

# 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**

**AIRwise**

**Airwise Travel**

Book Flights, Hotels and Rental Cars

**Flight Arrivals**

Check Flight Arrival Times

**Washington Dulles Airport**

Index

Dulles Airport News

Washington D.C. Weather

Airlines

Getting to Dulles

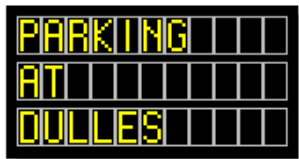
Transportation from Dulles

Airport Parking

Restaurants and Bars

Car Rental

Airport Hotels



**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**

**ORBITZ**

flight search >

**THE Orbot**

Your search:

Mon, Sep 10 a

Sat, Sep 15 a

Web-only fare

**(9 flights out of)**

**PER PERSON**

**\$1842**

**SELECT**

**\$1842**

**SELECT**

**\$1845**

**SELECT**

- [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...](#)

Today	Tomorrow	Sun	Mon	Tue
Sunny	Sunny	Sunny	Sunny	Sunny
High: <b>32</b> Low: <b>19</b>	High: <b>31</b> Low: <b>18</b>	High: <b>33</b> Low: <b>16</b>	High: <b>32</b> Low: <b>14</b>	High: <b>33</b> Low: <b>16</b>

**10**

**Free AA**

# 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

HERACLES

File New Cache Settings Help

HERACLES

TravelPlanner

- 1 Meeting (Round Trip)
  - Fly
    - Take a Taxi to Airport
    - Take a Taxi from Airport
  - Hotel
  - Fly Home
    - Take a Taxi to Airport
    - Take a Taxi from Airport
  - Flights (Complete Itinerary)
  - Monitor

## Round Trip

Week of

Month Day Year

Meeting

Subject Location

Starting At

Month Day Year Time

Ending At

Month Day Year Time

Meeting With

First Name Last Name Company Name

Leaving From

Street City State

Traveling To

Street City State

Outbound Mode

Hotel

# Supports Informed Choices



Fly

From

Street City State

To

Street City State

### Getting to Airport

Parking

Lot Daily Rate(dollars) Duration(days) Total(dollars)

Taxi

Distance Taxi

Mode to Airport

### Flights

Itinerary

From To Month Day



Fly

From

Street City State

To

Street City State

### Getting to Airport

Parking

Lot Daily Rate(dollars) Duration(days) Total(dollars)

Taxi

Distance Taxi fare(dollars)

Mode to Airport

### Flights

Itinerary

From To Month Day

# Changes Propagate Throughout

## Round Trip Flights

Preference: **Lowest Price**

Departs: **LAX** | **Los Angeles, CA**

Returns: **LGB** | **Wash, DC/Dulles,**

Price: **192**

Outbound Flight 1: **11:55 PM** | **7:36 AM**

## Taxi

Leaving From: **2700 University Park** | **Los Angeles** | **CA**

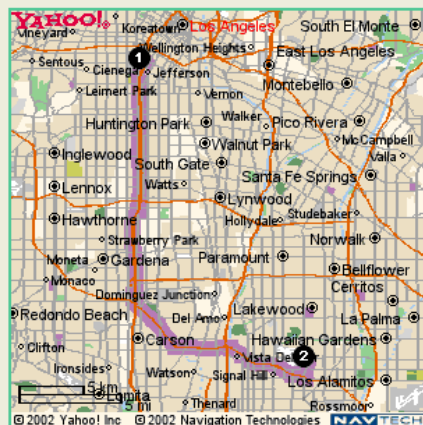
Driving To: **LGB** | **Los Angeles** | **CA**

