

VeriWeb: Automatically Testing Dynamic Web Sites

Juliana Freire

<http://www-db.bell-labs.com/~juliana>

Bell Labs

Joint work with Michael Benedikt and Patrice Godefroid

Web pages became very complex



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The screenshot shows the Travelocity.com website interface. At the top, there is a navigation bar with links for Home, Dream, Plan, Go, Flights, Lodging, Cars, Vacations, Cruises, Deals & Rewards, and My Stuff. Below this is a secondary navigation bar with Travelocity and Business Travel Center. The main content area is divided into several sections: 'Dream, Plan, Go' with a search box and 'Best fare finder' form; 'Special Offers' with a 'Win a trip to a Castle!' promotion; 'Customer Service' with a 'Alert: Comair flight cancellation info' and a '24/7 Support' link; 'Deals & News' with a 'ATA's Spring Forward Sale!' and 'More Reasons to Love L.A. | United Offers Fares from \$79!'; 'Partners' with 'BRITISH AIRWAYS' and '21st Century Air Travel'; 'Fare Watcher' with a table of flight prices; 'Vacations & Cruises' with 'Lowest Cruise Rates of the Year Now Available!'; and 'Tip of the week' with 'Flying with Fido? Check out our tips for traveling with your pet.' The footer contains international site links, a site guide, and various legal notices.

- ◆ Almost 90 different actions (85 links and 3 forms);
- ◆ 96 gif images;
- ◆ 113 lines of JavaScript code;
- ◆ ~570 lines of HTML

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Web navigation became very complex



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Travel Tools: Reservations, Today's Deals, Information/Guides, Fare Weather, Special Deals, Destination Guide

Find the best fare for your country's flight now! Leaving from: Going to: Adults: Children: Seniors:

Special Offers: **SAVE 20% OFF** AVIS

Travel Alerts: **Special Rates on Sale - As Low as \$150 Roundtrip**

Member Rewards: Earn 20,000 AA+ Rewards Bonus Miles. **Star Coach**: Super savings on your favorite vacation destinations.

Enter login info

Welcome easySABRE Members... Click here to Log In

Been here before? Remember my login name

First time here?

Your security is guaranteed on Travelocity.com!

Login name: [jrose]

Password: [*****]

My location: [Use My Profile Address]

Remember my login name

Terms and Conditions

Making travel reservations through Travelocity.com is FREE. We only need a credit card number on file when you put a reservation on hold or purchase tickets. To keep your credit card information private, we recommend that you use Internet Explorer's Internet Options to secure Travelocity.com. Helppage Navigator uses a "secure socket layer" encryption to protect information you send over the Internet.

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5 navigation steps,
650kb transferred

Choose 9 best itineraries

Travelocity.com **Best fare finder** Tell us what you want

My travel dates are flexible.

- Search for the lowest fares offered and show me the dates I can travel.
- NEW!** Now available for all domestic and international travel.

Travelocity.com **Best Itineraries** Tell us what you want

My travel dates are NOT flexible but my travel times are.

- Search for the nine best-priced itineraries for my date(s).
- Available for all domestic and international travel.

Travelocity.com **Search By Schedule** Tell us what you want

I need to travel on specific dates and times.

- Search all flights so that I can build my own itinerary, then show me the total price. (Travelocity will also find up to three low-cost alternatives.)
- Available for all domestic and international travel.

Travelocity.com **Name Your Own Price** Tell us what you want

I want to name my own price with priceline.com

- My flight times and connections are flexible.
- I choose the travel dates, but the airlines will choose flights and times where they have seats available.
- Only valid for travel originating in United States or Puerto Rico and returning to United States.

Travelocity.com **Select a Flight**

Flying from 21 gateways in the US to 81 countries. You won't find a better service provider. **BRITISH AIRWAYS** The world's favorite airline.

Select a flight with our express buy feature... the fastest path to travel. All times shown are local to each city. Click Buy to purchase your tickets. If you're not ready to purchase your tickets now, click Hold if that option is offered.

