

Learning to Optimize Plan Execution in Information Agents

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Acknowledgements

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 - Jose Luis Ambite
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Introduction

- ◆ The Web is a tremendous resource, but designed for browsing
 - Sites provide limited capabilities for personalization
 - Few sites are designed to be integrated with others
- ◆ Goal: Develop technology to rapidly construct personal software agents
 - Build agents that can perform retrieval, integration, and monitoring tasks on any online source

Outline

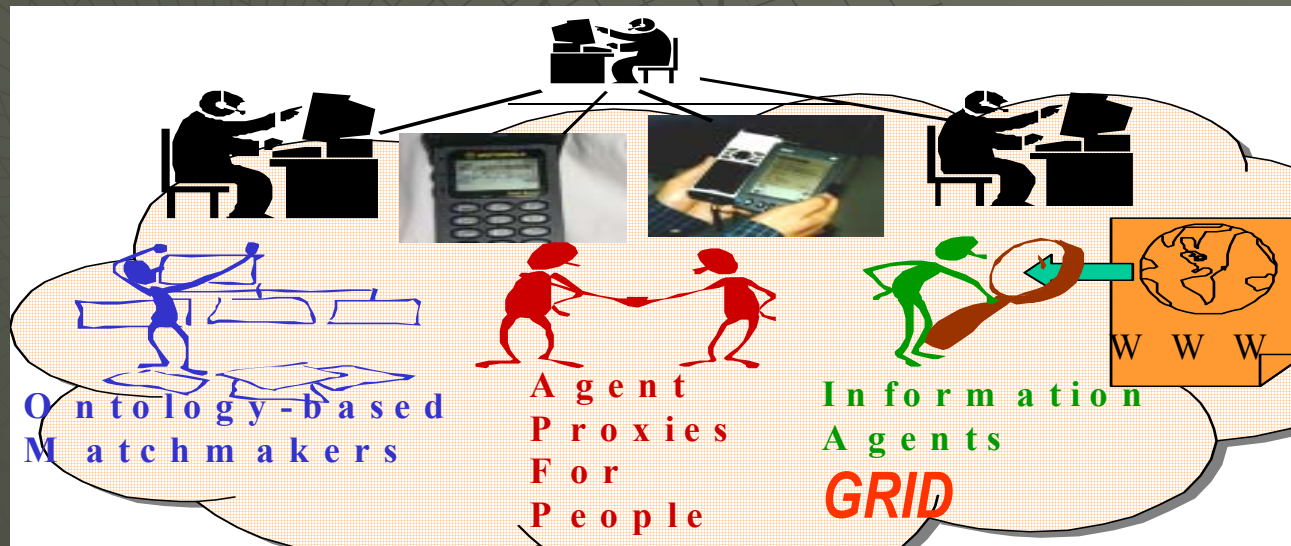
1. **Motivating Application: The Electric Elves**
2. Efficiently executing agent plans
3. Speculative plan execution
4. Value prediction for speculative execution
5. Related Work
6. Conclusions

Electric Elves Project

[Chalupsky et al, 2001]

Elves project goal: Apply agent technology to support human organizations

- Develop software agents that automate routine tasks
 - Enable software agents and humans to work together
 - Support coordination of tasks
- ◆ Applications: Office Elves and Travel Elves



Agents for Monitoring Travel

[Ambite et al, 2002]

- Travel Elves created as an application of the Electric Elves
- Given travel itinerary, generates set of agents for anticipating travel-related failures and opportunities:
 - Price changes
 - Schedule changes
 - Flight delays & cancellations
 - Earlier and close connections
 - Finding the closest restaurant given GPS coordinates

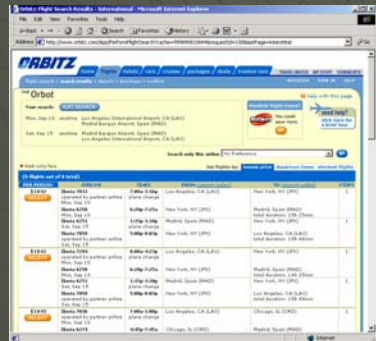
Monitoring Travel Plans

Monitoring Tasks

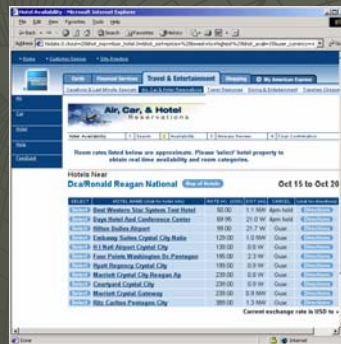
Monitor Flight Status	<input checked="" type="radio"/> Monitor Flights	7038128516	7034948462	
	<input type="radio"/> Stop Monitoring	Notify Hotel (Fax)	Notify Car Rental Counter (Fax)	
Status	Active	Active	Active	Active
	Outbound flight 1	Outbound flight 2	Inbound flight 1	Inbound flight 2
Monitor Flight Schedule	<input checked="" type="radio"/> Monitor Schedule	Active		
	<input type="radio"/> Stop Monitoring	Status		
Monitor Earlier Flights	<input checked="" type="radio"/> Monitor Earlier Flights	Active		
	<input type="radio"/> Stop Monitoring	Status		
Monitor Connecting Flights	<input checked="" type="radio"/> Monitor Connecting Flights	Active	Active	
	<input type="radio"/> Stop Monitoring	Status (Outbound)	Status (Inbound)	
Monitor Airfare	Decrease only	<input checked="" type="radio"/> Monitor Airfare	Active	
	Mode	<input type="radio"/> Stop Monitoring	Status	
		Airfare		

Agents Deployed to Monitor Travel Itinerary

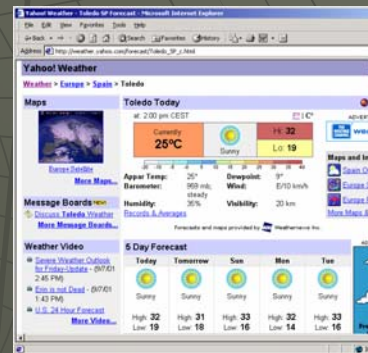
Travel Itinerary



Flight Prices & Schedules



Flight Status



Weather



Restaurants

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

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Efficiently Executing Agent Plans

◆ Problem

- Information gathering may involve accessing and integrating data from many sources
- Total time to execute these plans may be large

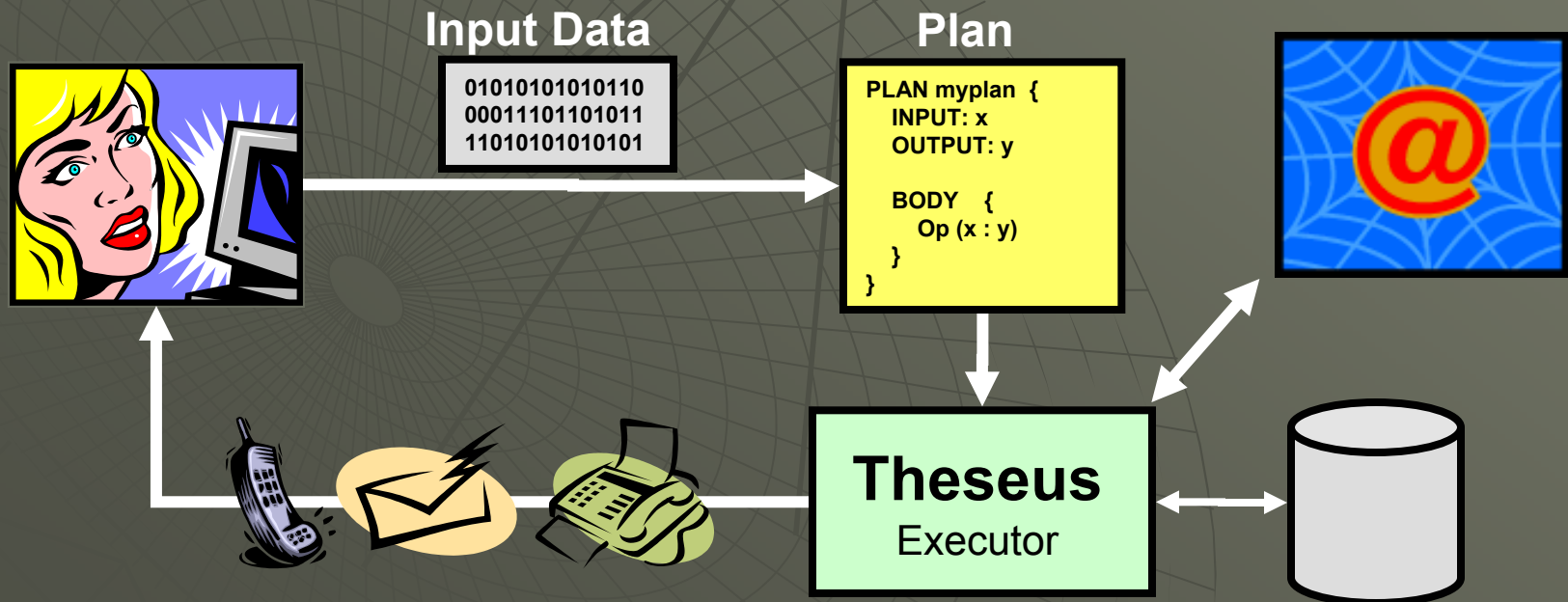
◆ Why?

- Slow remote sources
- Unpredictable network latencies
- Binding patterns
 - ◆ Source cannot be queried until a previous query has been answered
- Result: execution is often I/O-bound

Theseus Agent Execution System

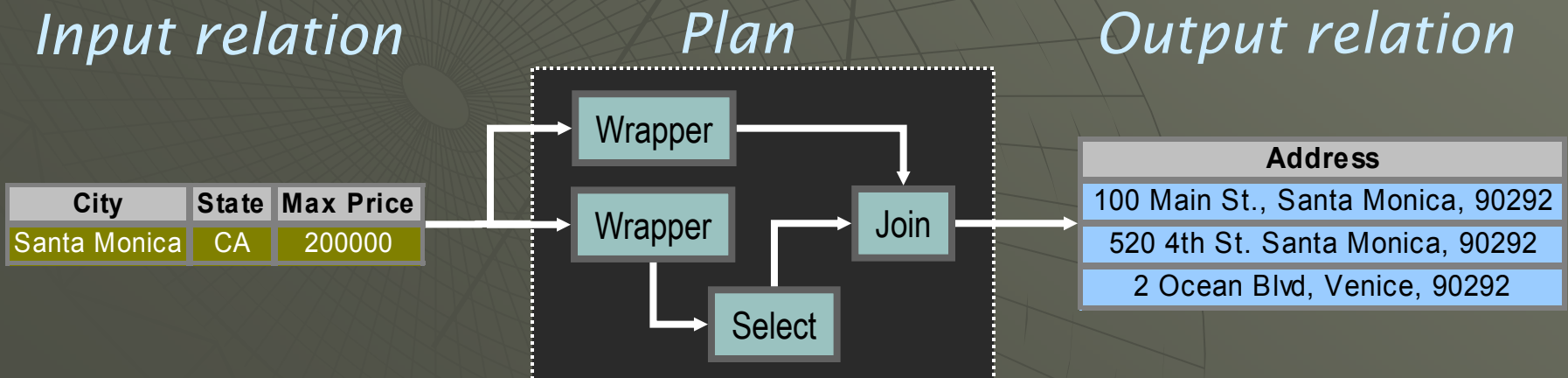
[Barish & Knoblock, JAIR'05]