Suggested Departure: **Apr 18 2002** | **08:22 PM**

Predicted Arrival: **Apr 18 2002** | **08:50 PM**

Taxi fare: **34.20**

Total Drive: **23.3** | **0** | **28**



## Taxi

Leaving From: **2700 University Park** | **Los Angeles**

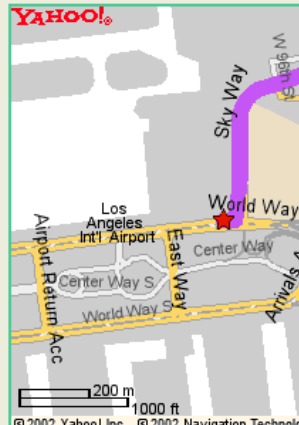
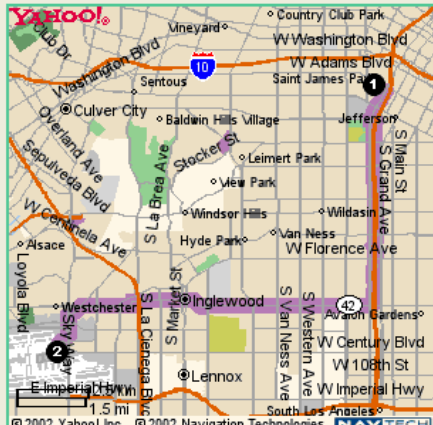
Driving To: **LAX** | **Los Angeles** | **CA**

Suggested Departure: **Apr 18 2002**

Predicted Arrival: **Apr 18 2002** | **10:55 PM**

Taxi fare: **19.50**

Total Drive: **12.7** | **0** | **24**



## Maps

## Maps

# Monitoring Travel Plans

## Monitoring Tasks

**Monitor Flight Status**

**Monitor Flights**
 **Stop Monitoring**

Notify Hotel (Fax)      Notify Car Rental Counter (Fax)

**Status**

Outbound flight 1      Outbound flight 2      Inbound flight 1      Inbound flight 2

**Monitor Flight Schedule**

**Monitor Schedule**
 **Stop Monitoring**

Status

**Monitor Earlier Flights**

**Monitor Earlier Flights**
 **Stop Monitoring**

Status

**Monitor Connecting Flights**

**Monitor Connecting Flights**
 **Stop Monitoring**

Status (Outbound)      Status (Inbound)

**Monitor Airfare**

**Monitor Airfare**
 **Stop Monitoring**

Mode      Airfare      Status

# 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

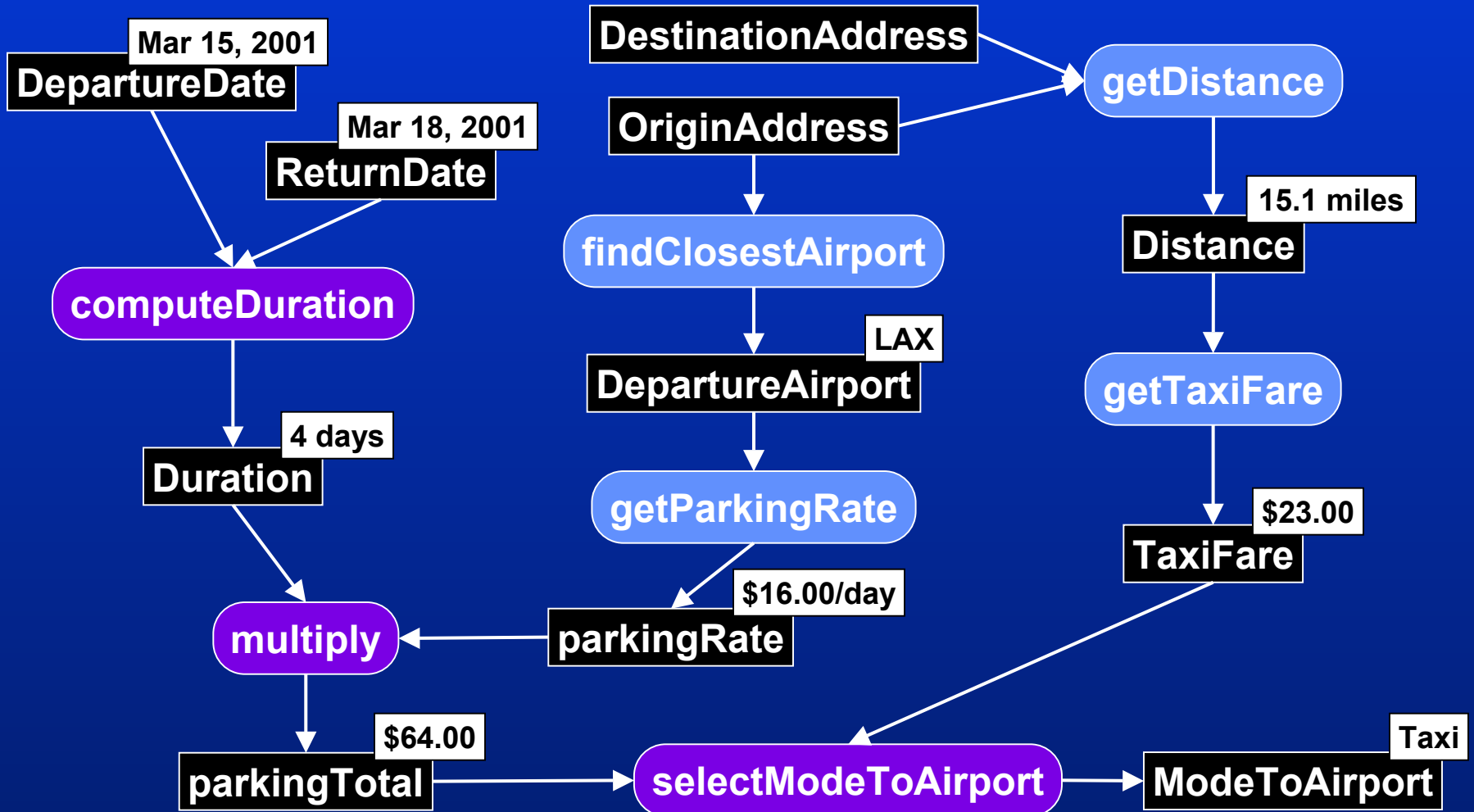
# 1534 DEN (1:20 PM) - IAD (6:06 PM) On Time