Option 1 **Price:** \$648 @ USD 1122.70 **Total:** us\$ 1122.70

Singapore Airlines Flight 23 on a Boeing 747
From: Newark, NJ (EWR) **Sunday, May 14** 10:15pm
To: Amsterdam Netherlands (AMS) **Monday, May 15** 11:20am

British Midland Flight 106 on a Boeing 737-300
From: Amsterdam Netherlands (AMS) **Saturday, May 20** 1:40pm
To: London Heathrow, UK (LHR) 1:20pm

British Airways Flight 189 on a Boeing 777-300
From: London Heathrow, UK (LHR) **Saturday, May 20** 3:15pm
To: Newark, NJ (EWR) 6:05pm

Option 2 **Price:** \$648 @ USD 1139.10 **Total:** us\$ 1139.10

Singapore Airlines Flight 23 on a Boeing 747
From: Newark, NJ (EWR) **Sunday, May 14** 10:15pm
To: Amsterdam Netherlands (AMS) **Monday, May 15** 11:20am

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British Airways Flight 189 on a Boeing 777-300
From: London Heathrow, UK (LHR) **Saturday, May 20** 3:15pm
To: Newark, NJ (EWR) 6:05pm

Flight list

Travelocity.com **Book a Flight**

Switch me to... **Best fare finder** Tell us what you want | **Search By Schedule** Tell us what you want

9 Best Itineraries

1 What type of trip do you want to take?
 Round Trip One Way Multiple Destinations

2 How many travelers?
Total number of travelers: [1] How many are aged 2 thru 11? [0]

3 What is your departure and destination?
Departure City/Airport: [Newark, NJ] Search for the closest airport.
Destination City/Airport: [AMS] Search for the closest airport.
Return Date: [May 20] [20] Calendar Departure Time: [6:00 PM] Arrival Time: [1:00 PM]

4 How would you like us to price this trip?
 Economy class with restrictions. **Anytime** on my travel dates, up to [2] connections Save!
 Available for round trip within the United States only
 Economy class with restrictions. Prefer to stay close to my desired travel times
 Economy class without restrictions
 Business class
 First class

5 Do you have an airline preference?
 Search all airlines Search [airline]

Enter itinerary

Many things can go wrong

- ◆ Interactions between HTML pages
- ◆ Applications that run in Web pages (e.g., applets, javascript, plug-in applications)
- ◆ Applications that run on the server side (e.g., cgi scripts, database interfaces, logging applications, dynamic page generators, asp)
- ◆ Wide variety of servers and browsers
- ◆ Rapidly changing technologies, multiple standards and protocols

Many things can go wrong

- ◆ Interactions between HTML pages
- ◆ Applications that run in Web pages (e.g., applets, javascript, plug-in applications)
- ◆ Applications that run on top of scripts, database interfaces, dynamic page generators,
- ◆ Wide variety of servers and protocols
- ◆ Rapidly changing technologies



The screenshot shows a web page for 'benefits central'. On the left is a vertical navigation menu with links: 'my health and wellness', 'my earnings and savings', 'my life@work', and 'my changing'. The main content area features the 'benefits central' logo and a personalized greeting: 'Hello, JULIANA FREIRE. Welcome to your personalized benefits website!'. Below this is a 'hot news & features' section with three items: 'Your Benefits Snapshot Your Information for 2001.', 'Visit the Library For online forms and tools.', and 'Browse Service Awards on is here.'. At the bottom, there is a 'Lucent Stock Quote:' section with the following data: 'V057_STOCK_PRICE_' and 'V058_STOCK_CHG_'.

Need testing!