- ◆ **Plan language** and **execution system** for Web-based information integration
 - Expressive enough for monitoring a variety of sources
 - Efficient enough for real-time monitoring



Streaming Dataflow

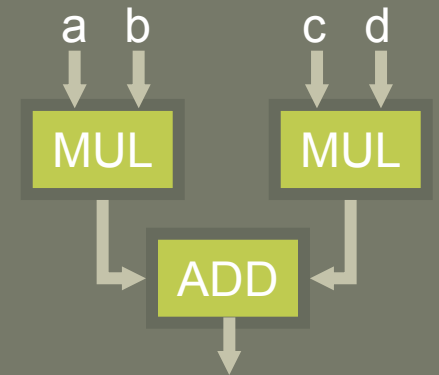
- ◆ Plans consist of a network of operators
 - Examples: **Wrapper**, **Select**, etc.
 - Operators produce and consume data
 - Operators “fire” upon any input data
- ◆ Data passed as tuples of a relation



Parallelism in Streaming Dataflow

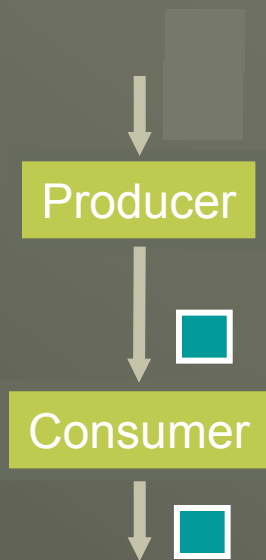
◆ Dataflow

- Operations scheduled by data availability
 - ◆ Independent operations execute in parallel
 - ◆ **Maximizes horizontal parallelism**
- Example: computing $(a*b) + (c*d)$



◆ Streaming

- Operations emit data as soon as possible
 - ◆ Independent data processed in parallel
 - ◆ **Maximizes vertical parallelism**



CarInfo Agent

- ◆ Agent for recommending used cars:
 - Combine information from
 - ◆ Prices of used cars
 - ◆ Safety ratings
 - ◆ Reviews
 - Example:
 - ◆ 2002 Midsize coupe/hatchback
 - ◆ \$4K-\$12K,
 - ◆ No Oldsmobiles

The CarInfo agent

1. Locate cars that meet criteria
- Edmunds.com



The screenshot shows the Edmunds.com website interface. At the top, there's a navigation bar with links for HOME, NEW CARS, USED CARS, CAR REVIEWS, TIPS & ADVICE, OWNERSHIP, and CAR. Below this, a search bar displays "Used Car Pricing: Midsize Coupe/Hatchbacks" with "12 vehicle(s) found". A dropdown menu for "Choose a Sub-Type:" is set to "Midsize".

The first listing is for "ACURA COUPE/HATCHBACKS". It features a sub-section for "2002 Acura CL Midsize Coupe/Hatchback". The listing includes a small image of the car, its TMV® Dealer Retail price range (\$20,789 - \$22,638), and a list of pros and cons. The pros mention powerful V6 engines and a comfortable cabin, while the cons note interior trimmings and suspension. The "What Edmunds.com says" section provides a price-based recommendation. Ratings are shown as 7.0 for Editors' and 8.8 for Consumer, with a "RATE IT" button.

The second listing is for "CHEVROLET COUPE/HATCHBACKS". It features a sub-section for "2002 Chevrolet Camaro Midsize Coupe/Hatchback". It includes a small image of the car, its TMV® Dealer Retail price range (\$12,835 - \$17,821), and a list of pros and cons. The pros mention fun, speed, and power, while the cons note styling and interior materials. The "What Edmunds.com says" section states it's a "donesville" car. Ratings are shown as 5.3 for Editors' and 8.7 for Consumer, with a "RATE IT" button.

The CarInfo agent

1. Locate cars that meet criteria

- Edmunds.com

2. Filter out Oldsmobiles



The screenshot shows the Edmunds.com website interface. At the top, there is a navigation bar with links for HOME, NEW CARS, USED CARS, CAR REVIEWS, TIPS & ADVICE, OWNERSHIP, and CAR. Below the navigation bar, the main heading is "Used Car Pricing: Midsize Coupe/Hatchbacks" with a sub-heading "12 vehicle(s) found". There is a dropdown menu for "Choose a Sub-Type:" set to "Midsize" and a "Go" button. A link "Browse All Models" is visible. The first listing is for "ACURA COUPE/HATCHBACKS" with a sub-heading "2002 Acura CL Midsize Coupe/Hatchback". It includes a photo of the car, an Editors' Rating of 7.0, a Consumer Rating of 8.8, and a "RATE IT" button. The listing text includes "TMV® Dealer Retail: \$20,789 - \$22,638", "Pros: Powerful V6 engines, lavish standard features list, comfortable cabin, great value.", "Cons: Interior trimmings lack refinement, rough ride from Type-S suspension, front-wheel drive, no manual transmission.", and "What Edmunds.com says: If you are looking for a luxury coupe for about \$30,000, you'll be hard-pressed to find anything better." A link "Get detailed pricing for the 2002 Acura CL" is provided. The second listing is for "CHEVROLET COUPE/HATCHBACKS" with a sub-heading "2002 Chevrolet Camaro Midsize Coupe/Hatchback". It includes a photo of the car, an Editors' Rating of 5.3, a Consumer Rating of 8.7, and a "RATE IT" button. The listing text includes "TMV® Dealer Retail: \$12,835 - \$17,821", "Pros: Fun (Base), fast (Z28), furious (SS).", "Cons: Chrysler Concorde front styling, cheapo interior materials, boy-racer image.", and "What Edmunds.com says: Camaro is donesville." A link "Get detailed pricing for the 2002 Chevrolet Camaro" is provided.

The CarInfo agent

1. Locate cars that meet criteria

- Edmunds.com

2. Filter out Oldsmobiles

3. Gather safety reviews for each

- NHSTA.gov

The screenshot displays a web interface for a car search. At the top, there is a navigation bar with the word "cars" and several icons: a back arrow, a car head, a truck, a van, an SUV, and a "make what you car" logo. Below the navigation bar, the car model "2002 Dodge Stratus 4-DR" is highlighted in a purple box. To the right of the car name, there is a URL "http://www.nhtsa.dot.gov/ncap" and the text "Posted 04/29/2003".

The main content area is divided into two sections. The top section is titled "Frontal Star Rating" and contains two tables. The first table has two columns: "Driver's Side" and "Passenger's Side". Both columns show a rating of five stars. The second table is titled "Frontal Vehicle Weight" and shows a weight of 3221 lbs.

The bottom section is titled "Side Impact Star Rating" and contains two tables. The first table has two columns: "Front Occupant" and "Rear Occupant". Both columns show a rating of three stars. Below the tables, there is a large grey rectangular area.

Two images of crash tests are shown on the left. The top image is labeled "frontal crash" and shows a silver car being hit from the front. The bottom image is labeled "side crash" and shows a blue car being hit from the side.

The CarInfo agent

1. Locate cars that meet criteria

- Edmunds.com

2. Filter out Oldsmobiles

3. Gather safety reviews for each

- NHSTA.gov

4. Gather detailed reviews of each

- ConsumerGuide.com

CONSUMERGUIDE[®] Automotive Consumer Products

New Cars Used Cars Articles & Advice Approved Dealers

Used Car Pricing & Reviews

1995-2000 Dodge Stratus



1995 Dodge Stratus ES (more pictures)

Year	Price Range
1997	\$3,700-4,700
1998	\$4,700-5,700
1999	\$6,000-7,200
2000	\$7,200-9,000

Class
midsize car

Powertrain Layout
transverse front-engine/front-wheel drive

Built In
USA

Find a used Dodge Stratus in your area using CarsDirect.com

Zip

Listings updated daily.

For
Antilock brakes (ES), Acceleration, Ride, Steering/handling, Passenger and cargo room

Against
Noise, Rear visibility

Other Stratus Models
[2004 Stratus](#)
[2003 Stratus](#)
[2002 Stratus](#)
[1995-2000 A \(used\)](#)

Research
[Free Quote](#)
[New Car Reviews & Pricing](#)
[Used Car Reviews & Pricing](#)
[Consumer Guide@ Approved Dealers](#)
[Advanced Search](#)

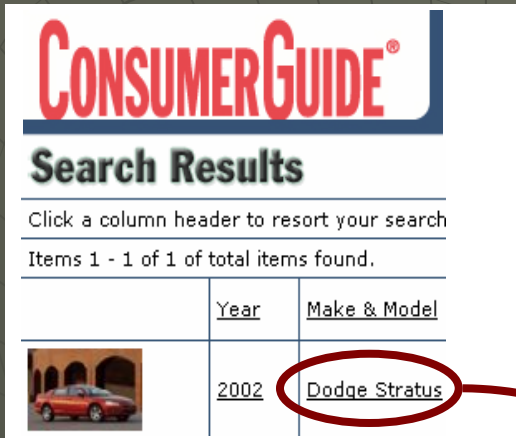
Buy
[Locate Dealer](#)
[Vehicle History Report](#)
[Used Car Listing](#)
[Finance & Credit](#)
[Insurance & Warranty](#)

Sell
[Sell Your Car](#)
[Auto Seller's Kit](#)
[Used Car Seller's Guide](#)
[Calculate Trade-In Value](#)

Learn
[Sneak Peeks](#)
[Articles & Advice](#)

ConsumerGuide Navigation

- ◆ Requires navigating through multiple pages




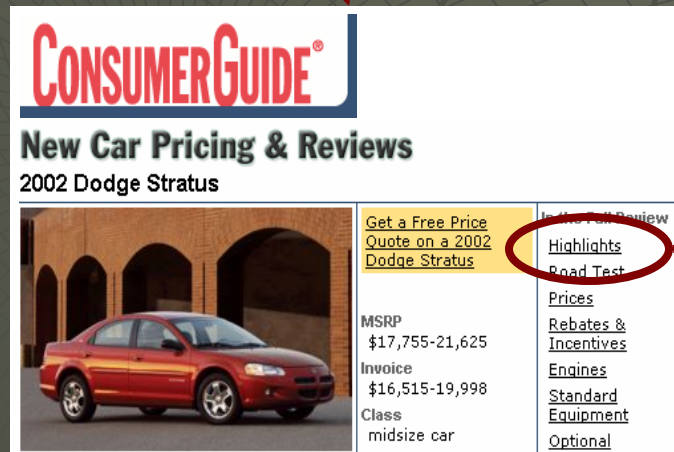
CONSUMERGUIDE®

Search Results

Click a column header to resort your search

Items 1 - 1 of 1 of total items found.