# Heracles: Constraint Networks for Managing Information

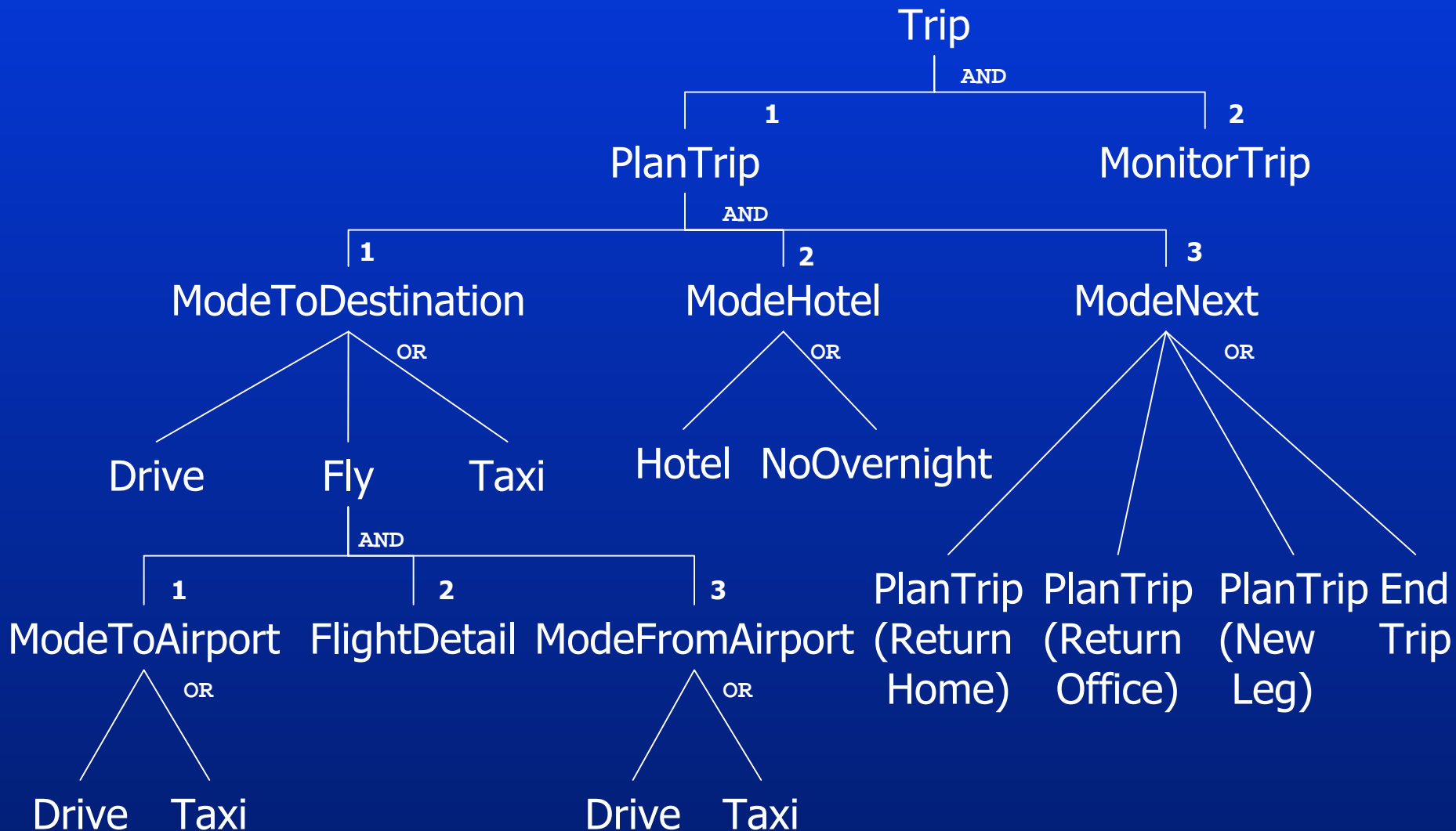
## Hierarchical Constraint Reasoning System