Web Site Testing: Challenges



- ◆ Sites are complex applications: hard to test
- ◆ Web sites are updated often (content and structure) → hard to keep testsuite up-to-date manually
- ◆ Web-based systems are highly intertwined with the environment (browsers, operating systems, database engines, applications, etc) → impossible to test stand-alone
- ◆ Users are inexperienced → unexpected behavior
 - Need to test system response to the actions of novice/inexperienced users: number of error conditions is huge

Changes to Travelocity



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Home Dream, Plan, Go Flights Lodging Cars Vacations Cruises Deals & Rewards My Stuff

Find the best round trip
From: [City] To: [City]
My dates are flexible
I need to depart [Date] and return [Date]
Adults: [Number] Children: [Number] Seniors: [Number]
[Search Now]

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Find the best round trip
From: [City] To: [City]
My dates are flexible
I need to depart [Date] and return [Date]
Adults: [Number] Children: [Number] Seniors: [Number]
[Search Now]

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Adults: [Number] Children: [Number] Seniors: [Number]
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I need to depart [Date] and return [Date]
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[Search Now]

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[Search Now]

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Find the best round trip
From: [City] To: [City]
My dates are flexible
I need to depart [Date] and return [Date]
Adults: [Number] Children: [Number] Seniors: [Number]
[Search Now]

Welcome back Juliana
Not Juliana? [Log in as a different user.](#)

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Find the best round trip
From: [City] To: [City]
My dates are flexible
I need to depart [Date] and return [Date]
Adults: [Number] Children: [Number] Seniors: [Number]
[Search Now]

Travel advice personalized for YOU.
Let our Trip Expert help you.

Fare Watcher
From: [City] To: [City]
Price: [Amount]

Flight Deals
From: [City] To: [City]
Price: [Amount]

Lodging Deals
From: [City] To: [City]
Price: [Amount]

Travel Alerts

Select a Flight

Flying from 21 gateways in the US to 81 countries. You won't find a better service provider. [Click here.](#)

Select a flight with our express buy feature... Use fastest path to travel. All times shown are local to each city. [Click Buy](#) to purchase your tickets. If you're not ready to purchase your tickets now, click [Hold Save](#). That option is offered.

Option 1	Preferred	Adult @ USD 1122.70	Total: USD 1122.70
		Singapore Airlines Flight 23 on a Boeing 747 From: Newark, NJ (EWR) To: Amsterdam (AMS) Monday, May 14 10:15pm Monday, May 15 11:20am	
		British Midland Flight 106 on a Boeing 737-300 From: Amsterdam (AMS) To: London Heathrow, UK (LHR) Saturday, May 20 1:40pm 1:50pm	
		British Airways Flight 189 on a Boeing 777-300 From: London Heathrow, UK (LHR) To: Newark, NJ (EWR) Saturday, May 20 3:19pm 6:05pm	
Option 2	Preferred	Adult @ USD 1139.10	Total: USD 1139.10
		Singapore Airlines Flight 23 on a Boeing 747 From: Newark, NJ (EWR) To: Amsterdam (AMS) Monday, May 14 10:15pm Monday, May 15 11:20am	
		Lufthansa Flight 9006 operated by British Midland on a Boeing 737 From: Amsterdam (AMS) To: London Heathrow, UK (LHR) Monday, May 14 1:40pm 1:50pm	
		British Airways Flight 189 on a Boeing 777-300 From: London Heathrow, UK (LHR) To: Newark, NJ (EWR) Saturday, May 20 3:19pm 6:05pm	

Select a Flight

Select a flight with our express buy feature... Use fastest path to travel. All times shown are local to each city. [Click Buy](#) to purchase your tickets. If you're not ready to purchase your tickets now, click [Hold Save](#). That option is offered.