	Year	Make & Model
	2002	Dodge Stratus



CONSUMERGUIDE®

New Car Pricing & Reviews

2002 Dodge Stratus



[Get a Free Price Quote on a 2002 Dodge Stratus](#)

MSRP
\$17,755-21,625

Invoice
\$16,515-19,998

Class
midsize car

[In the Car Review](#)

[Highlights](#)

[Road Test](#)

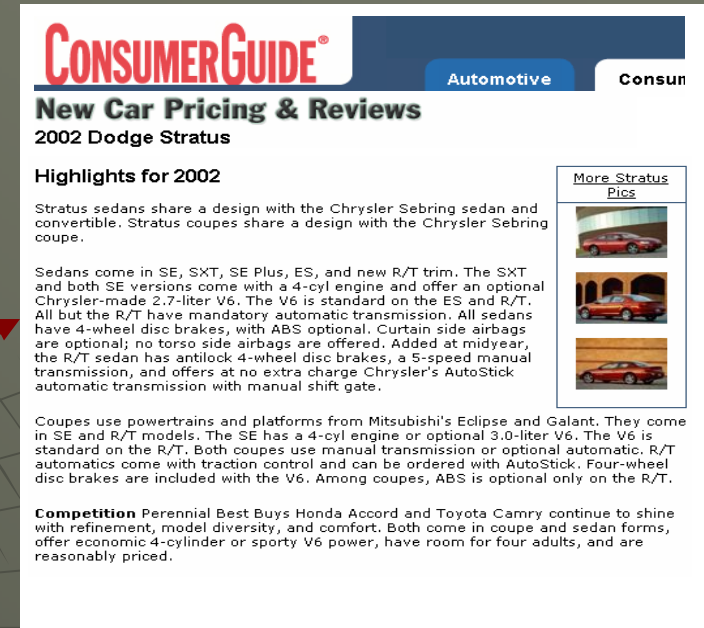
[Prices](#)

[Rebates & Incentives](#)

[Engines](#)

[Standard Equipment](#)

[Optional](#)



CONSUMERGUIDE® Automotive **Consum**

New Car Pricing & Reviews

2002 Dodge Stratus

Highlights for 2002


Stratus sedans share a design with the Chrysler Sebring sedan and convertible. Stratus coupes share a design with the Chrysler Sebring coupe.

Sedans come in SE, SXT, SE Plus, ES, and new R/T trim. The SXT and both SE versions come with a 4-cyl engine and offer an optional Chrysler-made 2.7-liter V6. The V6 is standard on the ES and R/T. All but the R/T have mandatory automatic transmission. All sedans have 4-wheel disc brakes, with ABS optional. Curtain side airbags are optional; no torso side airbags are offered. Added at midyear, the R/T sedan has antilock 4-wheel disc brakes, a 5-speed manual transmission, and offers at no extra charge Chrysler's AutoStick automatic transmission with manual shift gate.

Coupes use powertrains and platforms from Mitsubishi's Eclipse and Galant. They come in SE and R/T models. The SE has a 4-cyl engine or optional 3.0-liter V6. The V6 is standard on the R/T. Both coupes use manual transmission or optional automatic. R/T automatics come with traction control and can be ordered with AutoStick. Four-wheel disc brakes are included with the V6. Among coupes, ABS is optional only on the R/T.

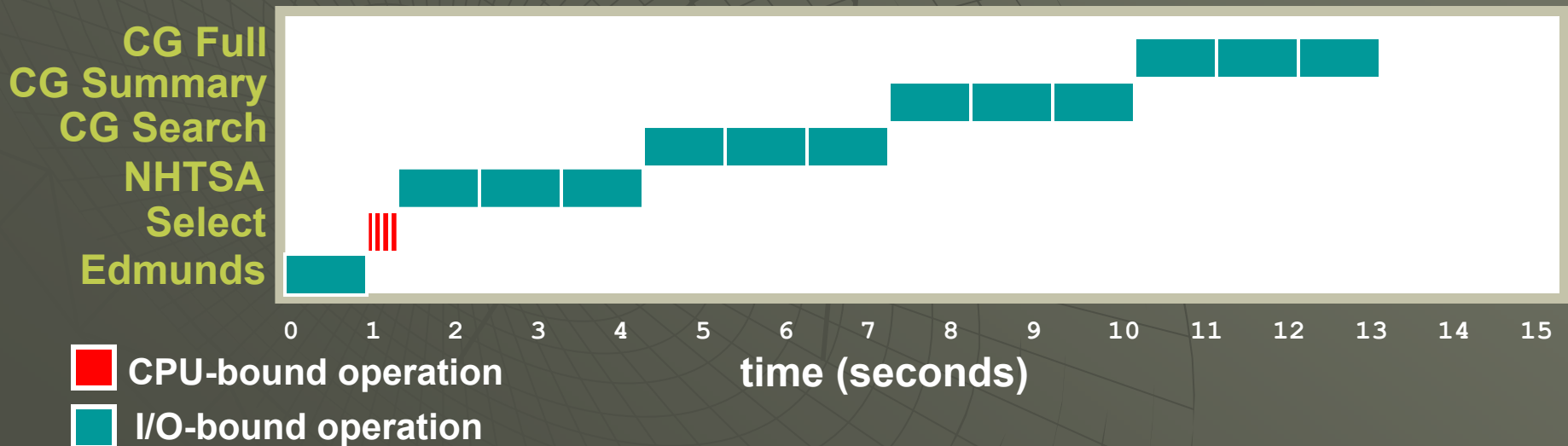
Competition Perennial Best Buys Honda Accord and Toyota Camry continue to shine with refinement, model diversity, and comfort. Both come in coupe and sedan forms, offer economic 4-cylinder or sporty V6 power, have room for four adults, and are reasonably priced.

[More Stratus Pics](#)



Agent Execution Performance

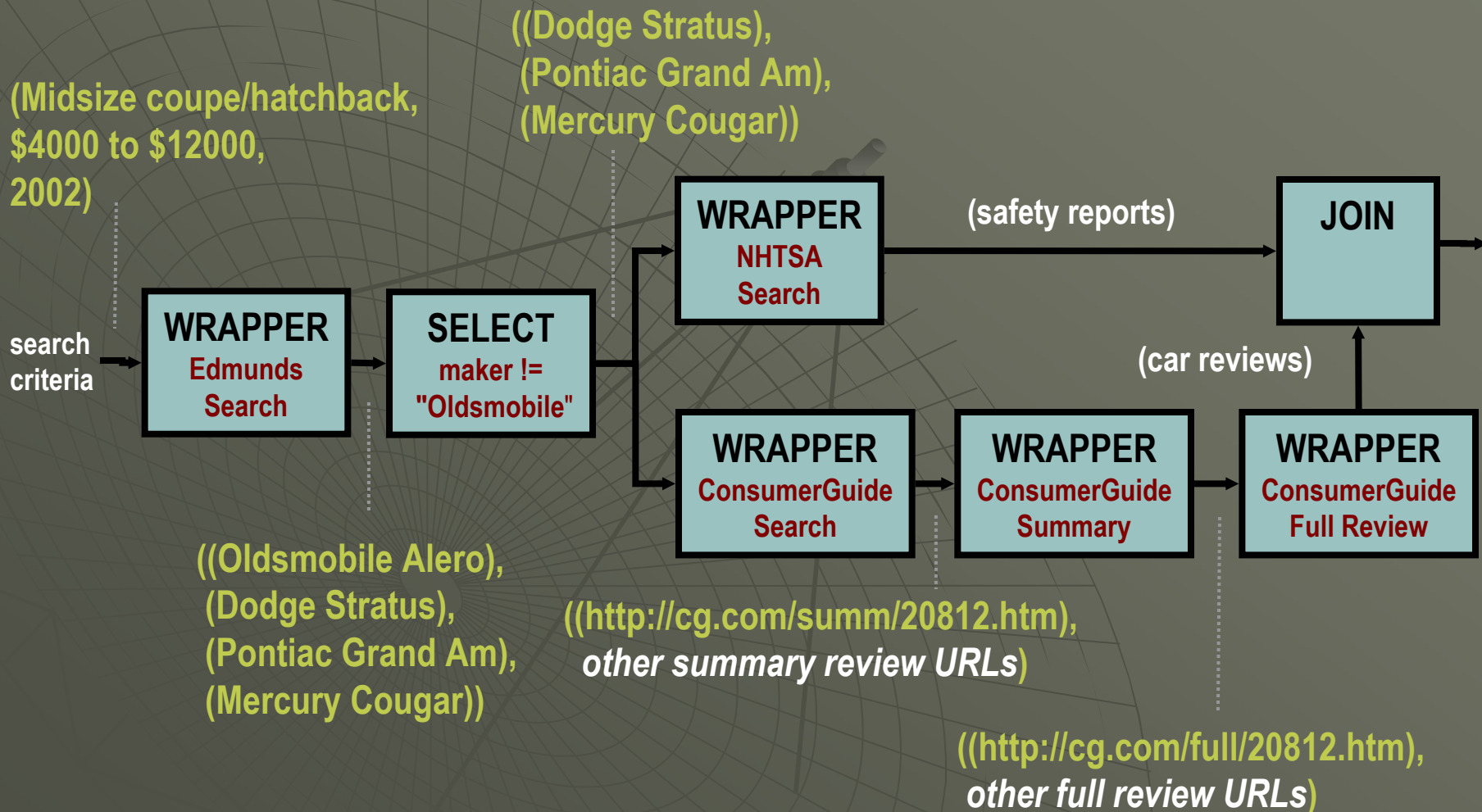
- ◆ Standard von Neumann model
 - Execute one operation at a time
 - Each operation processes all of its input before output is used for next operation
 - Assume: 1000ms per I/O op, 100ms per CPU op
- ◆ Execution time = 13.4 sec



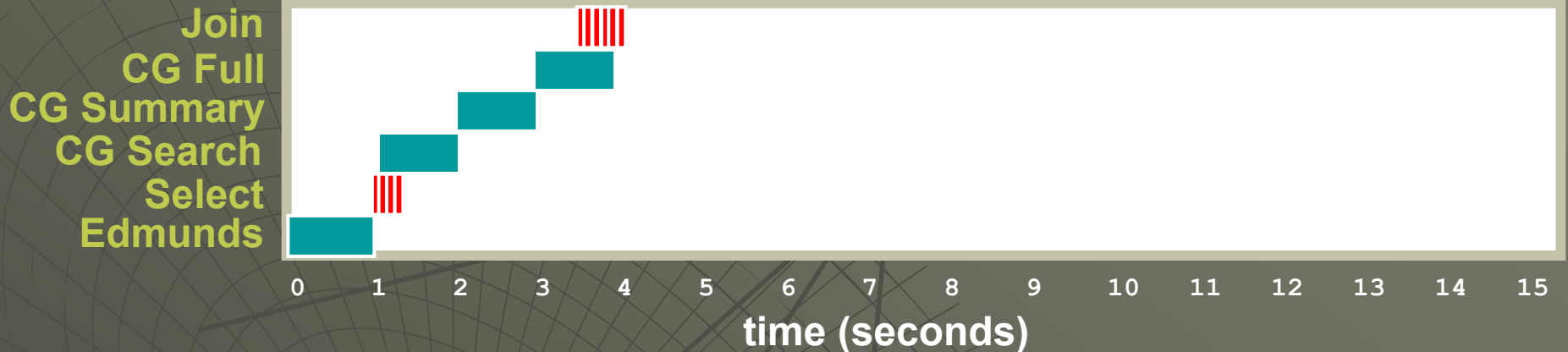
■ CPU-bound operation

■ I/O-bound operation

Dataflow-style CarInfo agent plan



Streaming Dataflow Performance



- ◆ Improved, but plan remains I/O-bound (76%)
- ◆ Main problem: **remote source latencies**
 - Meanwhile, local resources are wasted
- ◆ Complicating factor: **binding constraints**
 - Remote queries dependent on other remote queries
- ◆ Question: How can execution be more efficient?

