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

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Fetch Technologies

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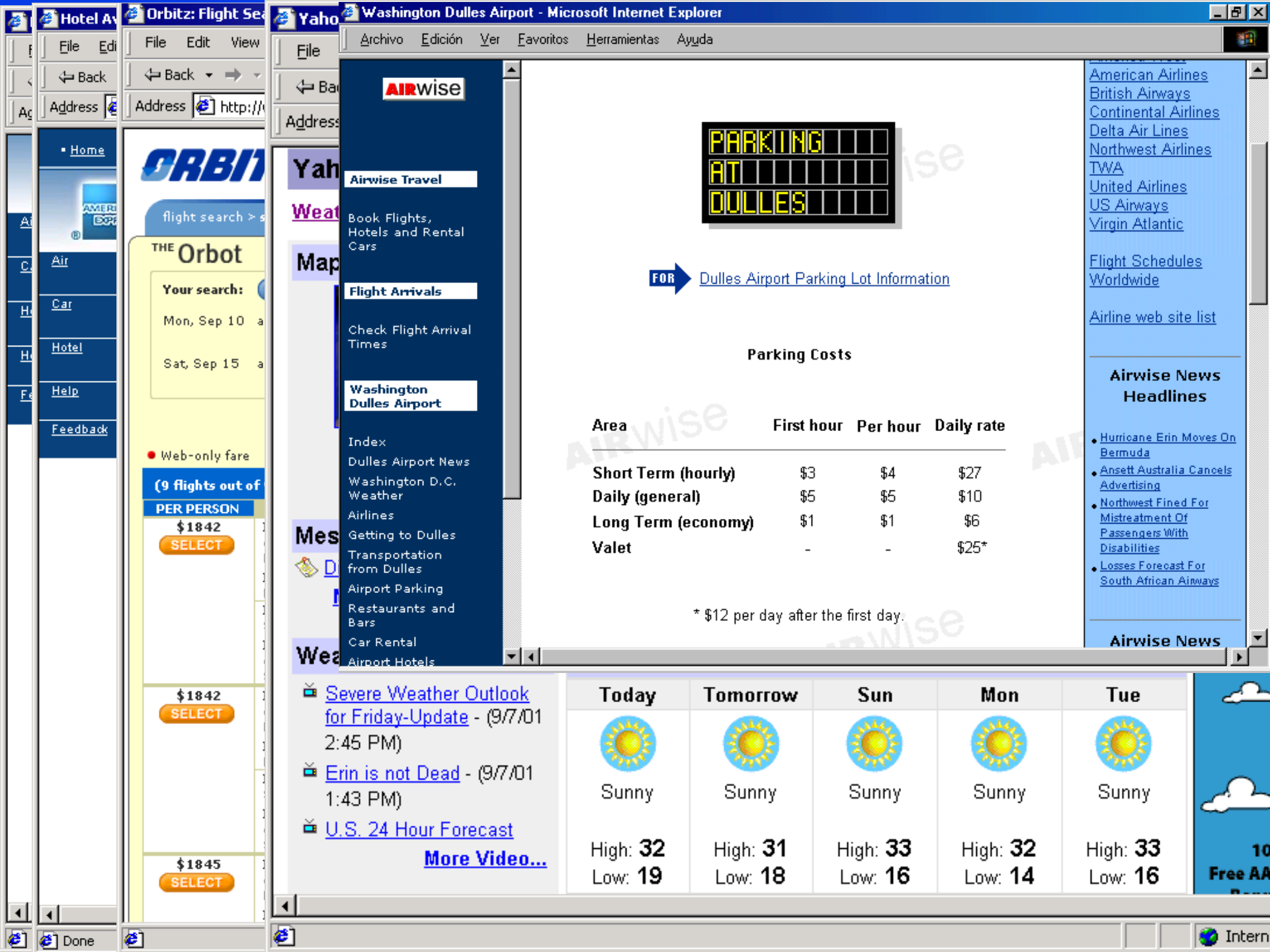
Outline

- 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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Severe Weather Outlook for Friday-Update - (9/7/01 2:45 PM)
Erin is not Dead - (9/7/01 1:43 PM)
U.S. 24 Hour Forecast
More Video...
Washington Dulles Airport - Microsoft Internet Explorer
Archivo Edición Ver Favoritos Herramientas Ayuda
AIRwise
Airwise Travel
Book Flights, Hotels and Rental Cars
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Dulles Airport News
Washington D.C. Weather
Airlines
Getting to Dulles
Transportation from Dulles
Airport Parking
Restaurants and Bars
Car Rental
Airport Hotels
PARKING AT DULLES
FOR Dulles Airport Parking Lot Information
Parking Costs
Area First hour Per hour Daily rate
Short Term (hourly) $3 $4 $27
Daily (general) $5 $5 $10
Long Term (economy) $1 $1 $6
Valet - - $25*
* $12 per day after the first day.
American Airlines
British Airways
Continental Airlines
Delta Air Lines
Northwest Airlines
TWA
United Airlines
US Airways
Virgin Atlantic
Flight Schedules Worldwide
Airline web site list
Airwise News Headlines
Hurricane Erin Moves On Bermuda
Ansett Australia Cancels Advertising
Northwest Fined For Mistreatment Of Passengers With Disabilities
Losses Forecast For South African Airways
Airwise News
Today Tomorrow Sun Mon Tue
Sunny Sunny Sunny Sunny Sunny
High: 32 Low: 19
High: 31 Low: 18
High: 33 Low: 16
High: 32 Low: 14
High: 33 Low: 16
Free AA
Done
Intern

