

AI-Driven Test Generation

Machines Learning from Human Testers

36TH ANNUAL
PACIFIC NW SOFTWARE
QUALITY
CONFERENCE
OCTOBER 8-10, 2018

Dionny Santiago

Test Architect, Ultimate Software

Tariq M. King

Senior Director/Engineering Fellow, Ultimate Software

Peter J. Clarke

Associate Professor, Florida International University

Ultimate
SOFTWARE

FIU



Agenda

Motivation

AI/Machine Learning

Applying AI to Testing

State of the Art

Breaking into AI



Web Automation

Expensive

Lacks generality

High maintenance

Sign In

Email

Password

Login failed. Please enter a valid email and password.

[Sign In](#) [Forgot your password?](#)

Don't have an account? [Register](#)



```
@Test
public void successLoginSampleTest() {
    product.login.userNameTextBox
        .set("user@test.com");

    product.login.passwordTextBox
        .set("testp@ssword");

    product.login.loginButton.click();
}
```

```
public class LoginPage extends Page {
    public TextBox userNameTextBox;
    public TextBox passwordTextBox;
    public Button loginButton;

    public LoginPage(AutomationInfo automationInfo) {
        userNameTextBox = new TextBox(automationInfo,
            By.cssSelector("input#email"));

        passwordTextBox = new TextBox(automationInfo,
            By.cssSelector("input#password"));

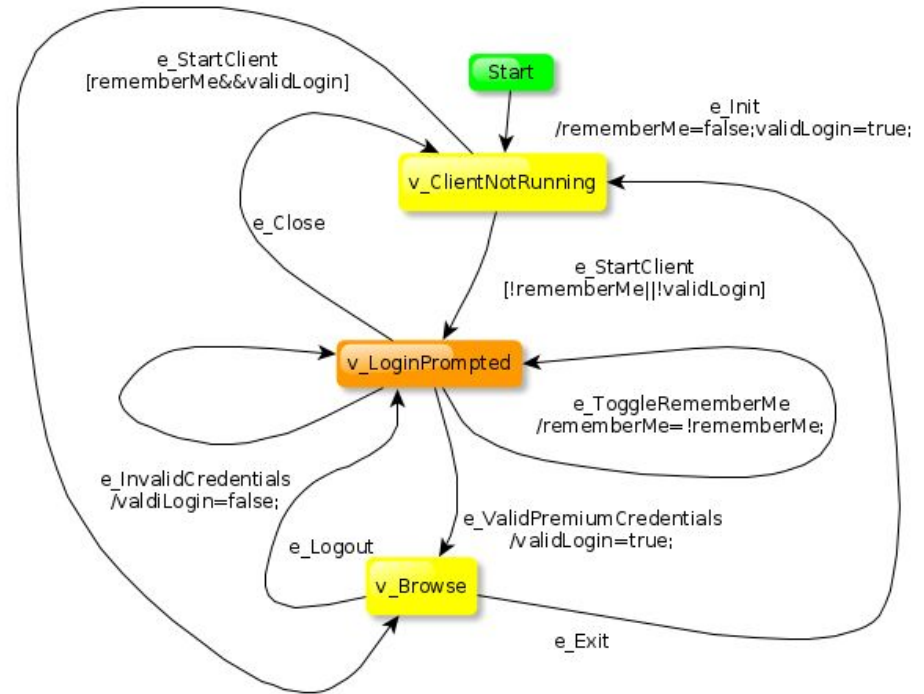
        loginButton = new Button(automationInfo,
            By.cssSelector("button#login"));
    }
}
```

Model-Based Testing

Semi-automated

Build model, generate tests. Generality?

Model maintenance.



Machine vs. Human Testing

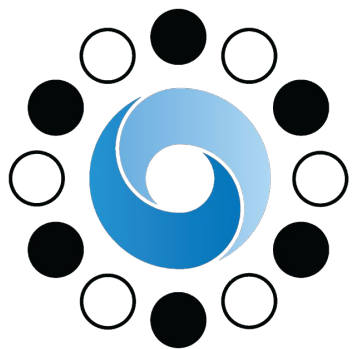
How do we...

Enable Learning?

Mimic Humans?