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3. **Speculative plan execution**
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Speculative Execution

[Barish & Knoblock '02, '03]

◆ Basic idea

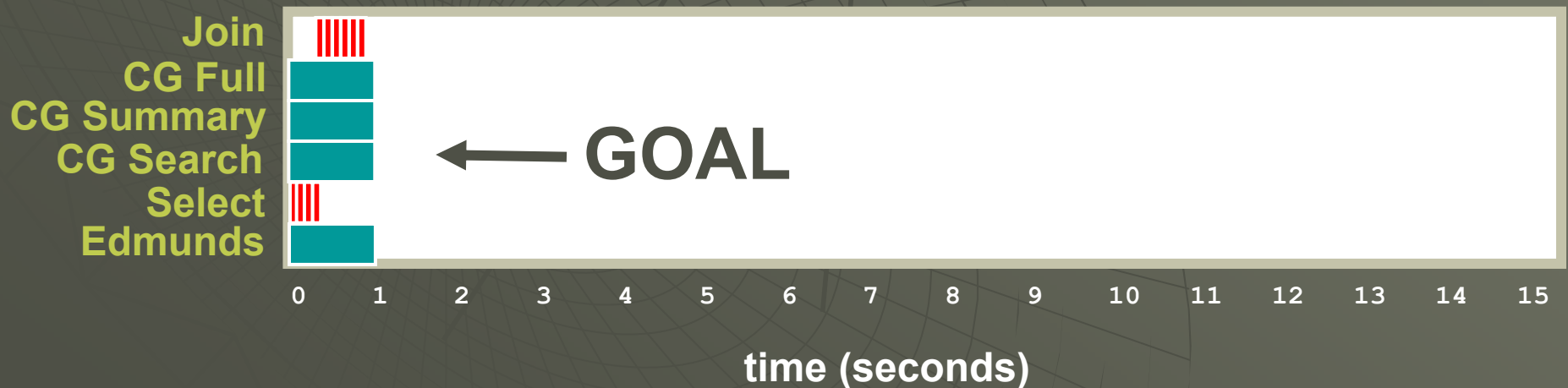
- Exploit idle resources to execute future instructions in advance of when they are normally issued

◆ Challenges

- How to augment plans for speculation
- How to ensure correctness and fairness
- How to decide what to speculate on

Speculative plan execution

- ◆ Execute operators ahead of schedule
 - Predict data based on past execution
- ◆ Allows greater degree of parallelism
 - Solves the problem caused by binding constraints
- ◆ Can lead to speedups > streaming dataflow



How to speculate?

- ◆ General problem
 - Means for issuing and confirming predictions
- ◆ Two new operators
 - **Speculate**: Makes predictions based on "hints"



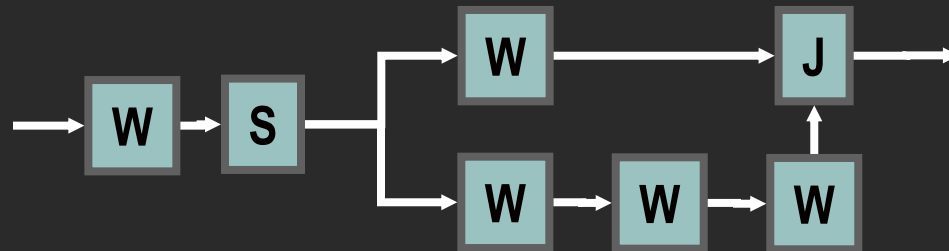
- **Confirm**: Prevents errant results from exiting plan



How to speculate?

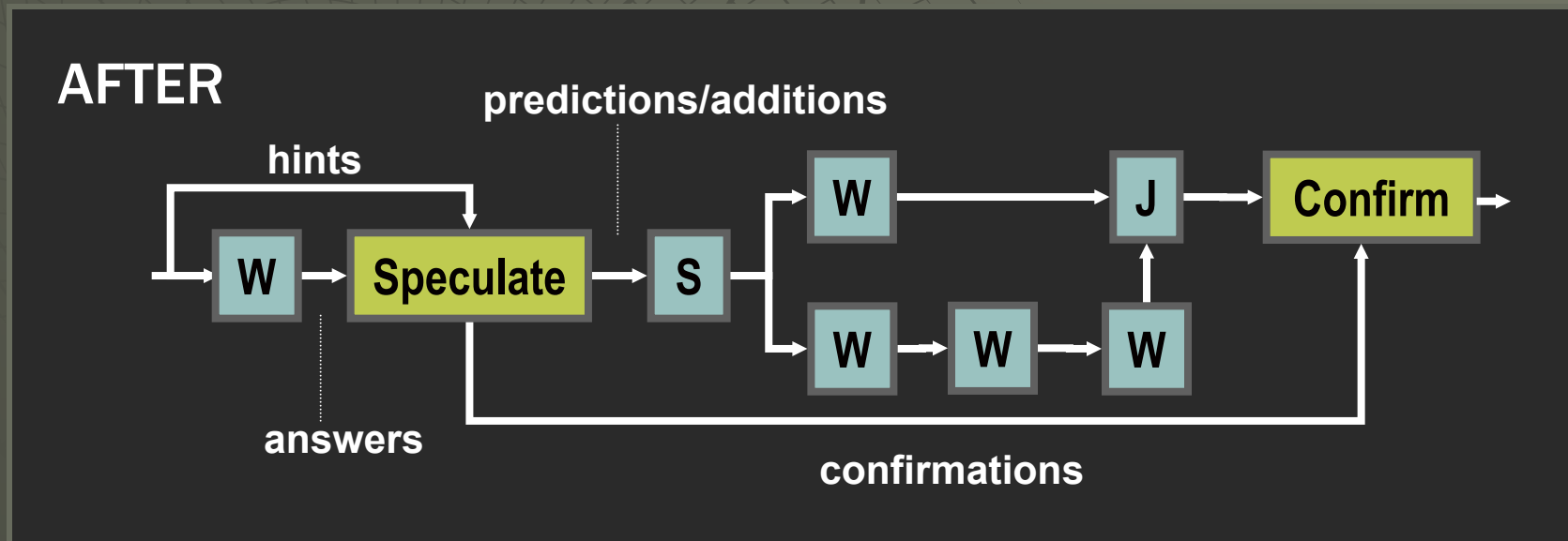
- ◆ Example: CarInfo
 - Predict cars based on search criteria
 - Makes practical sense:
 - ◆ Same criteria yields same cars

BEFORE



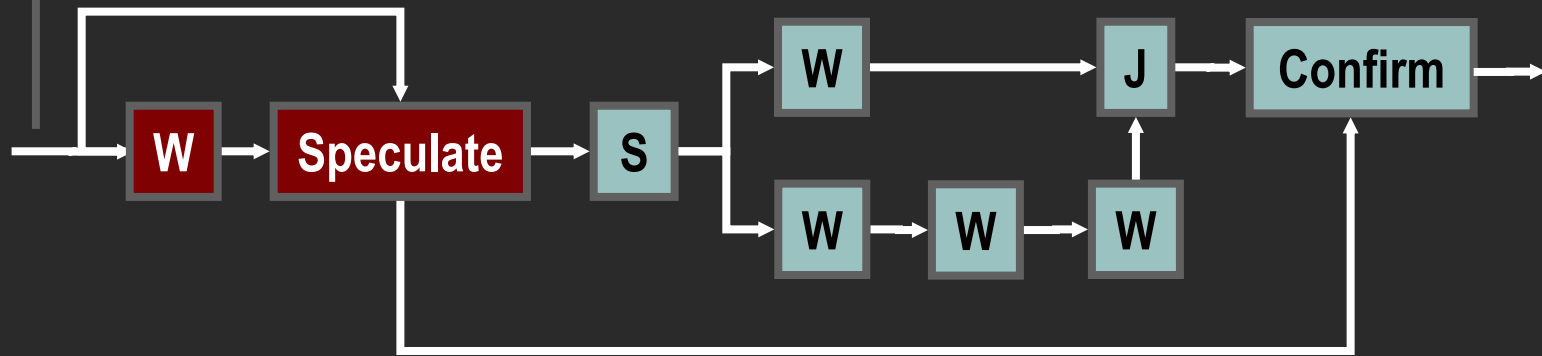
How to speculate?

- ◆ Example: CarInfo
 - Predict cars based on search criteria
 - Makes practical sense:
 - ◆ Same criteria yields same cars