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, …

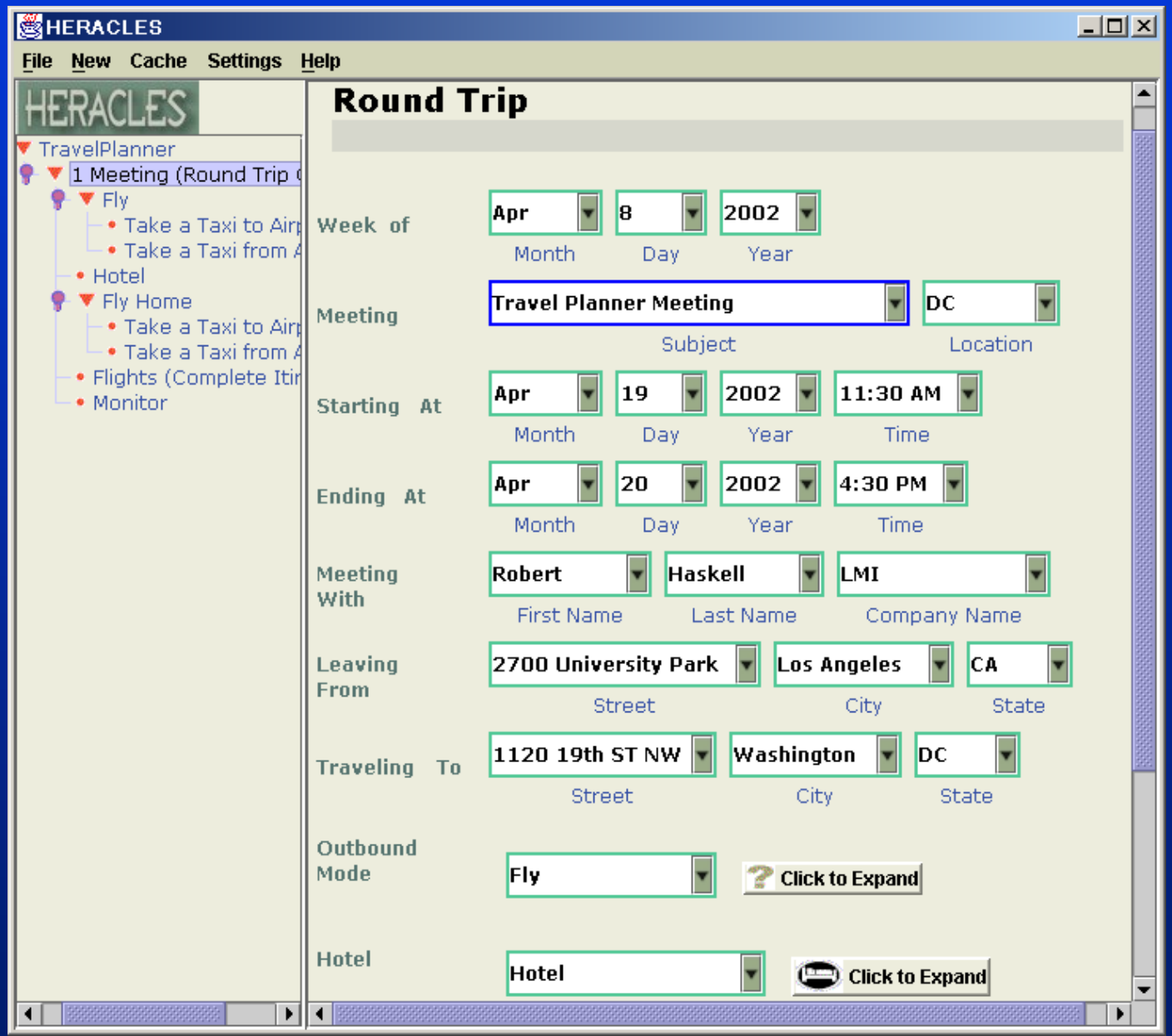
Information Integration, Planning and Monitoring

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

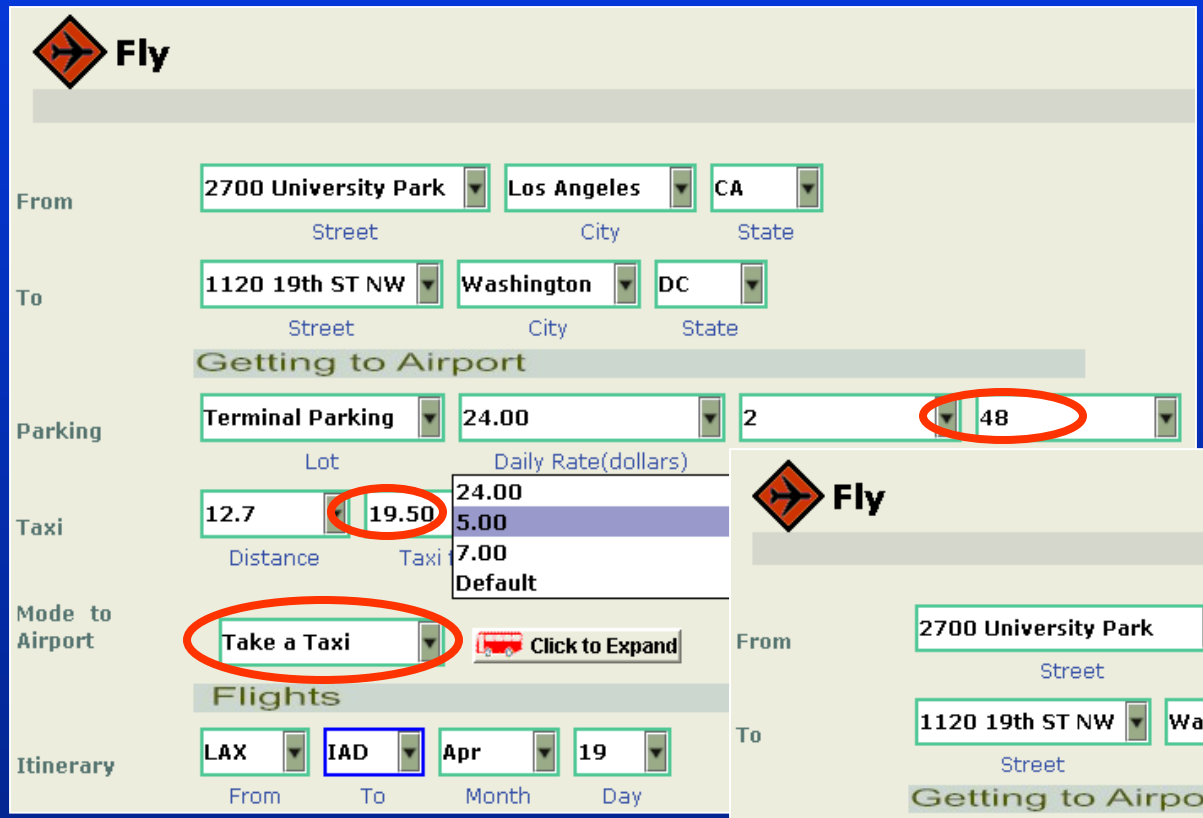
Two underlying technologies:

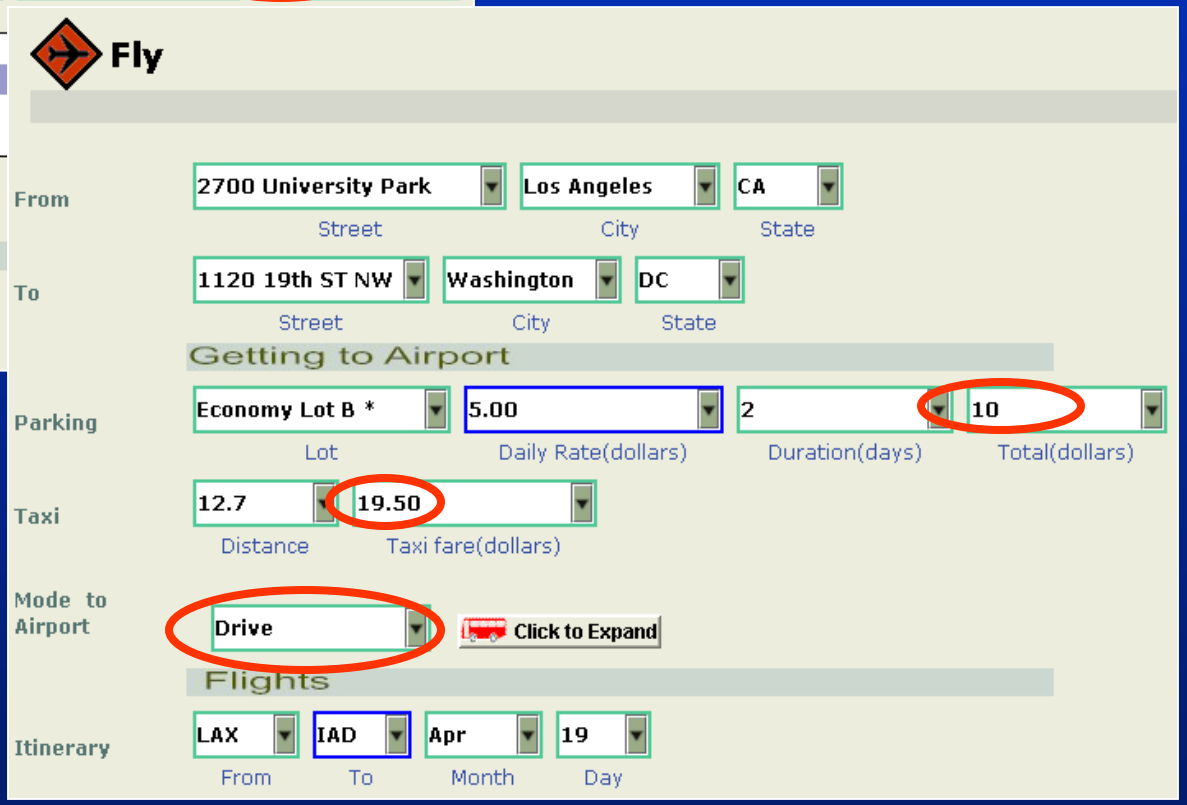
- **Heracles:** Hierarchical constraint planner
  - Organizes information
  - Decides what sources to query
  - Integrates results
  - Evaluates and suggests courses of action
- **Theseus:** Efficient dataflow plan execution
  - Information-gathering agents
  - Monitoring agents

The Travel Assistant



Supports Informed Choices





Changes Propagate Throughout

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Round Trip Flights

Preference: Lowest Price

Departs: LAX (Code) — Los Angeles, CA (City, State)

Returns: Wash, DC/Dulles, (City, State)

Price

Outbound Flight 1: lines (Airline) — 192 (Flight) — 11:55 PM (Depart) — 7:36 AM (Arrive)

LAX
BUR
LGB
SNA
ONT
BFL
SAN
Default

Taxi

Leaving From: 2700 University Park (St.) — Los An

Driving To: LAX (St.) — Los Angeles (City) — CA (Sta)

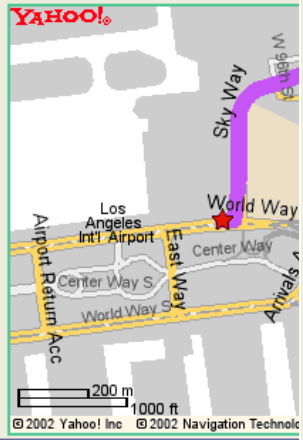
Suggested Departure: Apr (Month) — 18 (Day) — 2002 (Year)

Predicted Arrival: Apr (Month) — 18 (Day) — 2002 (Year) — 10:55 PM (Time)

Taxi fare: 19.50

Total Drive: 12.7 (DistYahoo) — 0 (Hrs4) — 24 (Mins)