Option 1	Preferred	Adult @ USD 1117.98	Total: USD 1117.98
		Neosair, NJ (EWR) to Hong Kong, Hong Kong (HKG) Departure Date: [Date] Return Date: [Date] Preferred Time Range: [Time]	
		Flight United Airlines Flight 643 on a Boeing 727-200 Jet Departure: Friday, Apr 27 From: Newark, NJ (EWR) @ 9:15am To: Chicago O'Hare (ORD) @ 9:23am Friday, Apr 27 Stop: None	
		Flight United Airlines Flight 895 on a Boeing 747 Jet Departure: Friday, Apr 27 From: Chicago O'Hare (ORD) @ 11:00am To: Hong Kong, Hong Kong (HKG) @ 4:29pm Saturday, Apr 28 Stop: None	
		Flight United Airlines Flight 896 on a Boeing 747 Jet Departure: Sunday, May 06 From: Hong Kong, Hong Kong (HKG) @ 8:00am To: Chicago O'Hare (ORD) @ 9:23am Sunday, May 06 Stop: None	
		Flight United Airlines Flight 644 on a Boeing 737-200 Jet Departure: Sunday, May 06 From: Chicago O'Hare (ORD) @ 11:30am To: Newark, NJ (EWR) @ 2:31pm Sunday, May 06 Stop: None	
Option 2	Preferred	Adult @ USD 1135.16	Total: USD 1135.16
		Flight United Airlines Flight 837 on a Boeing 757 Jet Departure: Friday, Apr 27	

Select a Flight

Select a flight with our express buy feature... Use fastest path to travel. All times shown are local to each city. [Click Buy](#) to purchase your tickets. If you're not ready to purchase your tickets now, click [Hold Save](#). That option is offered.

Option 1	Preferred	Adult @ USD 726.50	Total: USD 726.50
		Flight TAM Linhas Aereas S.A. Flight 8101 operated by American Airlines on a Boeing 767 Jet, non-stop Depart: Miami, FL (MIA) - Fri, Mar 22 at 7:45pm Arrive: Sao Paulo, Brazil (GRU) - Sat, Mar 23 at 6:15am	
		Flight TAM Linhas Aereas S.A. Flight 3520 on a Fokker 100 Jet, non-stop Depart: Sao Paulo, Brazil (GRU) - Sat, Mar 23 at 5:00am Arrive: Fortaleza, Brazil (FOR) - Sat, Mar 23 at 8:20am	
		Flight TAM Linhas Aereas S.A. Flight 3529 on a Fokker 100 Jet, 1-Stop Depart: Rio De Janeiro, Brazil (GRU) - Wed, Mar 27 at 6:00pm Arrive: Rio De Janeiro, Brazil (GRU) - Wed, Mar 27 at 8:20pm	
		Flight TAM Linhas Aereas S.A. Flight 8112 operated by American Airlines on a Boeing 777 Jet, non-stop Depart: Rio De Janeiro, Brazil (GRU) - Wed, Mar 27 at 10:45pm Arrive: Miami, FL (MIA) - Thu, Mar 28 at 4:48am	
Option 2	Preferred	Adult @ USD 726.50	Total: USD 726.50
		Flight TAM Linhas Aereas S.A. Flight 8101 operated by American Airlines on a Boeing 767 Jet, non-stop Depart: Miami, FL (MIA) - Fri, Mar 22 at 7:45pm	

Before April, 2001

Before Feb, 2002

Since Feb, 2002

State of the Art

- ◆ Crawlers: check links and pages for common errors
 - E.g., LinkCheck, SiteInspector, Weblint, Webtrends
 - check for broken links, unreachable pages, HTML errors, etc
 - limited to static Web pages: can't test Web applications
- ◆ Capture-replay tools: explore particular scenarios in a dynamic Web site
 - E.g., Macrobot, Silktest, etester, Rational TestStudio, etc.
 - users record* interactive Web site application scenarios that can be played back unattended on any predefined schedule
 - user's must manually create testing scenarios

Too many paths



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Home | Dream, Plan, Go | Flights | Lodging | Cars | Vacations | Cruises | Deals & Rewards | My Stuff

Travelocity | Business Travel Center

Dream, Plan, Go
Visit Monaco!
Still the glamour capital of Europe--sponsored by **Lexus!**
[Go to Destination Guides](#)

Search all destinations

Site Tools

Flights **Lodging** **Cars** **Vacations** **Cruises**

Best fare finder
Show me the best roundtrip for: any date specific dates
From: To: Adults: 1
Depart: Return:

[Advanced Flight search](#)