Detailed example

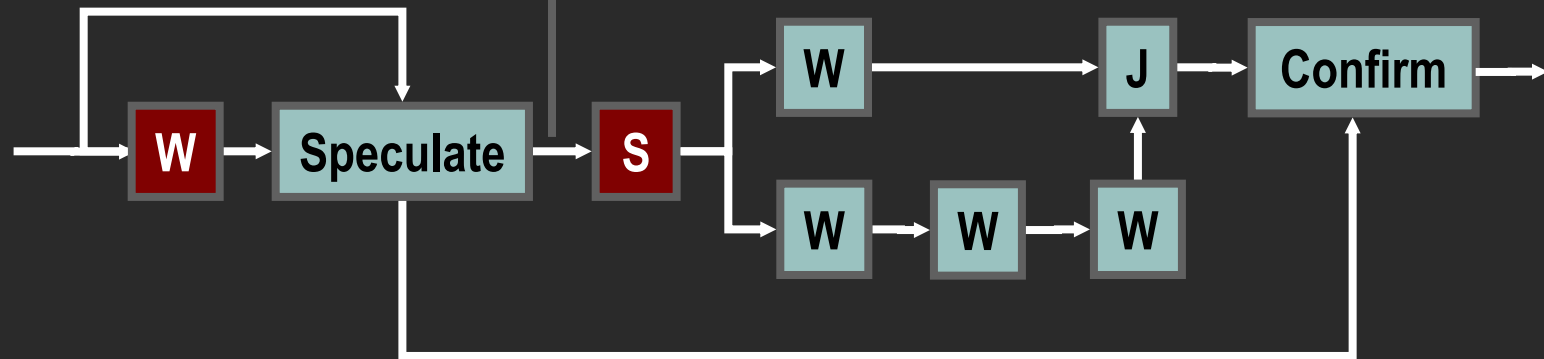
2002
Midsize coupe
\$4000-\$12000



Time = 0.0 sec

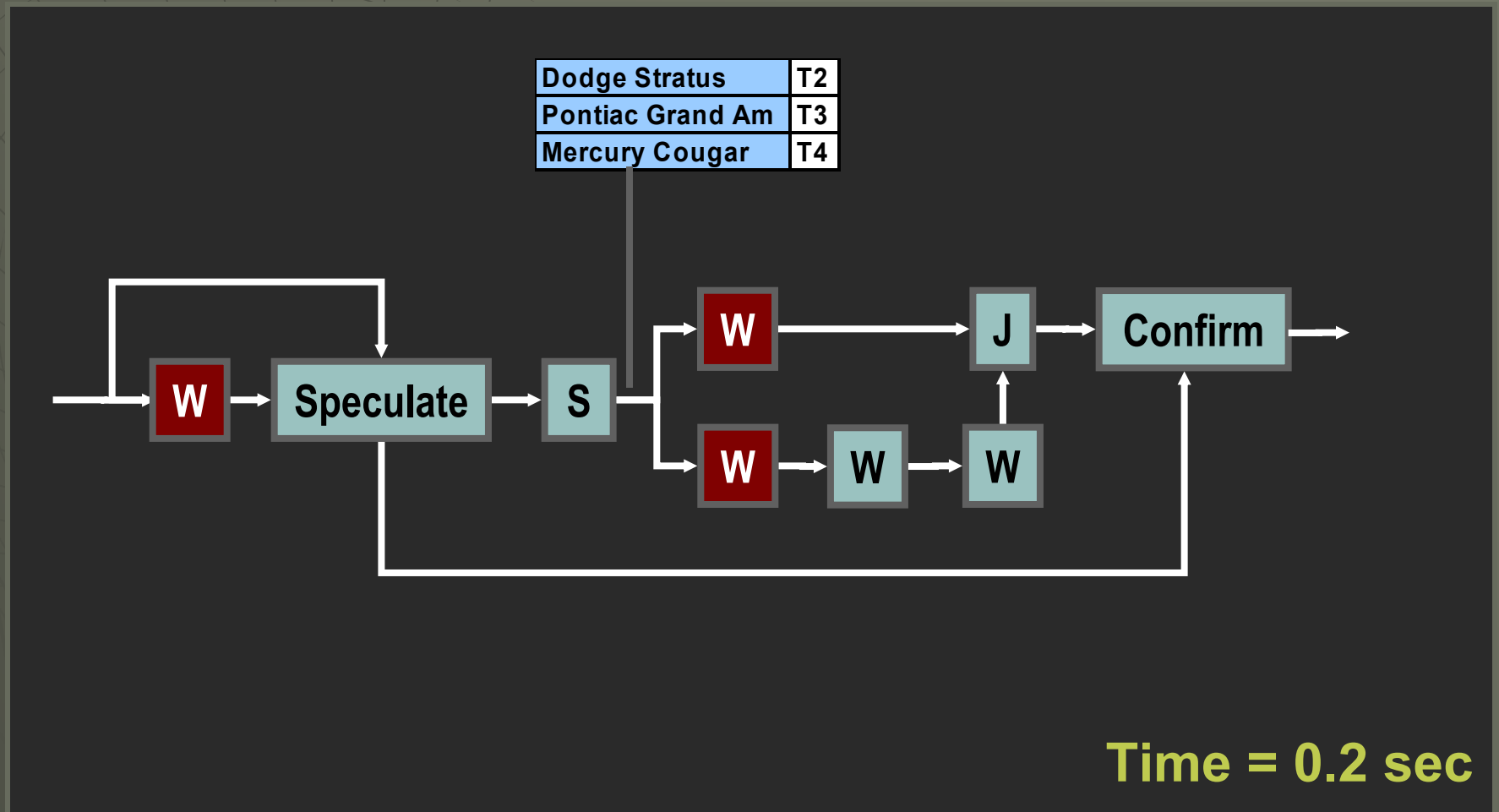
Issuing predictions

Oldsmobile Alero	T1
Dodge Stratus	T2
Pontiac Grand Am	T3
Mercury Cougar	T4

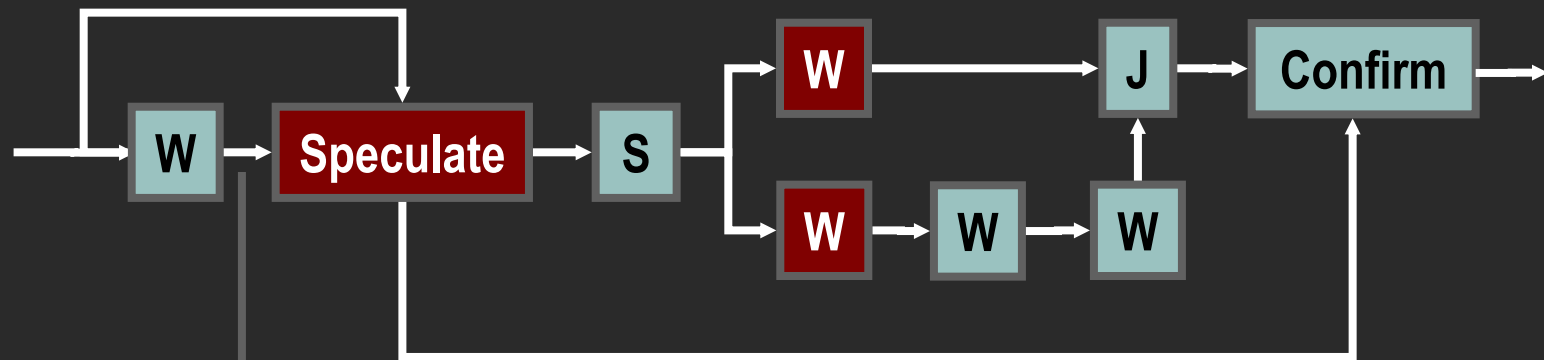


Time = 0.1 sec

Speculative parallelism



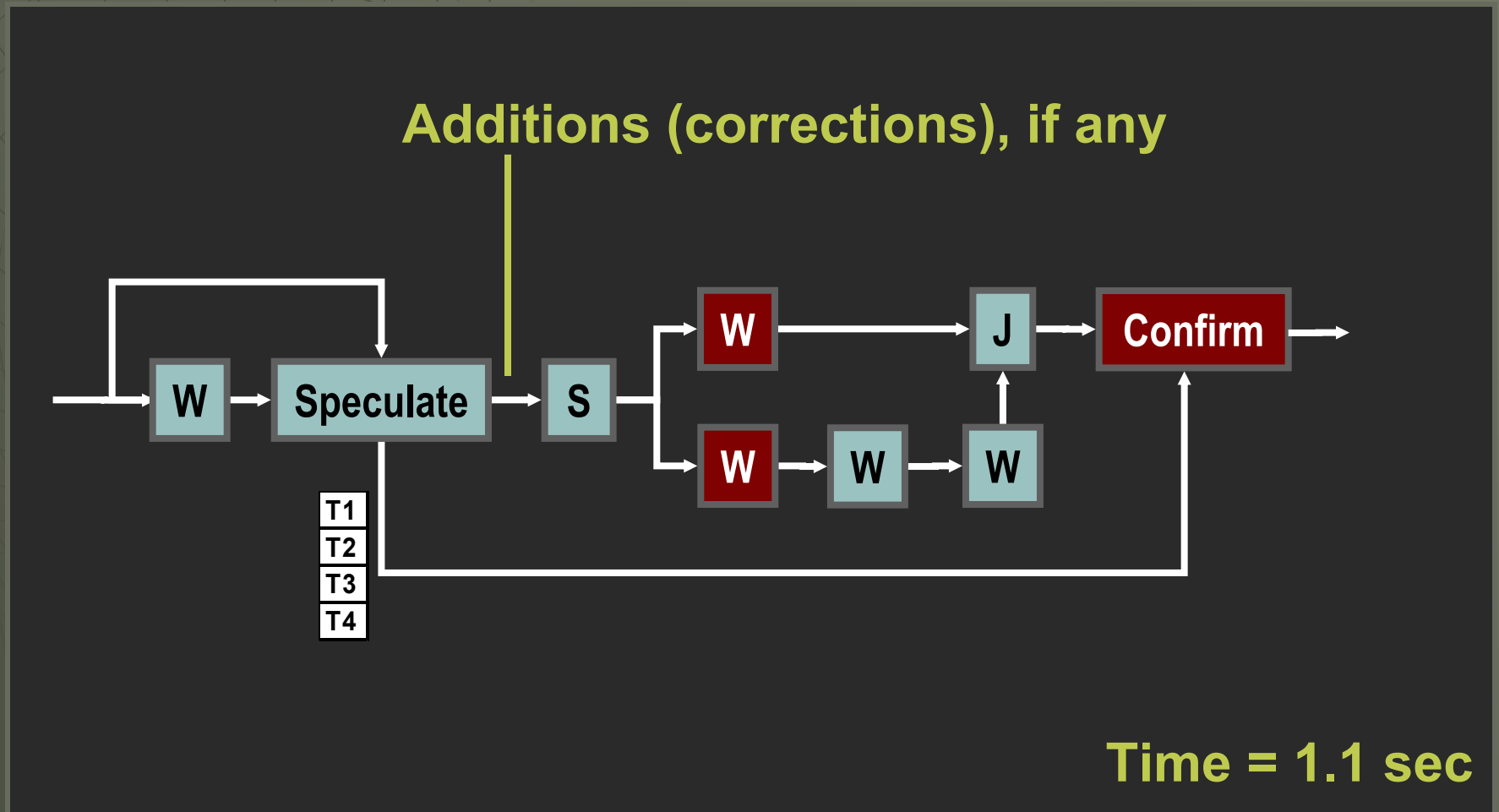
Answers to hints



Oldsmobile Alero
Dodge Stratus
Pontiac Grand Am
Mercury Cougar

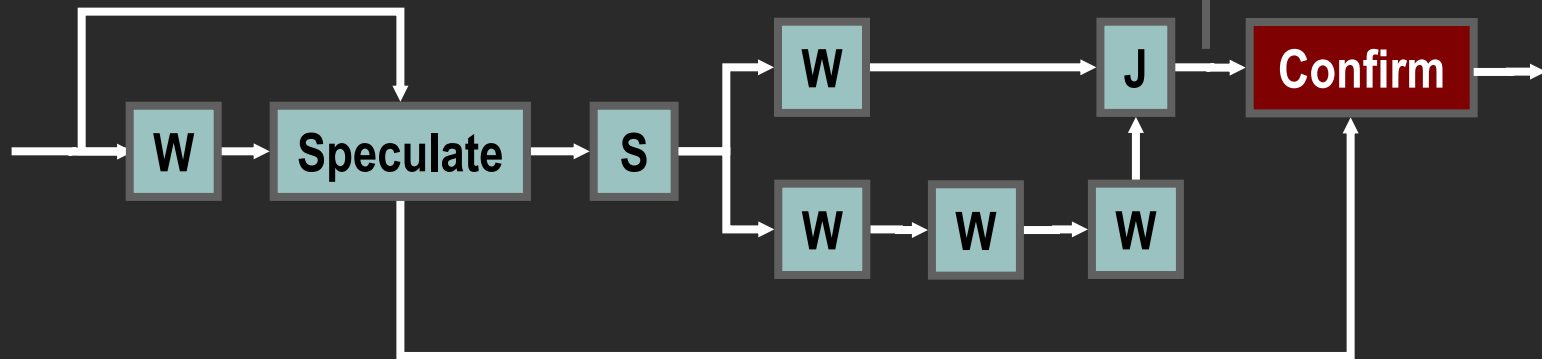
Time = 1.0 sec

Continued processing



Generation of final results

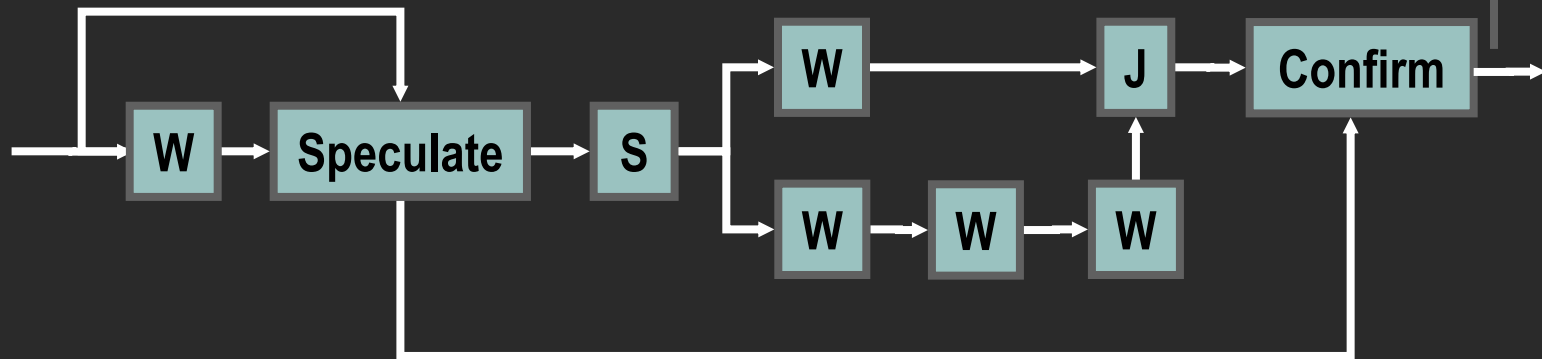
Dodge Stratus	(safety)	(review)	T2
Pontiac Grand Am	(safety)	(review)	T3
Mercury Cougar	(safety)	(review)	T4



Time = 3.2 sec

Confirmation of results

Dodge Stratus	(safety)	(review)
Pontiac Grand Am	(safety)	(review)
Mercury Cougar	(safety)	(review)



Time = 3.3 sec

Safety and fairness

◆ Safety

- **Confirm** blocks predictions (and results of) from exiting plan before verification

◆ Fairness

• CPU

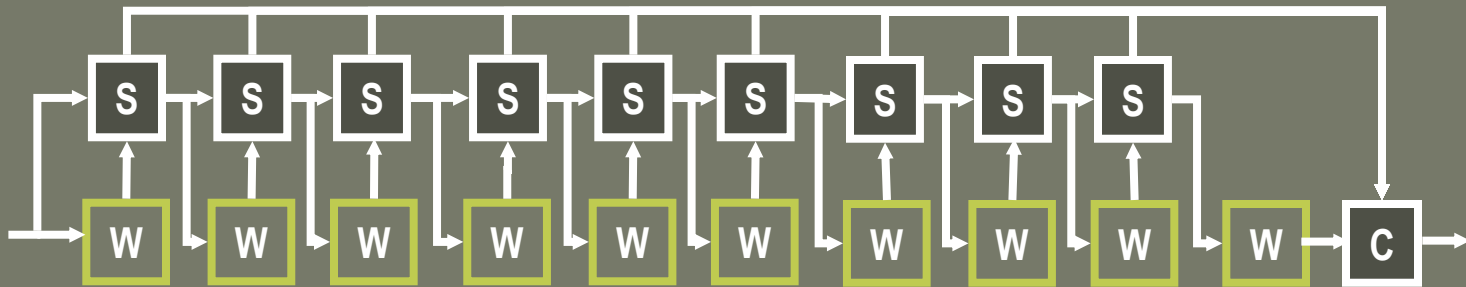
- ◆ Speculative operations use "speculative threads"
 - Lower priority threads

• Memory and bandwidth

- ◆ Speculative operations allocate "speculative resources"
 - Drawn from "speculative pool" of memory / objects

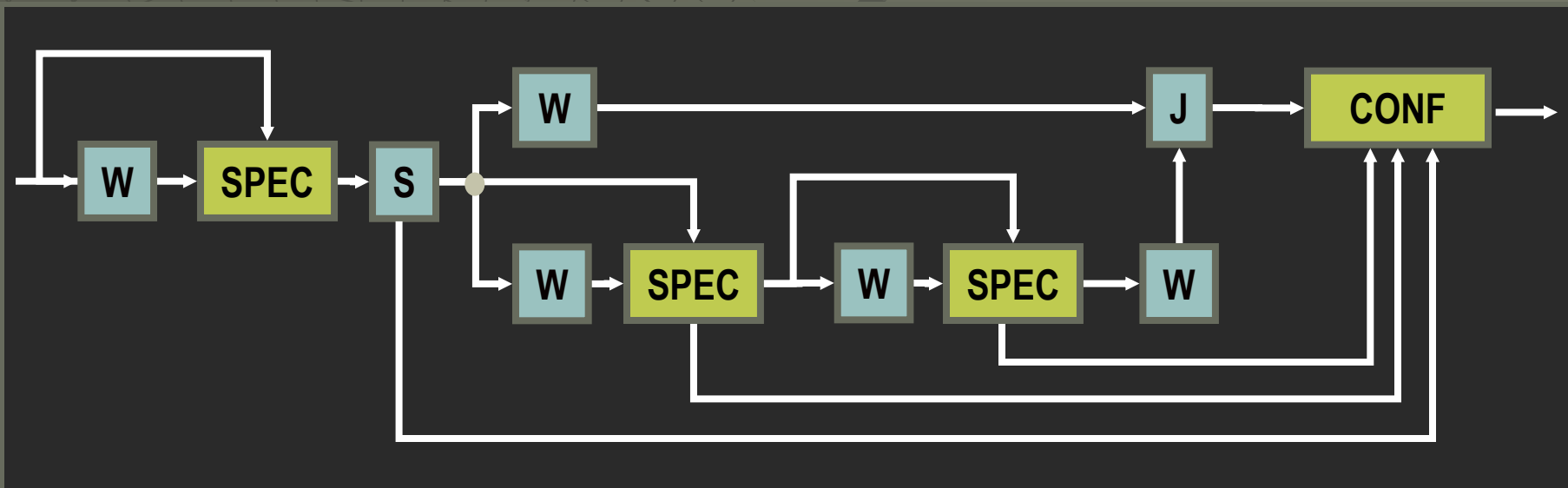
Getting better speedups

- ◆ Cascading speculation