Maps



Taxi

Leaving From: 2700 University Park (St.) — Los Angeles (City) — CA (State)

Driving To: LGB (St.) — Los Angeles (City) — CA (State)

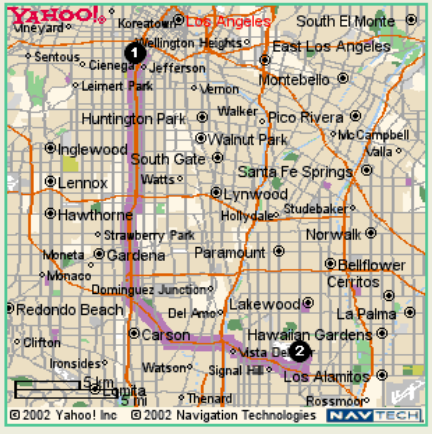
Suggested Departure: Apr (Month) — 18 (Day) — 2002 (Year) — 08:22 PM (Time)

Predicted Arrival: Apr (Month) — 18 (Day) — 2002 (Year) — 08:50 PM (Time)

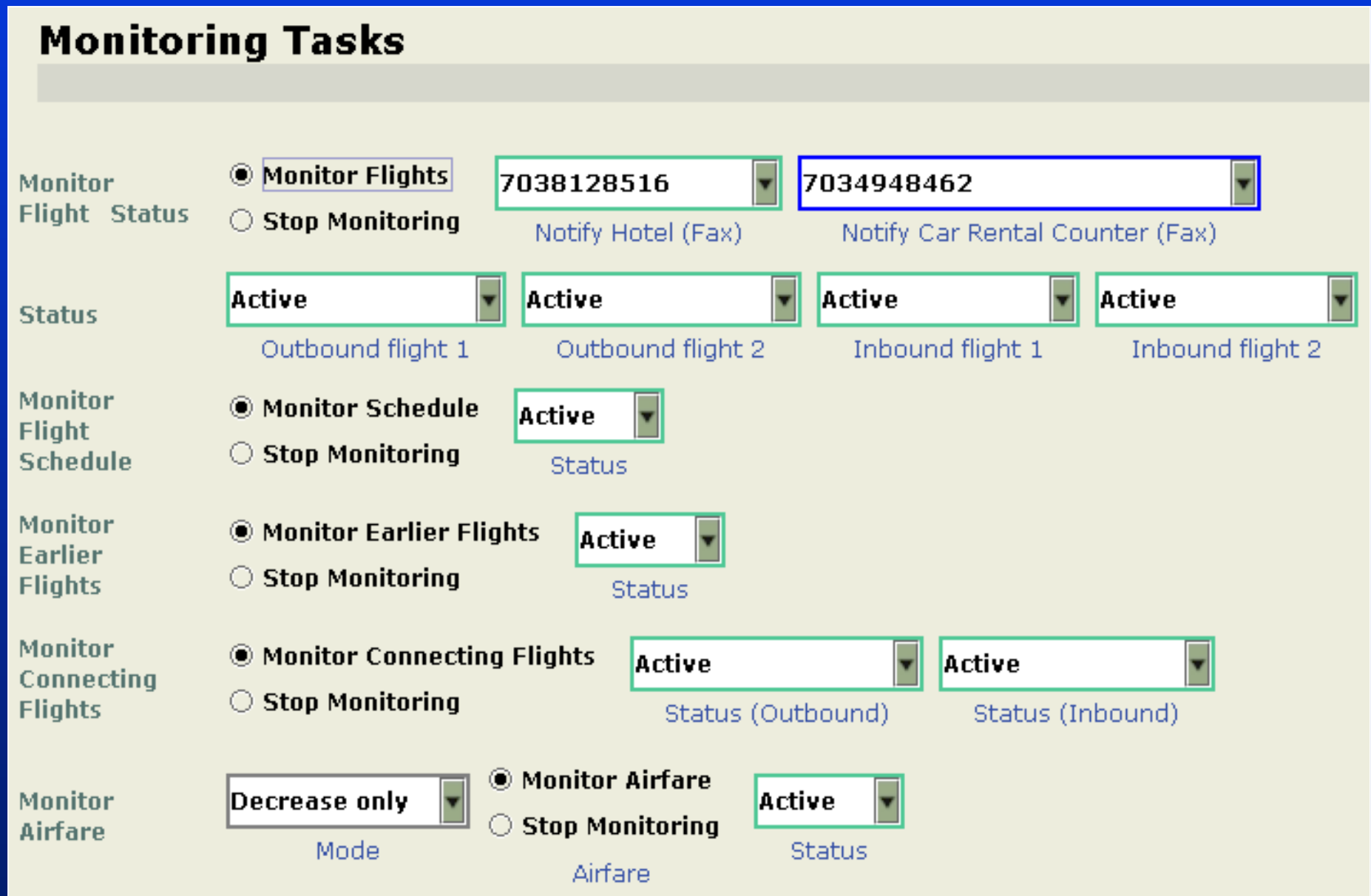
Taxi fare: 34.20

Total Drive: 23.3 (DistYahoo) — 0 (Hrs4) — 28 (Mins)