Special Offers
Win a trip to a Castle!
Blockbuster Offers to Switzerland!
Switzerland Tourism
Protect your trip
Click here for details

Customer Service
Alert: [Comair flight cancellation info.](#)
[24/7 Support](#)
[Security Guarantee](#)
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• [More Reasons to Love L.A! United Offers Fares from \\$78!](#)
• [Fly Lufthansa to Europe from \\$458 roundtrip!](#)
• [Great 2-Night Deals in Orlando From \\$295 Per Person!](#)
• [Spring in Chicago! Hyatt Regency Chicago from \\$119.95!](#)

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Boston \$204 [Select](#)
Philadelphia [Select](#)
Los Angeles \$92 [Select](#)
Las Vegas [Select](#)
New York \$258 [Select](#)
San Francisco [Select](#)
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Norwegian Cruise Line wants to take you to Europe, Alaska, and Canada/New England for less!
[Great 2-Night Deals in Orlando From \\$295!](#)
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85 links, 3 forms

Web sites change

Go to travelocity.com

Flight list

Enter login info

Enter itinerary

Choose 9 best itineraries

And sites change all the time!



- ◆ Exercises multiple scenarios in a Web application that are automatically discovered by the system
 - Like a crawler it exhaustively searches the site for errors
 - Like a capture-replay tool, it exploits scenarios that include dynamic portions of sites
 - Unlike a crawler, it can go through forms
 - Unlike a capture-replay tool, no recording is needed