 - Single speculation allows a max speedup of 2
 - ◆ Time spent either speculating or confirming
 - Cascading speculation allows **arbitrary speedups**
 - ◆ Up to the length of the longest plan flow



Cascading Speculation

- ◆ Use predicted cars to speculate about the ConsumerGuide summary and full URLs



- ◆ Optimistic performance

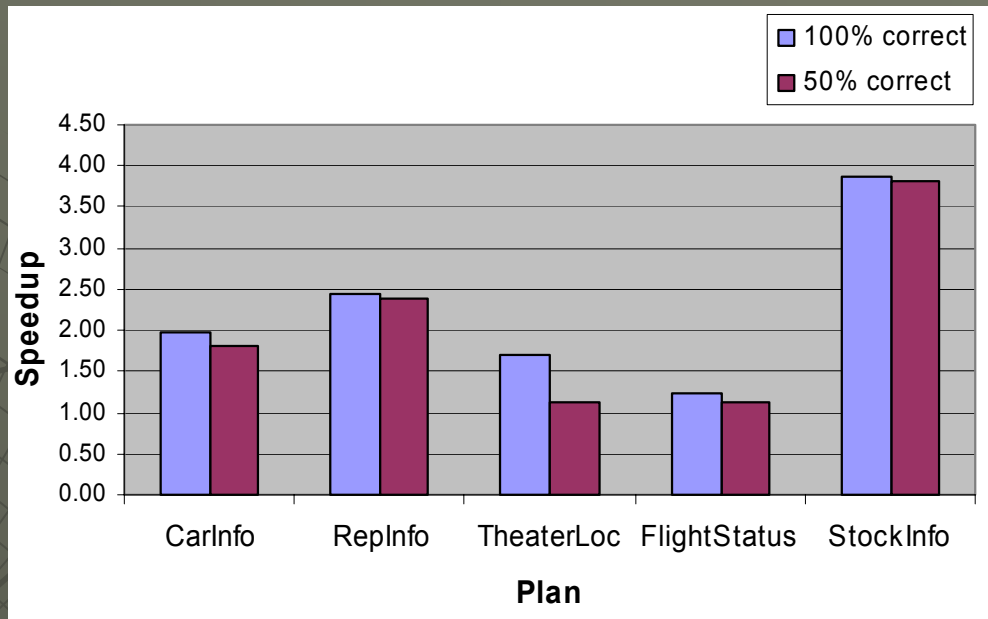
- Execution time: **max** {1.2, 1.4, 1.5, 1.6} = **1.6 sec**
- Speedup over streaming dataflow: $(4.2/1.6) = \mathbf{2.63}$

Automatic plan transformation

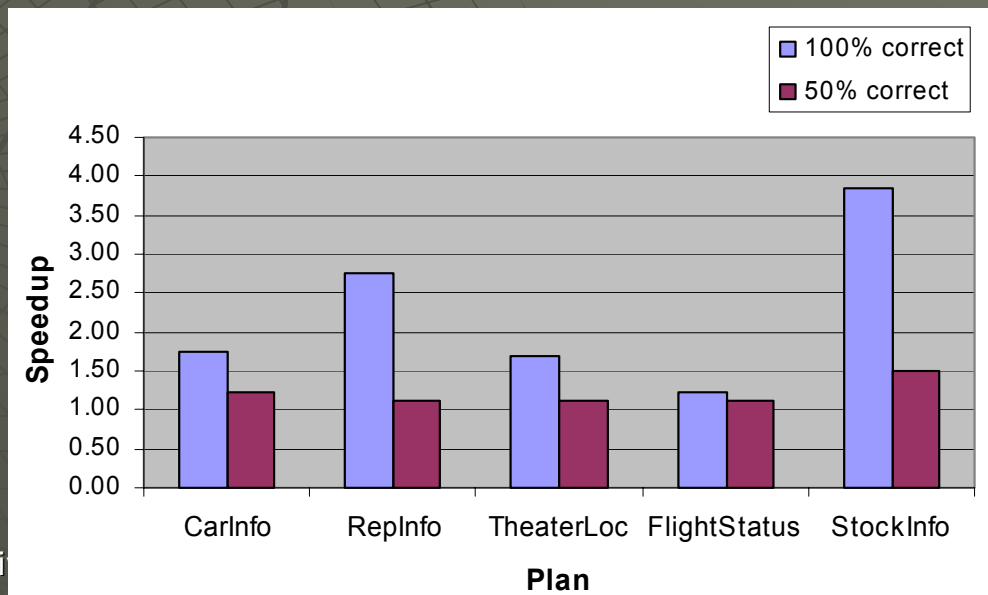
- ◆ Agent plans are automatically modified for speculative execution
 - **Successive runs of the plan benefit**
 - ◆ Even with different input data
- ◆ Optimize only the most expensive path (**MEP**)
- ◆ Algorithm
 - 1. Find MEP**
 - 2. Find best candidate speculative plan transformation**
 - 3. IF no candidate found, THEN exit**
 - 4. Transform plan accordingly**
 - 5. REPEAT** (anytime property)

Speculation Results

◆ Time to first tuple:



◆ Time to last tuple:



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Value prediction

- ◆ Better value prediction = better speedups
- ◆ Prediction capability

Category	Hint	Prediction
A	Previously seen	Previously seen
B	Never seen	Previously seen
C	Never seen	Never seen

- ◆ Examples:

Edmunds car list from search criteria

5K-12K ?