- 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?

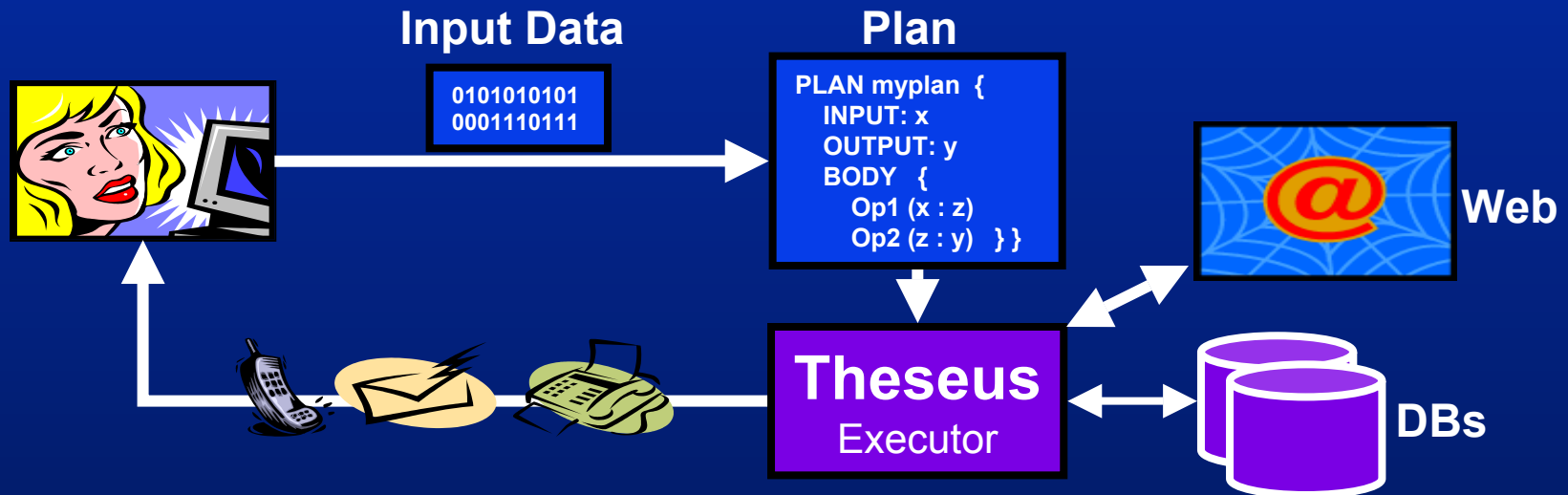


# Template Hierarchy



# 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

The screenshot shows a Yahoo! Weather page for Toledo, Spain. The current temperature is 25°C, with a high of 32°C and a low of 19°C. The outlook is Sunny. The 5-day forecast shows Sunny weather with high and low temperatures for each day.