Maps



Monitoring Travel Plans



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

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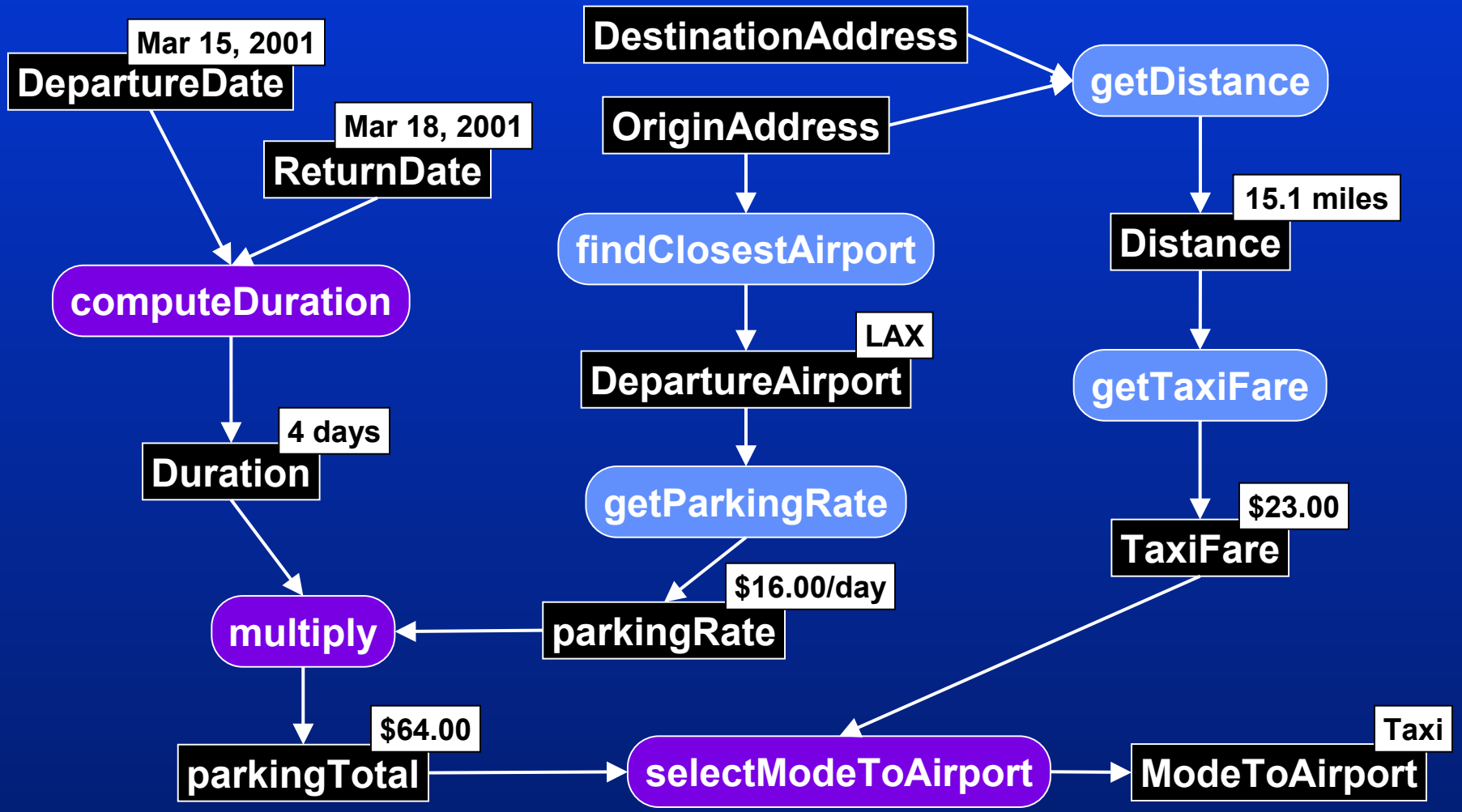
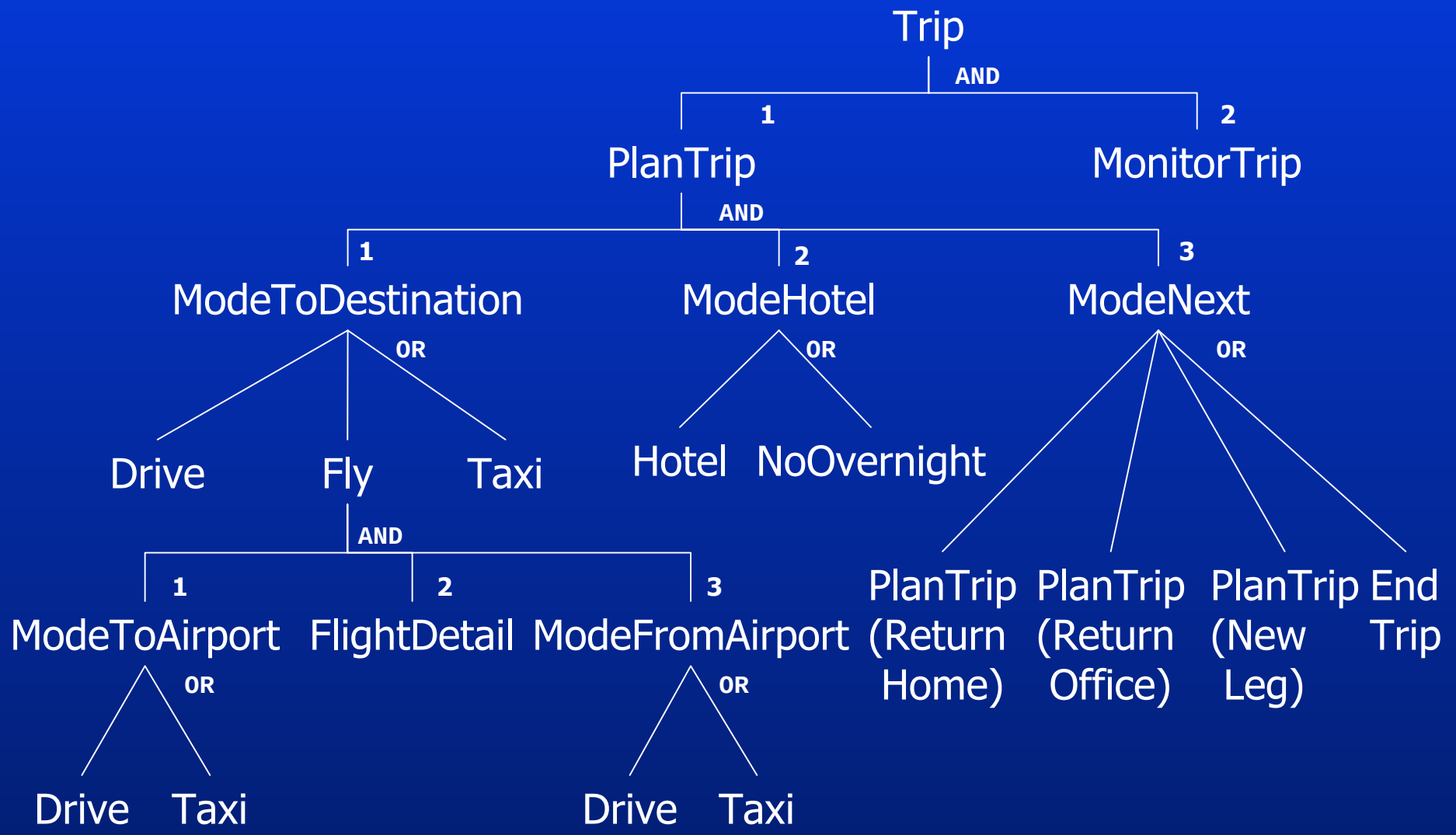
Hierarchical Constraint Reasoning System