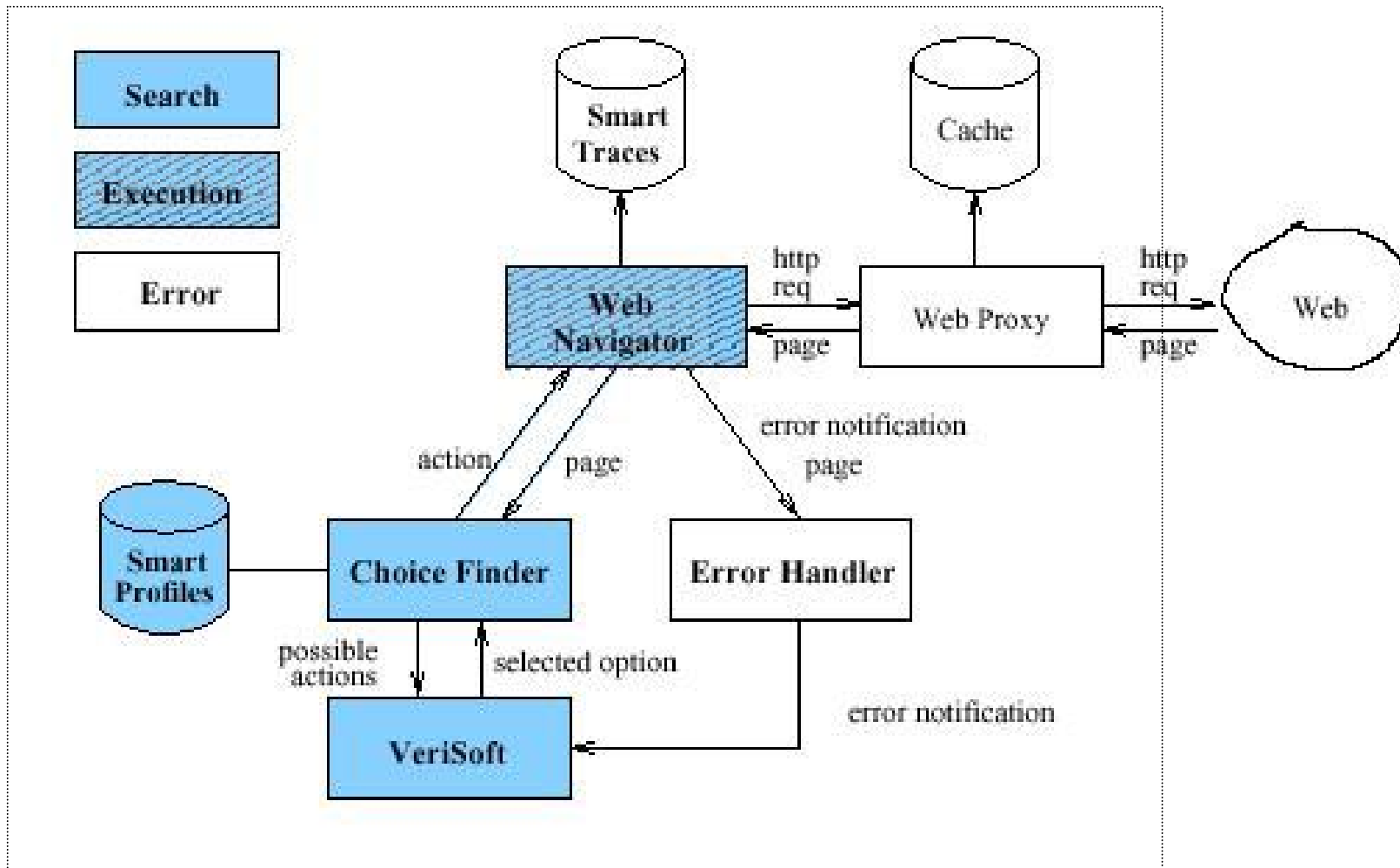
VeriWeb: Features

- ◆ **Functional testing** of both *static and dynamic elements* of Web site
- ◆ **Regression testing**
- ◆ **Standard correctness** checks (e.g., broken links, malformed URLs)
- ◆ **Realistic testing**
 - Tests are run through a Web browser and closely mimic users' actions

Outline

- ◆ VeriWeb architecture
- ◆ How does VeriWeb work?
- ◆ Automatically filling forms
- ◆ Controlling search
- ◆ Conclusion and Future Work

VeriWeb Architecture



Architecture Components

- ◆ ChoiceFinder
 - Find actions in page (JavaScript, links, forms)
- ◆ VeriSoft
 - Tool for systematic software testing ("model checking")
 - Controls the search
- ◆ WebNavigator
 - Executes browsing actions
- ◆ Error checker
 - Plugin your favorite checks (e.g., HTTP errors, HTML validation, ...)

How does VeriWeb work?

```
ExploreSite(startingURL, constraints)
currentPage = Navigator.load(startingURL);
while (true) {
    error = ErrorHandler(currentPage, constraints);
    if (error.status==true)
        VeriSoft.assert(currentPage, error);
    if (this page has been seen before)
        VeriSoft.abort(currentPage, ``cycle'');
    else {
        choices = ChoiceFinder(currentPage);
        selectedChoice = VeriSoft.toss(choices);
        currentPage =
            Navigator.execute(selectedChoice, choices);
        if (currentPage.error != null)
            VeriSoft.assert(currentPage, error);
    }
}
```


Form: Which values to use?

Login: _____

Password: _____

Form: Many Choices

Search Auto Classifieds

Keyword(s): (e.g. red mustang)

Price: From \$ to \$

Sale Type: [More Options...](#)

- ◆ 23 different values for both the From and the to prices (*i.e.*, Any, 1,000, 2,000, etc.);
- ◆ 4 values for the Sale Type (*i.e.*, No Preference, By Owner, etc.),
- ◆ Virtually infinite number of possible choices for Keyword(s);

Each way to fill up this form corresponds to a different action

- ◆ Flexible mechanism for populating forms
 - Provide values for text fields
 - Constrain the values for enumerated fields (e.g., lists)
- ◆ Tester specifies a **user view** of the data
 - independent of the structure of the Web site
 - reusable as structure of Web site changes
 - **not** scenario-based: testing engine tries all 'reasonable' combinations of profiles