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

```
<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

Wrapper Builder - detail.trn - [Teaching and Learning]

File Edit Mark-Up Tools View Window Help






New Open Save Fetch Define Teach Learn Verify Link


**detail**

- Page3.html
  - 3
  - Mostly Cloudy
  - 3
  - 11
  - 2
  - 80%
  - NE/38&nbsp;km/h
  - 6&nbsp;km
  - 6
  - 1022.00&nbsp;mb

**Yahoo! Weather - Beijing** [Add to My Yahoo!](#)

[Weather](#) > [Asia](#) > [China](#) > Beijing

Today	F° or C°	Sat	Sun	Mon	Tue
<div style="display: flex; justify-content: space-between;"> <div style="text-align: center;"> <p><b>-3°</b></p> <p>at: 10:00pm GMT</p> </div> <div style="text-align: center;">  <p>Mostly Cloudy</p> </div> <div style="text-align: center;"> <p>Hi <b>3°</b></p> <hr style="border: 0; border-top: 1px solid black;"/> <p>Lo <b>-11°</b></p> </div> </div>	<p>Wind Chill: -2°</p> <p>Humidity: 80%</p> <p>Wind: NE/3 km/h</p> <p>Visibility: 6 km</p> <p>Dewpoint: -6°</p> <p>Barometer: 1022.00 mb</p> <p><a href="#">Records &amp; Averages</a></p>	 Partly Cloudy	 Partly Cloudy	 Partly Cloudy	 Partly Cloudy