- 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?

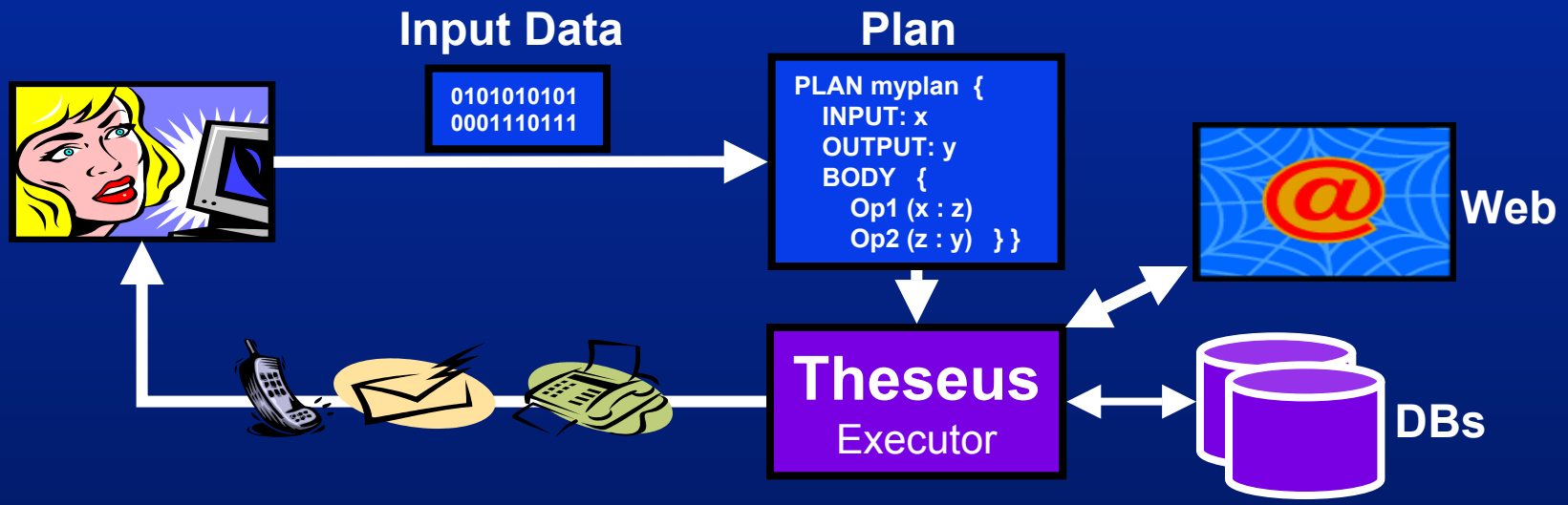


Template Hierarchy



Theseus

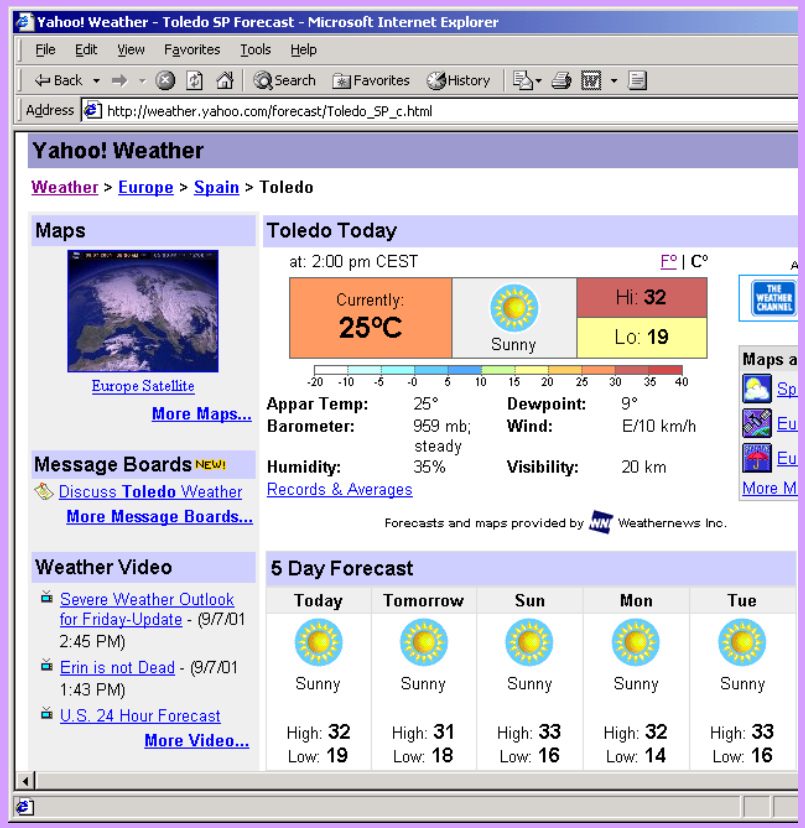
- A plan language and execution system for building Web-based information-gathering and monitoring agents
  - *Efficient* enough for near-real-time monitoring: streaming dataflow
  - *Expressive* enough for integrating a variety of sources (web sites, XML, databases, …)