H → 2002 Midsize coupe 4K-12K

P → Olds Alero, Dodge Stratus, Pontiac Grand Am, Mercury Cougar

ConsumerGuide full review URL from summary URL

<http://cg.com/summary/20812.htm>

<http://cg.com/full/20812.htm>

[http://cg.com/summary/12345.htm ?](http://cg.com/summary/12345.htm)

Learning for Speculative Execution

◆ Caching

- Associate a hint with a predicted value
 - ◆ 2002 Midsize coupe 4K-12K
 - Olds Alero, Dodge Stratus, Pontiac Grand Am, Mercury Cougar

◆ Classification

- Use features of a hint to predict value
 - ◆ **EXAMPLE:** Predicting car list from Edmunds

Year	Type	Min	Max	Car list
2002	Midsize	8000	15000	(Oldmobile Alero, Dodge Stratus)
2002	Midsize	7500	14500	(Oldmobile Alero, Dodge Stratus)
2002	SUV	14000	20000	(Nissan Pathfinder, Ford Explorer)
2001	Midsize	11000	18000	(Honda Accord, Toyota Camry)
2002	SUV	18000	22000	(Nissan Pathfinder, Ford Explorer)

← Cache

Decision list →

type = SUV : (Nissan Pathfinder, Ford Explorer)
type = Midsize :
...min ≤ 10000 : (Olds Alero, Dodge Stratus)
min > 10000 : (Honda Accord, Toyota Camry)

Learning for Speculative Execution

◆ Transduction

- Transducers are FSM that translate hints into predictions

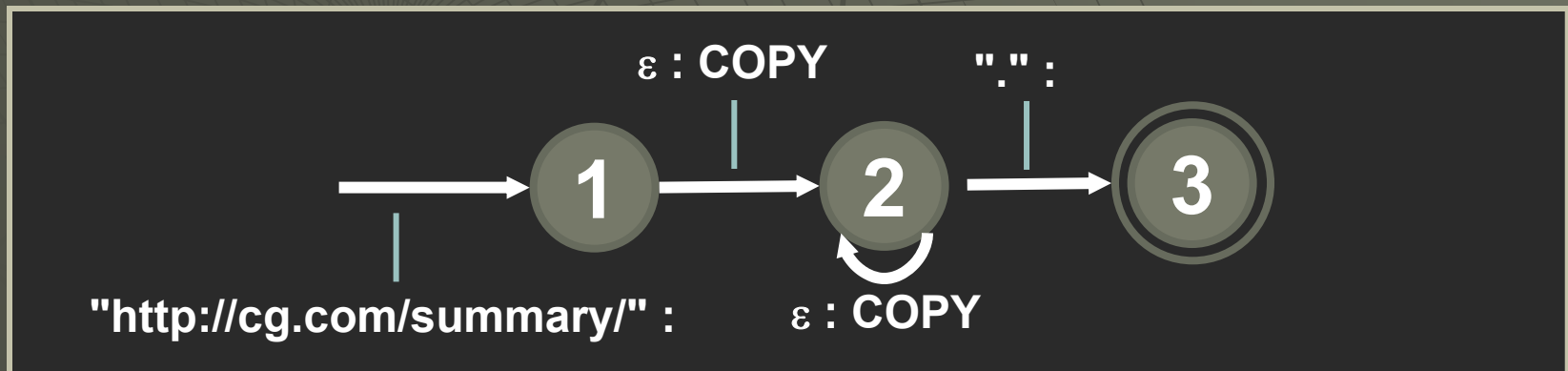
<http://cg.com/summary/20812.htm>



<http://cg.com/full/20812.htm>

To create full review URL:

1. Insert "http://cg.com/full/"
2. Extract & insert the dynamic part of the summary URL (e.g., 20812)
3. Insert ".htm"



Unifying Algorithm: Learn Value Transducers

- ◆ Combines different learning methods
- ◆ Identify predicted value "templates"
 - Alternating seq of STATIC/DYNAMIC elements
- ◆ Value transducers built from templates
 - State transitions (arcs) = high-level operations:
 - ◆ **INSERT, CACHE, CLASSIFY, TRANSDUCE**

<http://cg.com/summary/20812.htm>

TRANSDUCE



<http://cg.com/full/20812.htm>

1

STATIC

2

DYNAMIC

3

STATIC

Craig Knobloch, University of So

Dodge Stratus

CACHE or CLASSIFY



<http://cg.com/summary/20812.htm>

1

STATIC

2

DYNAMIC

3

STATIC

Learning value transducers

- ◆ Identify **STATIC/DYNAMIC** template
 - Find LCS for the set of predicted values, using technique based on (Hirschberg 1975)
- ◆ For each **STATIC** element,
 - Construct **INSERT** arc to next automata state
- ◆ For each **DYNAMIC** element,
 - Construct **TRANSDUCE**, **CLASSIFY**, or **CACHE** arc to next automata state
 - ◆ Prefer **TRANSDUCE** and **CLASSIFY** because
 - Better predictive capability on average
 - Better space efficiency on average

Detailed example: CarInfo URLs

HINTS:

<http://cg.com/summary/20812.htm>

<http://cg.com/summary/12345.htm>

ANSWERS:

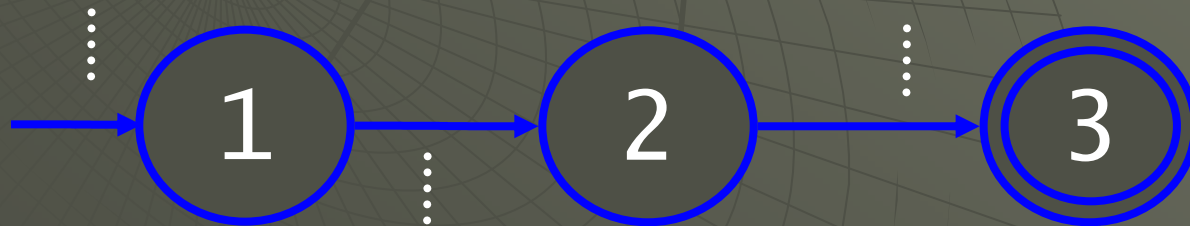
<http://cg.com/full/20812.htm>

<http://cg.com/full/12345.htm>

TEMPLATE

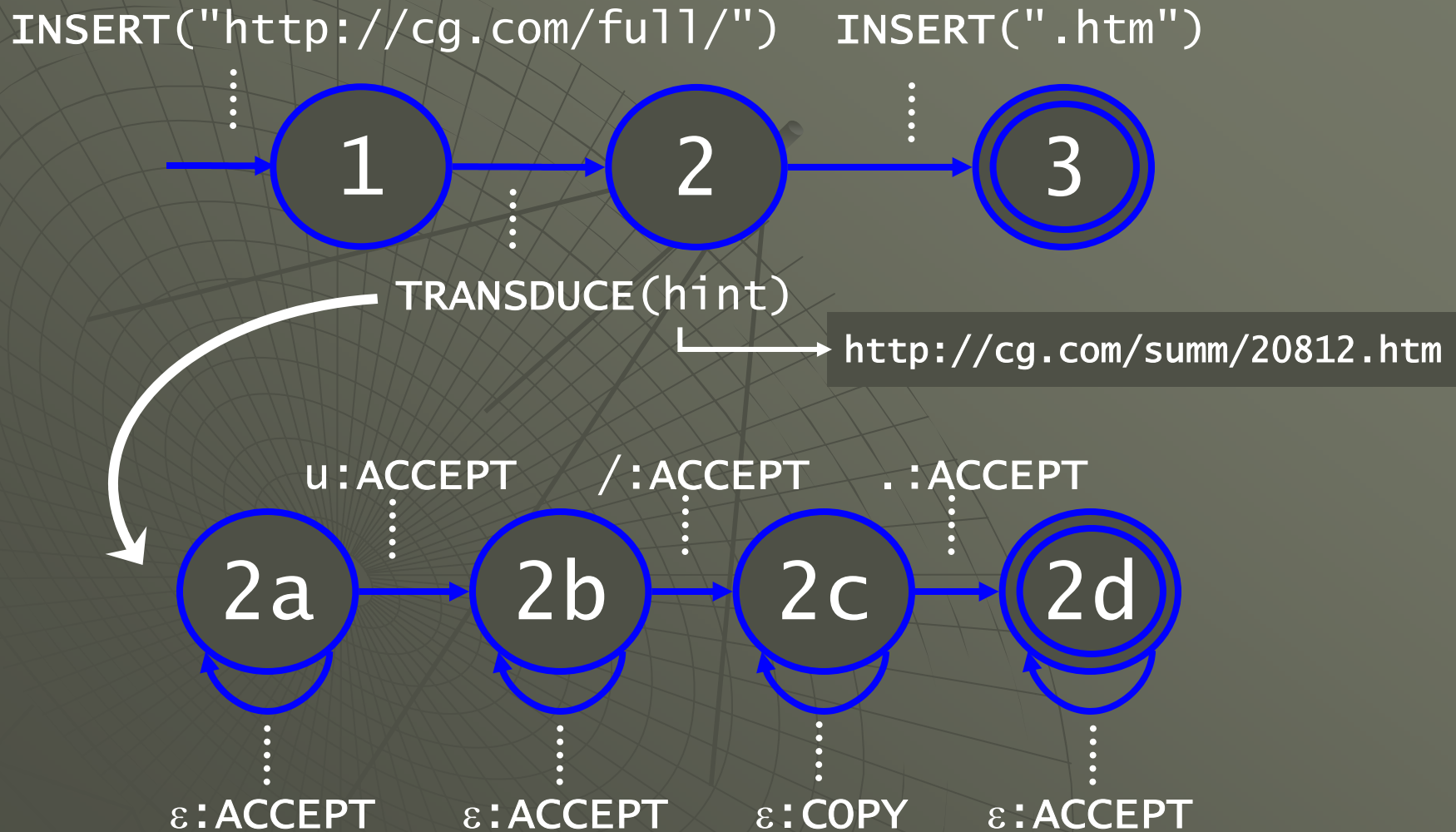
[http://cg.com/full/\[DYNAMIC\].htm](http://cg.com/full/[DYNAMIC].htm)

