple HTN planner written in Python
  - Works in both Python 2.7 and 3.2

- Planning algorithm is like the one in SHOP

- Main differences:
  - HTN operators and methods are ordinary Python functions
  - The current state is a Python object that contains variable bindings
    - Operators and methods refer to states explicitly
    - To say \( c \) is on \( a \), write \( s.loc['c'] = 'a' \) where \( s \) is the current state

- Easy to implement and understand
  - Less than 150 lines of code

- Open-source software, Apache license
  - [http://bitbucket.org/dananau/pyhop](http://bitbucket.org/dananau/pyhop)
Travel-Planning Methods

**Travel by foot** from \(x\) to \(y\)

- Task: travel from \(x\) to \(y\)
- Precond: agent is at \(x\), distance to \(y\) is \(\leq 4\) km
- Subtasks: walk from \(x\) to \(y\)

```python
def travel_by_foot(state,a,x,y):
    if state.dist[x][y] <= 4:
        return [('walk',a,x,y)]
    return False
```

**Travel by taxi** from \(x\) to \(y\)

- Task: travel from \(x\) to \(y\)
- Precond: agent is at \(x\), agent has money \(\geq 1.5 + \frac{1}{2} \text{distance}(x,y)\)
- Subtasks: call taxi to \(x\), ride taxi from \(x\) to \(y\), pay driver

```python
def travel_by_taxi(state,a,x,y):
    if state.cash[a] >= 1.5 + 0.5 * state.dist[x][y]:
        return [('call_taxi',a,x),
                ('ride_taxi',a,x,y),
                ('pay_driver',a,x,y)]
    return False
```

```
declare_methods('travel',travel_by_foot,travel_by_taxi)
```
**Travel-Planning Operators (1)**

**walk** from \(x\) to \(y\)
- Precond: agent is at location \(x\)
- Effects: agent is at location \(y\)

```python
def walk(state, a, x, y):
    if state.loc[a] == x:
        state.loc[a] = y
        return state
    else: return False
```

**call taxi** to location \(x\)
- Precond: (none)
- Effects: taxi is at location \(x\)

```python
def call_taxi(state, a, x):
    state.loc['taxi'] = x
    return state
```
**Travel-Planning Operators (2)**

**ride taxi** from $x$ to $y$

- Precond: agent and taxi are at $x$
- Effects: agent and taxi are at $y$, agent owes $1.5 + \frac{1}{2}$ distance($x,y$)

```python
def ride_taxi(state,a,x,y):
    if state.loc['taxi']==x and state.loc[a]==x:
        state.loc['taxi'] = y
        state.loc[a] = y
        state.owe[a] = 1.5 + 0.5*state.dist[x][y]
        return state
    else: return False
```

**pay driver**

- Precond: agent owes money, and has at least as much as what’s owed
- Effects: agent owes nothing, agent’s money reduced by what was owed

```python
def pay_driver(state,a):
    if state.cash[a] >= state.owe[a]:
        state.cash[a] = state.cash[a] - state.owe[a]
        state.owe[a] = 0
        return state
    else: return False
```

declare_operators(walk, call_taxi, ride_taxi, pay_driver)
Travel Planning Problem

Initial state: I’m at home, I have €20, there’s a park 8 km away

state1 = State('state1')
state1.loc = {'me':'home'}
state1.cash = {'me':20}
state1.owe = {'me':0}
state1.dist = {'home':{'park':8}, 'park':{'home':8}}

Task: travel to the park

# Invoke the planner
pyhop(state1,[(‘travel’,’me’,’home’,’park’)])

Solution plan: call taxi, ride taxi from home to park, pay driver

[(‘call_taxi’, ’me’, ’home’),
 (‘ride_taxi’, ’me’, ’home’, ’park’),
 (‘pay_driver’, ’me’)]
Planning Versus Games

- Pyhop resolves these incompatibilities

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- Are there general solutions for these?
  » Or do they need to be game-specific?
Summary

- State-variable representation makes it easier to integrate planning into ordinary programming

- Pyhop is an HTN planner that does this
  - Written in Python
  - Simple algorithm, easy to understand
  - Open source (Apache license)
  - Downloadable at [http://bitbucket.org/dananau/pyhop](http://bitbucket.org/dananau/pyhop)

- I hope some of you will find it useful
  - If you use it, please let me know
  - I hope some of you will post enhancements

- Resolves some of the incompatibilities between AI planning and games
  - But not all of them
  - How best to resolve the others?