Live Access to Web Sources

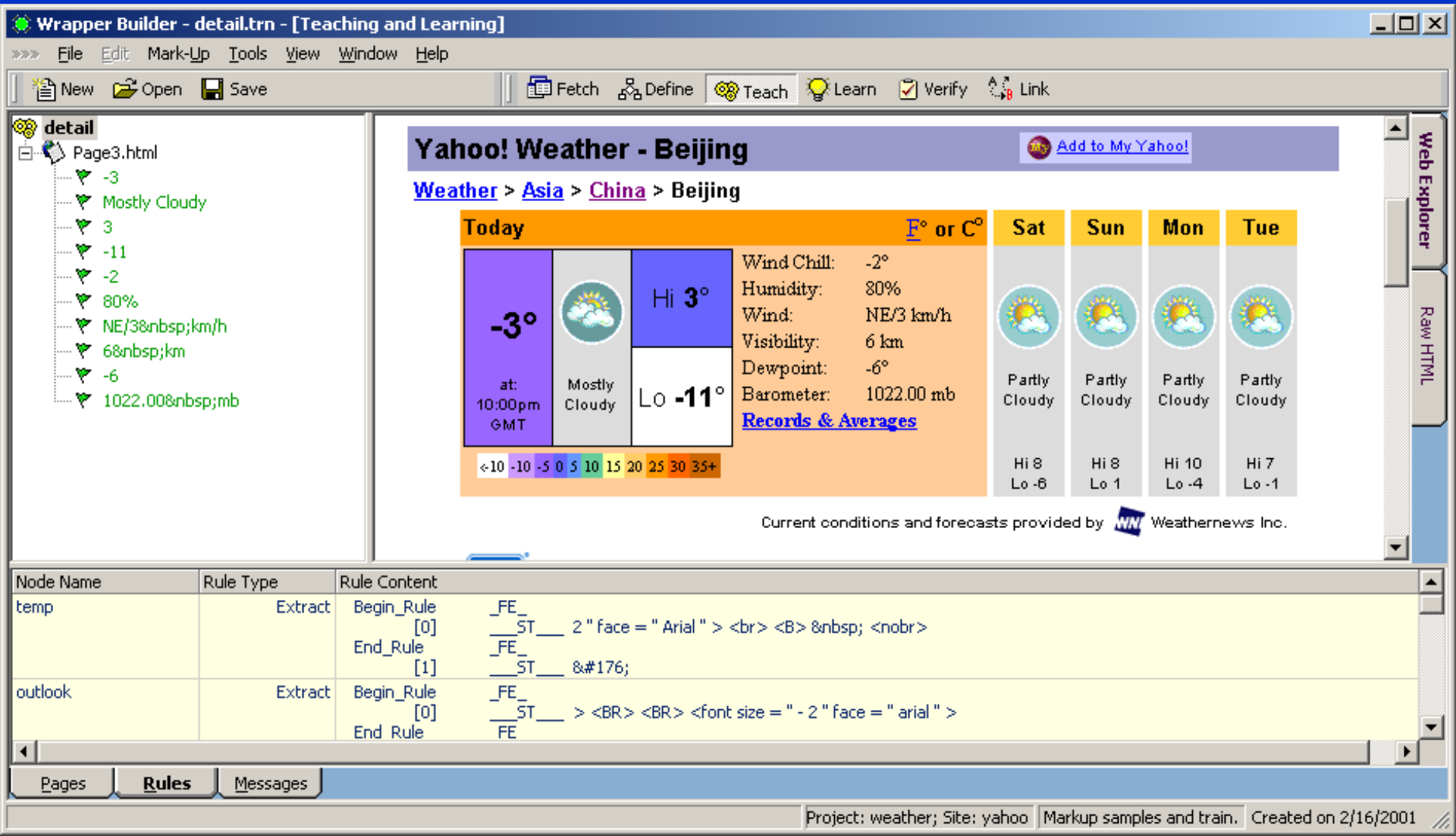
- HTML sources turned into queryable XML