INSERT("http://cg.com/full/") INSERT(".htm")



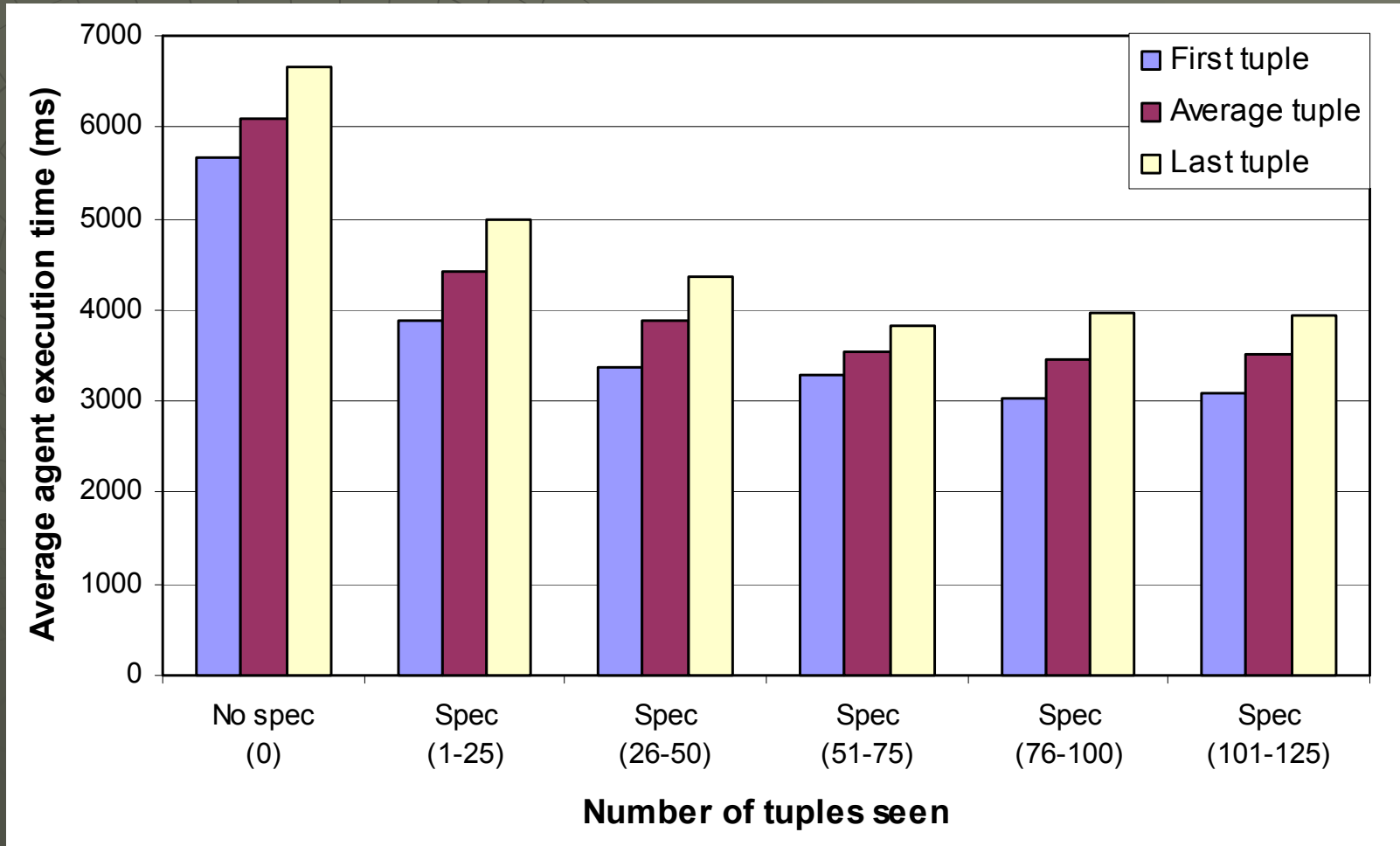
TRANSDUCE

Example Value Transducer



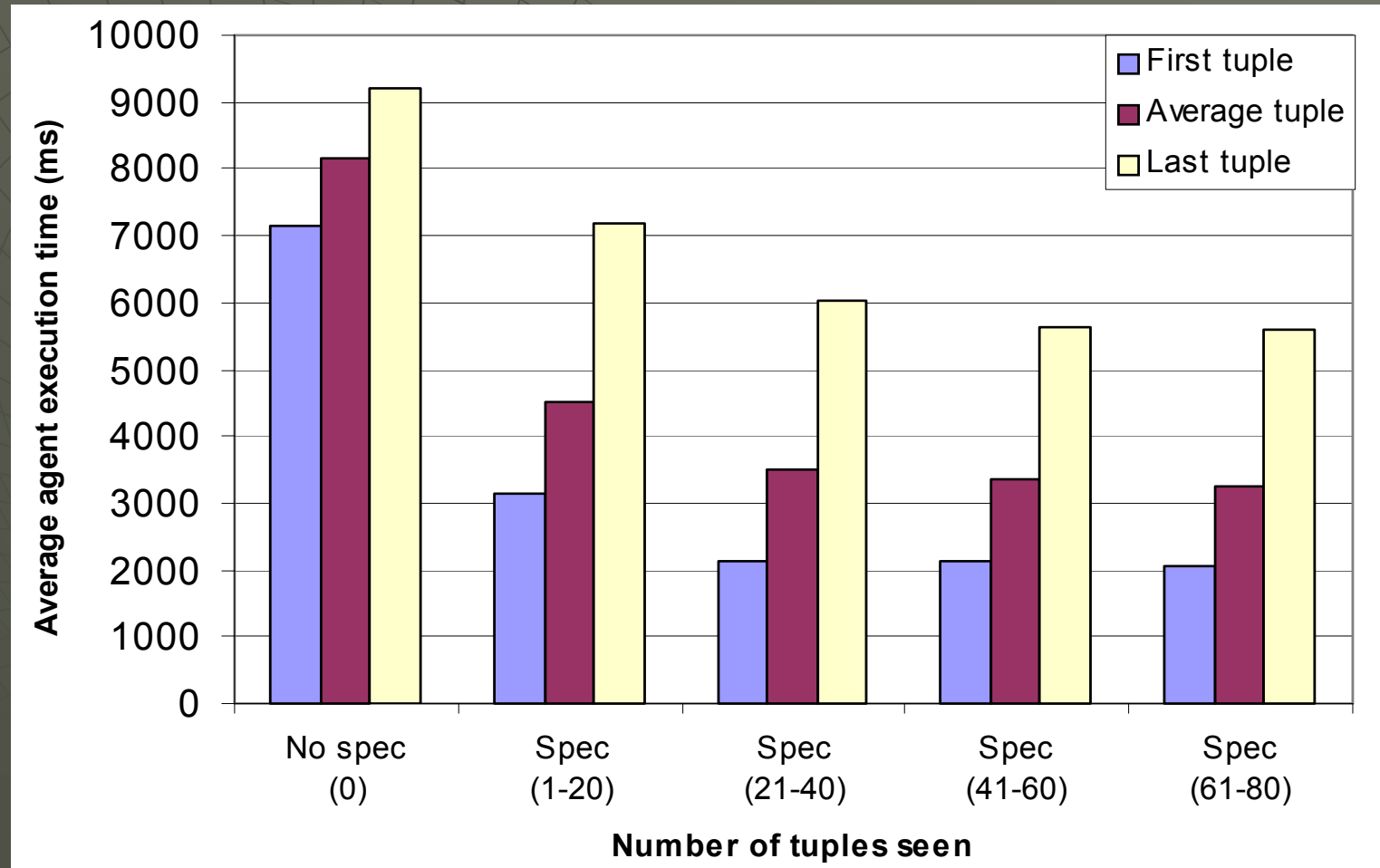
Effect on spec exec performance

◆ CarInfo



Effect on spec exec performance

◆ RepInfo



Outline

1. Motivating Application: The Electric Elves
2. Efficiently executing agent plans
3. Speculative plan execution
4. Value prediction for speculative execution
5. **Related Work**
6. Conclusions

Related Work

- ◆ Speculative execution
 - **Approximate & partial query results**
 - ◆ [Hellerstein et al. 1997] [Shanmugasundaram et al. 2000] [Raman and Hellerstein 2001]
 - **Executing anticipated actions in advance**
 - ◆ Continual computation [Horvitz 2001], time-critical decision making [Greenwald and Dean 1994]
 - **Other types of speculative execution**
 - ◆ File system prefetching [Chang and Gibson 1999], control speculation in workflow processing [Hull et al. 2000]
 - **Network prefetching**

Related Work

- ◆ Learning value predictors
 - Predicting commands
 - ◆ **Command line prediction** [Davison and Hirsh 1998, 2001]
 - ◆ **Assisted browsing** [Lieberman 1995] [Joachims et al. 1997]
 - Value prediction as speedup learning
 - ◆ [Fikes et al. 1972], [Mitchell 1983], [Minton 1988]
 - Transducer learning
 - ◆ **Provably correct transducers** [Oncina et al. 1993]
 - Issues: Requires many examples, generalization capability differs
 - ◆ **Transducers for data extraction** [Hsu and Chang 1999]
 - URL prediction
 - ◆ [Zukerman et al. 1999], [Su et al. 2000]

Outline

1. Motivating Application: The Electric Elves
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Summary

- ◆ An approach to **speculative execution** of information agent plans
 - Can yield arbitrary speedups
 - Safe, fair
- ◆ Value prediction approach that combines **caching, classification, and transduction**
 - More accurate & space efficient than strictly caching

Conclusions

- ◆ Speculative execution is a form of speed-up learning
- ◆ Two very large search spaces:
 - Plan transformations for speculative execution
 - Value prediction for each speculate operator
- ◆ Both of these are potential opportunities for CBR in information gathering
 - Could learn finer-grained plan transformations that depend on the request
 - Could learn more sophisticated value prediction strategies (e.g., speculating on multiple inputs)
- ◆ Finding the right speculative plan and value predictions can provide significant speedups!

More Information

- ◆ My home page:
<http://www.isi.edu/~knoblock>
- ◆ Papers:
 - Theseus execution system: JAIR'05
 - Speculative execution: ICAPS'02
 - Value prediction: IJCAI'03
 - Electric Elves: IAAI'01, IAAI'02
- ◆ Thesis:
 - Greg Barish, 2004, USC



The End