Getting from Here to There: Interactive Planning and Agent Execution for Optimizing Travel

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Fetch Technologies
Outline

Introduction:
  Travel Planning
  Information Integration, Planning & Monitoring

The Travel Assistant

Technologies:
  Integration: Hierarchical Constraint Networks
    → Heracles
  Information-Gathering and Monitoring Agents
    → Theseus

Related Work, Future Work, Conclusions
Travel Planning

Parking Costs

<table>
<thead>
<tr>
<th>Area</th>
<th>First hour</th>
<th>Per hour</th>
<th>Daily rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short Term (hourly)</td>
<td>$3</td>
<td>$4</td>
<td>$27</td>
</tr>
<tr>
<td>Daily (general)</td>
<td>$5</td>
<td>$5</td>
<td>$10</td>
</tr>
<tr>
<td>Long Term (economy)</td>
<td>$1</td>
<td>$1</td>
<td>$5</td>
</tr>
<tr>
<td>Valet</td>
<td>-</td>
<td>-</td>
<td>$25*</td>
</tr>
</tbody>
</table>

* $12 per day after the first day.
Information Integration, Planning and Monitoring

Problem:

Need information in support of a particular task
  Travel planning
Many sources, hard to find, painful to use, and difficult to integrate
  Flights, Hotels, Car rentals, Airport parking, Weather ...
Gather information efficiently
  Given dates, query flights and hotels in parallel
Evaluate and choose among different actions
  Fly, rent a car, drive own car, or take a taxi?
Monitor and react to events that affect plan
  Fare changes, flight delays, ...
Information Integration, Planning and Monitoring

**Solution:** Framework for building information and planning assistants, domain-specific applications that extract and integrate data for a given task.

Two underlying technologies:

**Heracles:** Hierarchical constraint planner
- Organizes information
- Decides what sources to query
- Integrates results
- Evaluates and suggests courses of action

**Theseus:** Efficient dataflow plan execution
- Information-gathering agents
- Monitoring agents
## The Travel Assistant

### Round Trip

**Meeting**
- **Subject**: Travel Planner Meeting
- **Location**: DC
- **Date**: Apr 19, 2002
- **Time**: 11:30 AM

**Leaving From**
- **Address**: 2700 University Park, Los Angeles, CA

**Traveling To**
- **Address**: 1120 19th ST NW, Washington, DC

**Outbound Mode**
- **Fly**

**Hotel**
# Supports Informed Choices

## Fly

### From
- 2700 University Park
- Street: 
- City: Los Angeles
- State: CA

### To
- 1120 19th ST NW
- Street: 
- City: Washington
- State: DC

### Getting to Airport

<table>
<thead>
<tr>
<th>Mode to Airport</th>
<th>Distance</th>
<th>Taxi fare</th>
</tr>
</thead>
<tbody>
<tr>
<td>Take a Taxi</td>
<td>12.7</td>
<td>19.50</td>
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</tbody>
</table>

### Parking

<table>
<thead>
<tr>
<th>Lot</th>
<th>Daily Rate (dollars)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>24.00</td>
</tr>
<tr>
<td></td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>48</td>
</tr>
</tbody>
</table>

### Taxi

<table>
<thead>
<tr>
<th>Distance</th>
<th>Taxi fare</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.7</td>
<td>19.50</td>
</tr>
</tbody>
</table>

### Itinerary

<table>
<thead>
<tr>
<th>LAX</th>
<th>IAD</th>
<th>Apr</th>
<th>Day</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>19</td>
<td></td>
</tr>
</tbody>
</table>
## Monitoring Travel Plans