SmartProfile: Specification

```
<!DOCTYPE smartprofile [  
<!ELEMENT smartprofile (signature* |  
  profile*) >  
<!ELEMENT signature (name, field+) >  
<!ELEMENT field (name, synonym) >  
<!ATTLIST field key CDATA >  
<!ELEMENT profile (name, signature,  
  fieldvalue+) >  
<!ELEMENT fieldvalue (name, regexp) >  
<!ELEMENT regexp (#PCDATA) >  
<!ELEMENT name (#PCDATA) >  
<!ELEMENT synonym (#PCDATA) >  
>
```

SmartProfiles: Signature



```
<signature>
  <name> CarType </name>
  <field key=true>
    <name> Make </name>
    <synonym> *carmake* </synonym>
  </field>
  <field key=false>
    <name> Model </name>
  </field>
  <field key=false>
    <name> Year </name>
  </field>
  <field key=false>
    <name> Interior </name>
  </field>
  <field key=false>
    <name> Type </name>
  </field>
</signature>
```

SmartProfiles: Profiles



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```
<profile>
  <name> HondaCivicSedan </name>
  <signature> CarType </signature>
  <fieldvalue>
    <name> Make </name>
    <regexp> Honda </regexp>
  </fieldvalue>
  <fieldvalue>
    <name> Model </name>
    <regexp> *Civic*Sedan* </regexp>
  </fieldvalue>
  <fieldvalue>
    <name> Year </name>
    <regexp> 1999|2000 </regexp>
  </fieldvalue>
  <fieldvalue>
    <name> Interior </name>
    <regexp> Beige </regexp>
  </fieldvalue>
  <fieldvalue>
    <name> Type </name>
    <regexp> Sedan </regexp>
  </fieldvalue>
</profile>
```

```
<profile>
  <name> Rolls </name>
  <signature> CarType </signature>
  <fieldvalue>
    <name> Make </name>
    <regexp> Rolls-Royce </regexp>
  </fieldvalue>
  <fieldvalue>
    <name> Model </name>
    <regexp> *Corniche* </regexp>
  </fieldvalue>
  <fieldvalue>
    <name> Year </name>
    <regexp> 2002 </regexp>
  </fieldvalue>
  <fieldvalue>
    <name> Type </name>
    <regexp> Convertible* </regexp>
  </fieldvalue>
</profile>
```

Filling out Forms

- ◆ Page analysis
 - find keywords related to fields in forms
- ◆ Profile-to-form matching
 - expression matching, default policies and thresholds

```
ExecuteForm(form, policy)
  formSchema = analyzeForm(form);
  candidateProfiles = findProfile(formSchema, policy);
  selectProfile = VeriSoft.toss(candidateProfiles);
  consistentCompletions = formCompletion(form, selectProfile);
  selectCompletion = VeriSoft.toss(consistentCompletions);
  currentPage = Navigator.fillOut(form, selectCompletion);
```

Controlling the Search

- ◆ Verisoft
- ◆ Filtering
 - Ignore "unimportant" actions, e.g., links to postscript, Word docs, external sites, mailto links,...
- ◆ Cycle detection
 - State vs. stateless: page that look identical may represent different states. E.g., the initial page of Amazon with and without cookies
 - Configurable cycle-detection
- ◆ Profile policies
 - Number of profiles of interest to the user may be too large to exhaustively test every combination
 - User can control the matching process, e.g., do not consider more than one match per signature in a path

Contributions: Summary

- ◆ Novel infrastructure to **automate testing of dynamic Web sites**
- ◆ Search algorithms for automatically exploring all the paths a user might follow in a Web application
- ◆ SmartProfiles as a high-level specification of test data to populate forms
- ◆ Strategies for automatically filling forms during site exploration.

Conclusions

- ◆ Creating profiles is an iterative process
 - System prompts tester for missing information
- ◆ Flexibility is key
- ◆ Currently experimenting with different Web sites
- ◆ Sites are often developed in an "ad hoc" manner:
they are hard to test
 - Need web engineering guidelines
 - High-level specifications

Acknowledgements

- ◆ Avinash Vyas
- ◆ Randy Hackbarth
- ◆ Joanna McCaffrey