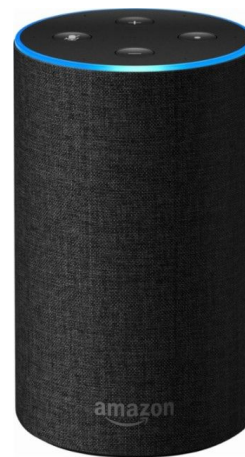
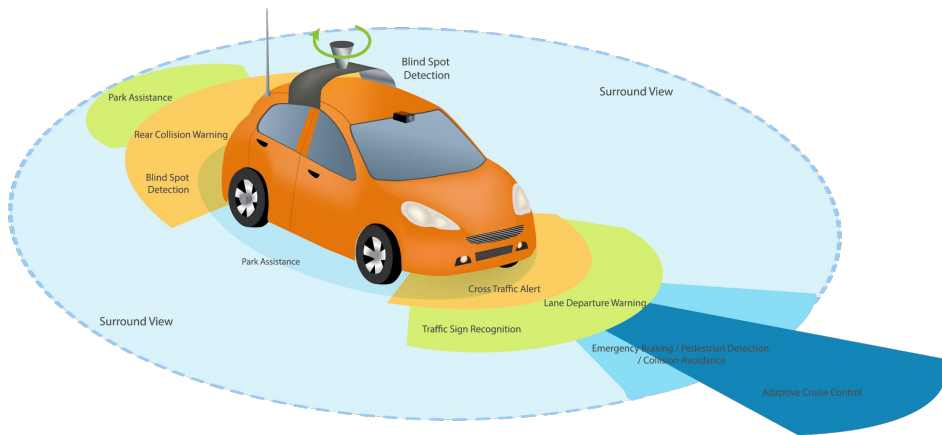
Support Generality?