### Monitoring Tasks

<table>
<thead>
<tr>
<th>Monitor Flight Status</th>
<th>Monitor Flights</th>
<th>7038128516</th>
<th>Notify Hotel (Fax)</th>
<th>7034948462</th>
<th>Notify Car Rental Counter (Fax)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outbound flight 1</td>
<td>Active</td>
<td>Outbound flight 2</td>
<td>Active</td>
<td>Inbound flight 1</td>
<td>Active</td>
</tr>
<tr>
<td>Monitor Flight Schedule</td>
<td>Monitor Schedule</td>
<td>Active</td>
<td>Status</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monitor Earlier Flights</td>
<td>Monitor Earlier Flights</td>
<td>Active</td>
<td>Status</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monitor Connecting Flights</td>
<td>Monitor Connecting Flights</td>
<td>Active</td>
<td>Status (Outbound)</td>
<td>Active</td>
<td>Status (Inbound)</td>
</tr>
<tr>
<td>Monitor Airfare</td>
<td>Monitor Airfare</td>
<td>Decrease only</td>
<td>Mode</td>
<td>Airfare</td>
<td>Active</td>
</tr>
</tbody>
</table>
Monitoring Agents

Flight-Status Agent:

Flight delayed message:
Your United Airlines flight 190 has been delayed. It was originally scheduled to depart at 11:45 AM and is now scheduled to depart at 12:30 PM. The new arrival time is 7:59 PM.

Flight cancelled message:
Your Delta Air Lines flight 200 has been cancelled.

Fax to hotel message:
Attention: Registration Desk
I am sending this message on behalf of David Pynadath, who has a reservation at your hotel. David Pynadath is on United Airlines 190, which is now scheduled to arrive at IAD at 7:59 PM. Since the flight will be arriving late, I would like to request that you indicate this in the reservation so that the room is not given away.
Monitoring Agents

Airfare Agent: Airfare dropped message
The airfare for your American Airlines itinerary (IAD - LAX) dropped to $281.

Earlier-Flight Agent: Earlier flights message
The status of your currently scheduled flight is:
# 190 LAX (11:45 AM) - IAD (7:29 PM) 45 minutes Late
If you would like to return earlier, the following United Airlines flights will arrive earlier than your scheduled flights:
# 946 LAX (8:31 AM) - IAD (3:35 PM) 11 minutes Late
# 388 LAX (9:25 AM) - DEN (12:25 PM) 10 minutes Late
# 1534 DEN (1:20 PM) - IAD (6:06 PM) On Time
Heracles: Constraint Networks for Managing Information

Hierarchical Constraint Reasoning System
Organizes and integrates information
Decides when to launch data requests
Evaluates constraints
Propagates information
Computes preferences
All run as asynchronous processes to support the user
Constraint Network: Drive or Taxi?

- DepartureDate: Mar 15, 2001
- ReturnDate: Mar 18, 2001
- DestinationAddress
- OriginAddress
- DepartureAirport: LAX
- Distance: 15.1 miles
- Duration: 4 days
- TaxiFare: $23.00
- ParkingRate: $16.00/day
- ParkingTotal: $64.00
- ModeToAirport: Taxi

The network computes the duration, parking total, and taxi fare based on the given dates and origin/destination addresses.
Theseus

A plan language and execution system for building Web-based information-gathering and monitoring agents

Efficient enough for near-real-time monitoring: streaming dataflow

Expressive enough for integrating a variety of sources (web sites, XML, databases, …)
Live Access to Web Sources

HTML sources turned into queryable XML

Wrapper

<YAHOO_WEATHER>
  - <ROW>
    <TEMP>25</TEMP>
    <OUTLOOK>Sunny</OUTLOOK>
    <HI>32</HI>
    <LO>19</LO>
    <APPARTEMP>25</APPARTEMP>
    <HUMIDITY>35%</HUMIDITY>
    <WIND>E/10 km/h</WIND>
    <VISIBILITY>20 km</VISIBILITY>
    <DEWPOINT>9</DEWPOINT>
    <BAROMETER>959 mb</BAROMETER>
  </ROW>
</YAHOO_WEATHER>
Machine Learning for Constructing Wrappers

Yahoo! Weather - Beijing

Weather > Asia > China > Beijing

Today

-3° Mostly Cloudy at: 10:00pm GMT
Hi 3° LO -11°

Wind Chill: -2°
Humidity: 80%
Wind: NE/3 km/h
Visibility: 6 km
Dewpoint: -6°
Barometer: 1022.00 mb

Records & Averages

Current conditions and forecasts provided by Weathernews Inc.