<p>&lt;-10 -10 -5 0 5 10 15 20 25 30 35+&gt;</p>		<p>Hi 8 Lo -6</p>	<p>Hi 8 Lo 1</p>	<p>Hi 10 Lo -4</p>	<p>Hi 7 Lo -1</p>

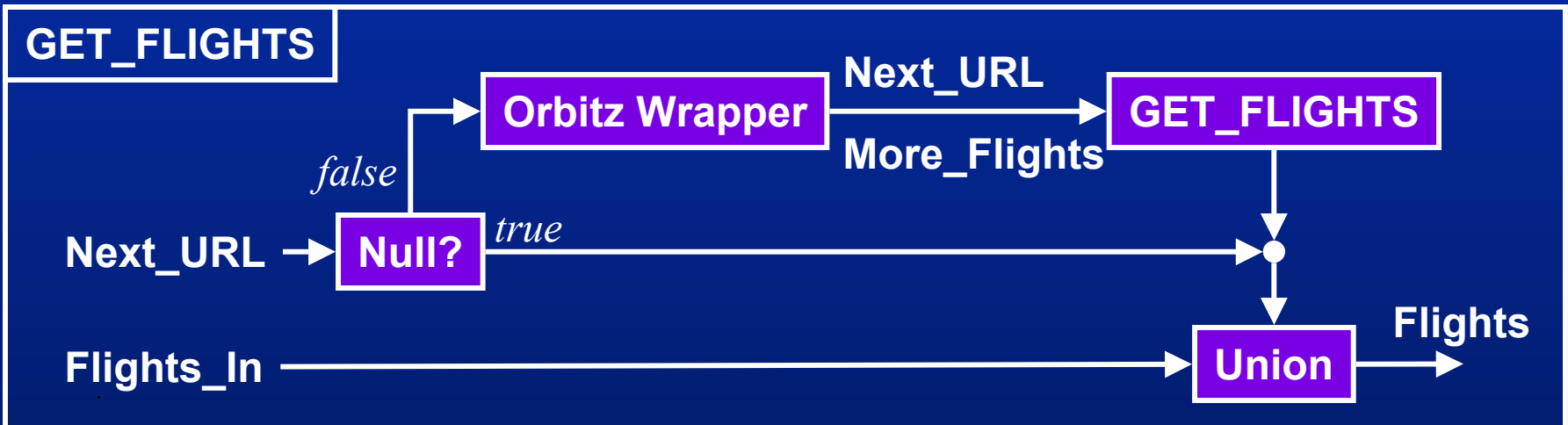
Current conditions and forecasts provided by  Weathernews Inc.

Node Name	Rule Type	Rule Content
temp	Extract	Begin_Rule    _FE_ [0]    __ST__ 2 " face = " Arial " >   <B> &nbsp; <noBr> End_Rule        _FE_ [1]    __ST__ &#176;
outlook	Extract	Begin_Rule    _FE_ [0]    __ST__ >     <font size = " - 2 " face = " arial " > End_Rule        FE

Pages   **Rules**   Messages

# 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)

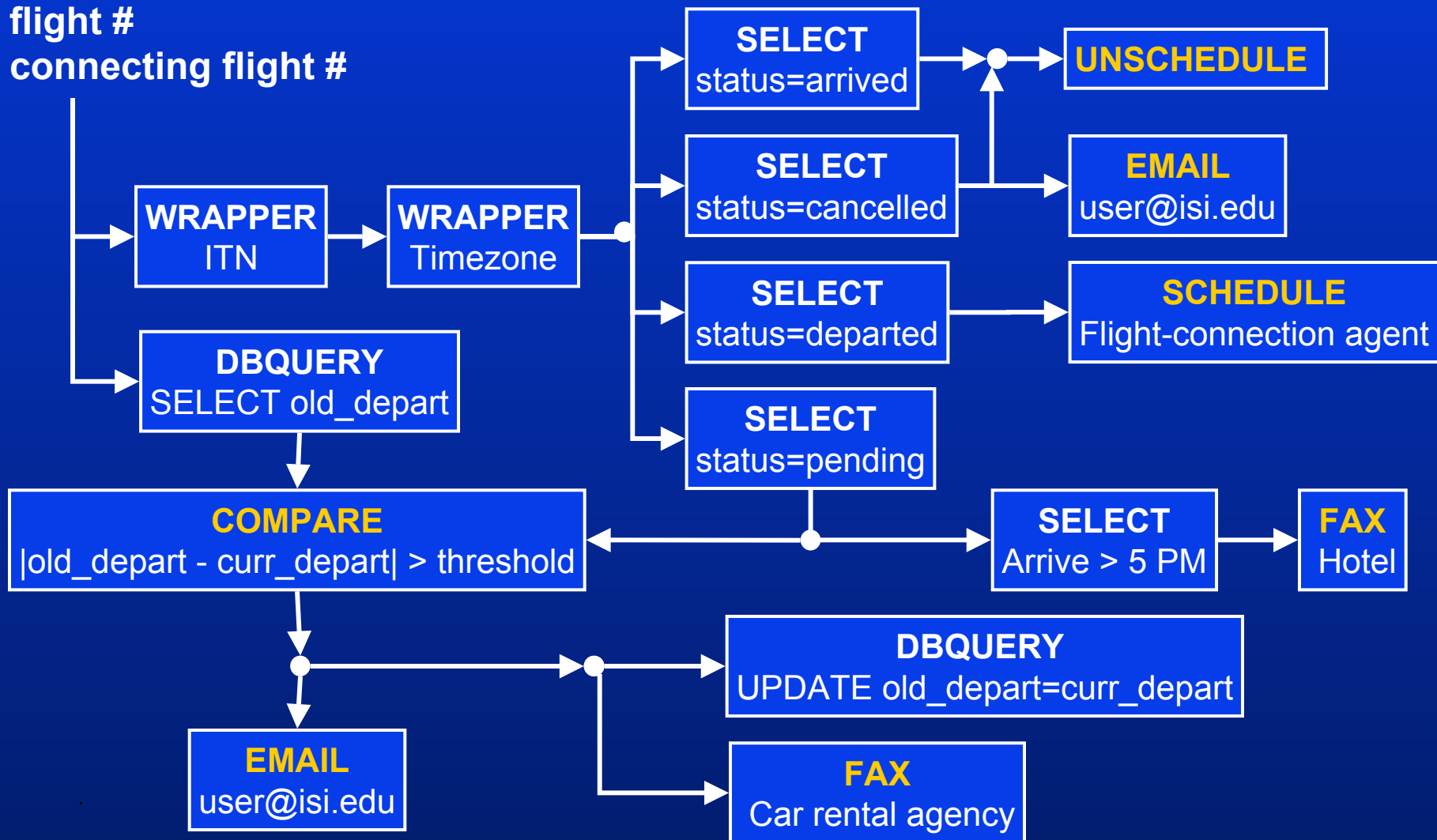
- **Basic relational-style operators**
  - Select, Project, Join, Union, ...
- **Operators for gathering Web data**
  - Wrapper
    - Database-like access to a Web source
  - XQuery, Rel2Xml, and Xml2Rel
    - Enables better integration with XML sources
- **Operators for monitoring Web data**
  - DbExport, 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