Wrapper



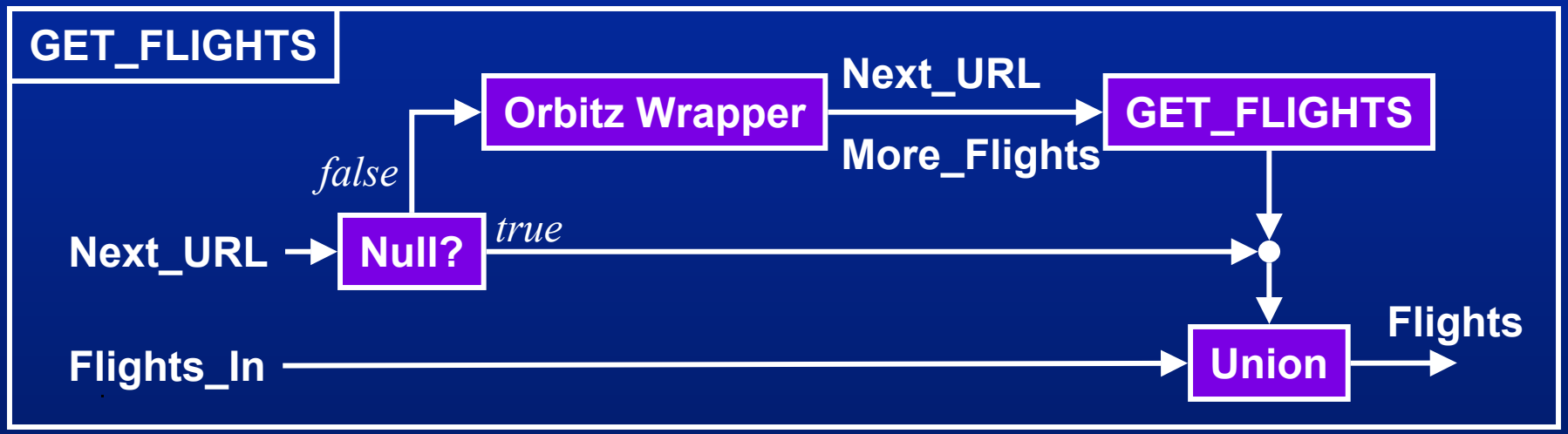

```
<YAHOO_WEATHER>
- <ROW>
  <TEMP>25</TEMP>
  <OUTLOOK>Sunny</OUTLOOK>
  <HI>32</HI>
  <LO>19</LO>
  <APPARTEMP>25</ APPARTEMP >
  <HUMIDITY>35%</HUMIDITY>
  <WIND>E/10 km/h</WIND>
  <VISIBILITY>20 km</VISIBILITY>
  <DEWPOINT>9</DEWPOINT>
  <BAROMETER>959 mb</BAROMETER>
  </ROW>
</YAHOO_WEATHER>
```

Machine Learning for Constructing Wrappers



Theseus Information Agent: Orbitz Plan

Recursive plan to collect all flights from Orbitz



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

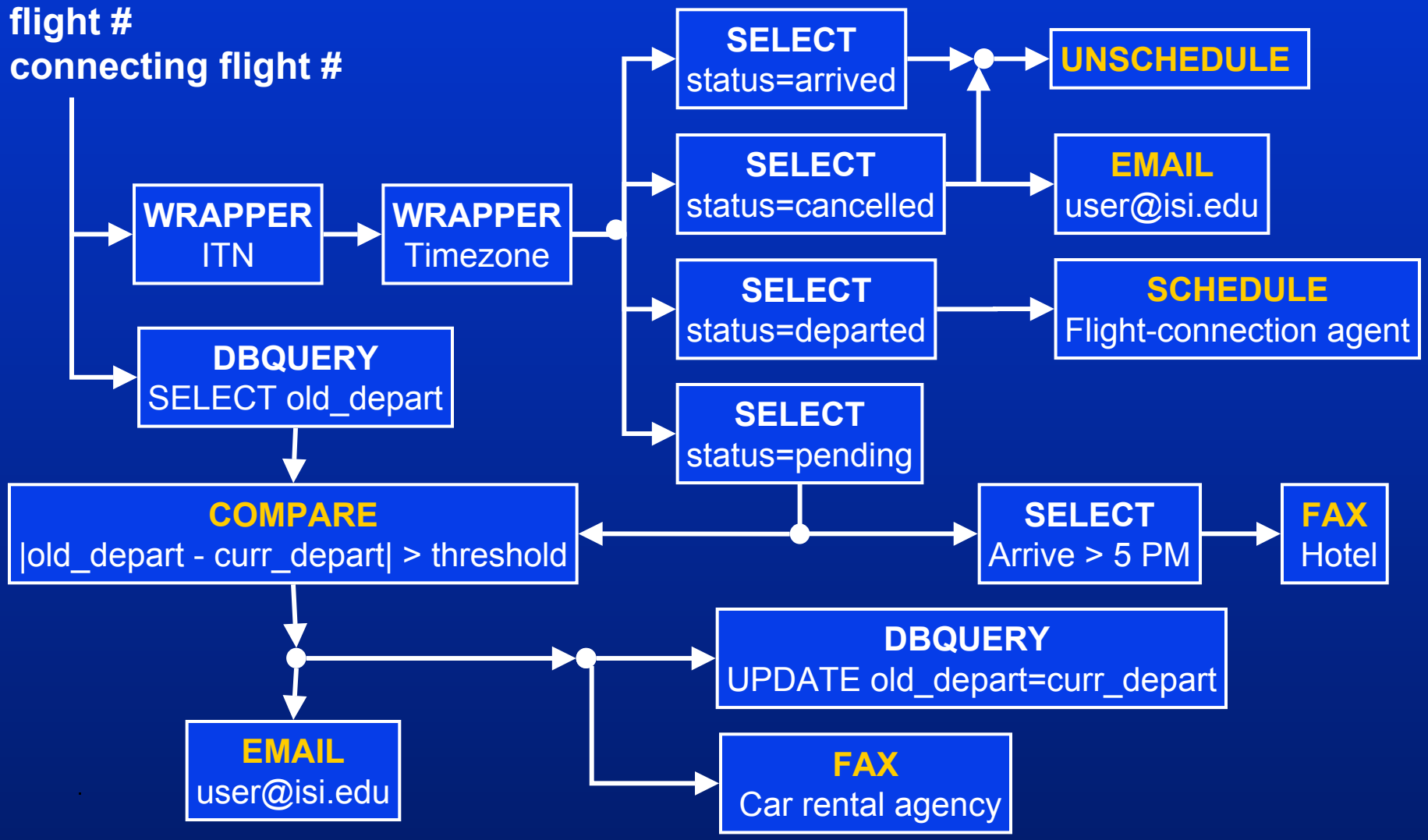
Theseus: Expressivity Plan Language (I)

- **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 → subplans**
  - **Subplans make recursion possible**
    - **Ex: "next page" links**
  - **Subplans encourage modularity & reuse**

Theseus Monitoring Agent: Flight Status Plan



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