<table>
<thead>
<tr>
<th>Node Name</th>
<th>Rule Type</th>
<th>Rule Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>temp</td>
<td>Extract:</td>
<td>Begin_Rule [0] <em>FE</em> _<strong>ST</strong> 2 &quot; face = &quot; Arial &quot; &gt; &lt;br&gt;   &lt;b&gt;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>End_Rule     [1] <em>FE</em> _<strong>ST</strong> °</td>
</tr>
<tr>
<td>outlook</td>
<td>Extract:</td>
<td>Begin_Rule [0] <em>FE</em> _<strong>ST</strong> &gt; &lt;BR&gt; &lt;BR&gt; &lt;font size = &quot; -2 &quot; face = &quot; arial &quot; &gt;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>End_Rule</td>
</tr>
</tbody>
</table>

Project: weather; Site: yahoo | Markup samples and train. Created on 2/16/2001
Theseus Information Agent: Orbitz Plan

Recursive plan to collect all flights from Orbitz

**ORBITZ-AGENT**
- Search criteria
- Orbitz Wrapper
- Next_URL
- Initial_Flights
- GET_FLIGHTS
- Flights

**GET_FLIGHTS**
- Next_URL
- Null?
- More_Flights
- Union
- Flights
- Flights_In
- true
- false
Theseus: Efficiency Streaming Dataflow

Dataflow-style execution

Operators execute when inputs become available

Optimizes *horizontal parallelism*

- Plan is as parallel as its data dependencies allow

Data Streaming

Data in the system represented as *relations*

- Producer operators pipeline *tuples* to consumers

Optimizes *vertical parallelism*

- Multiple operators can work on same relation concurrently
Theseus: Expressivity Plan Language (I)

Basic relational-style operators
Select, Project, Join, Union, …

Operators for gathering Web data
Wrapper
- Database-like access to a Web source
XQuery, Rel2Xml, and Xml2Rel
- Enables better integration with XML sources

Operators for monitoring Web data
DbExport, DbQuery, DbAppend, DbUpdate
- Facilitates the tracking of online data
Email, Phone, Fax
- Facilitates asynchronous notification
Theseus: Expressivity
Plan Language (II)

Operators for extensibility
Apply: single-row functions
• Ex: arithmetic, string ops, user-defined functions, …
Aggregate: multi-row functions (ex: SUM)

Operators for conditional plan execution
Null: Tests and routes data accordingly

Subplans and recursion
Plans are named and have INPUT & OUTPUT
• Can be operators in other plans \(\rightarrow\) subplans
Subplans make recursion possible
• Ex: “next page” links
Subplans encourage modularity & reuse
Theseus Monitoring Agent: Flight Status Plan

flight #
connecting flight #

WRAPPER ITN

WRAPPER Timezone

DBQUERY SELECT old_depart

COMPARE
|old_depart - curr_depart| > threshold

EMAIL user@isi.edu

EMAIL user@isi.edu

DBQUERY
UPDATE old_depart=curr_depart

FAX Hotel

FAX Car rental agency

SCHEDULE Flight-connection agent

SCHEDULE
Arrive > 5 PM

UNSCHEDULE
Related Work

Commercial Tools
- MyTrip XTRA Online
- I:OFAI (Faltings) [Torrens 2002]
- Airline flight reminders

Electric Elves [Chalupsky et al 2002]

Heracles
- Dynamic constraint satisfaction [Mittal & Falkenhainer 1990]
- Planning as dynamic CSP [Kambhampati 2000]
- Interactive constraint satisfaction [Lamma et al. 1999]
- Constraint logic programming applied to information integration [Bressan & Goh 1997]

Theseus
- Network query engines: Tukwila [Ives et al. 1999], Niagara [Naughton et al. 2001], Telegraph [Hellerstein et al. 2000]
- General agent executors: RAPS [Firby94], PRS [Myers96]
Discussion

The Travel Assistant:
- Interactive, real-time, efficient travel planning
- Monitors travel plans

General framework for building information, planning, and monitoring assistants

Heracles:
- Hierarchical Constraint Network
- Mixed-Initiative GUI

Theseus:
- Information gathering and monitoring agents
- Expressive plan language
- Efficient dataflow execution