AlphaGo

AUTONOMOUS CAR

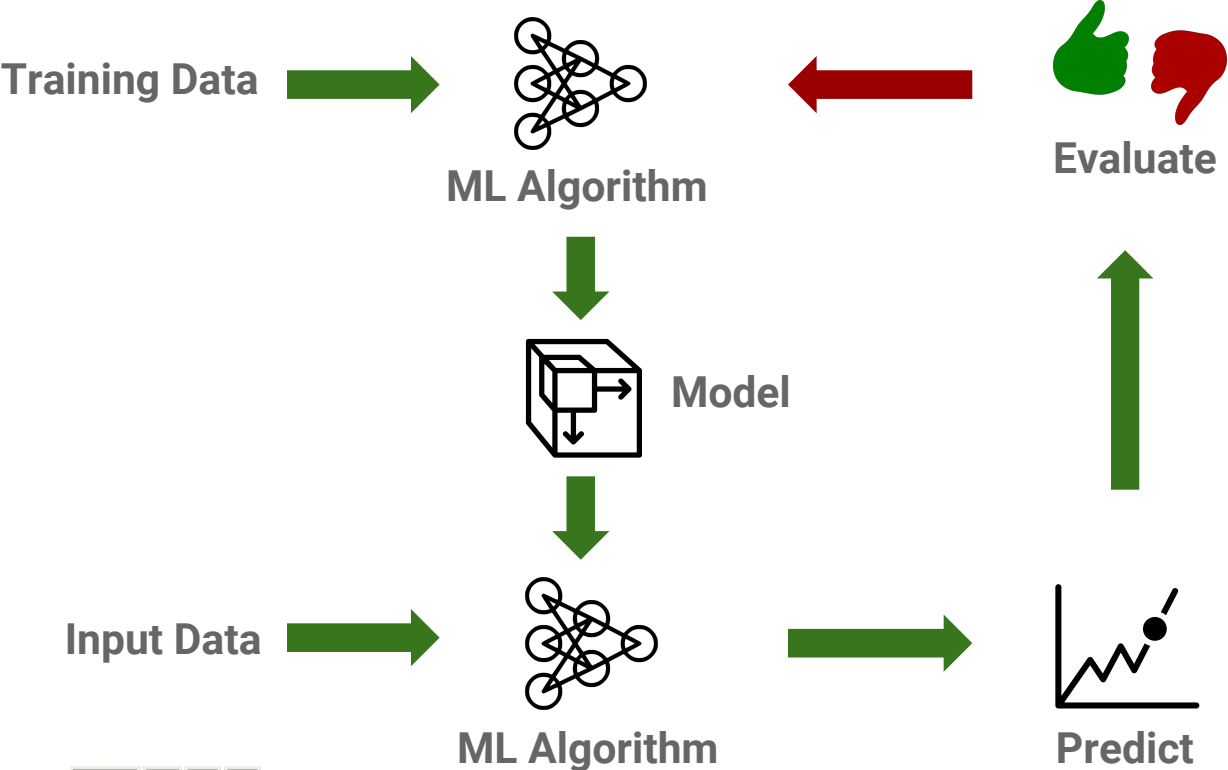


AI and Machine Learning

AI - A branch of CS dealing with simulation of intelligent behavior in computers.

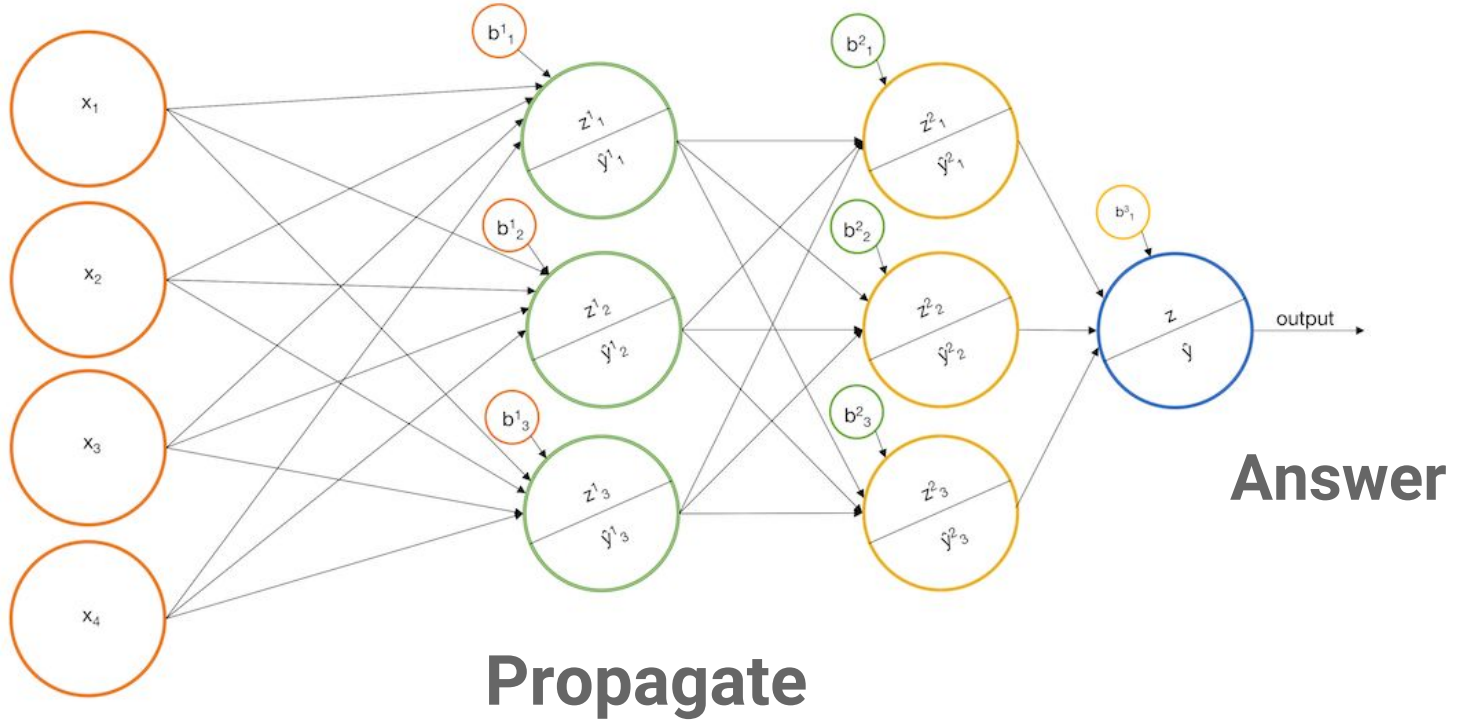
Machine Learning - Science of getting computers to act without being explicitly programmed. Data!

AI and Machine Learning



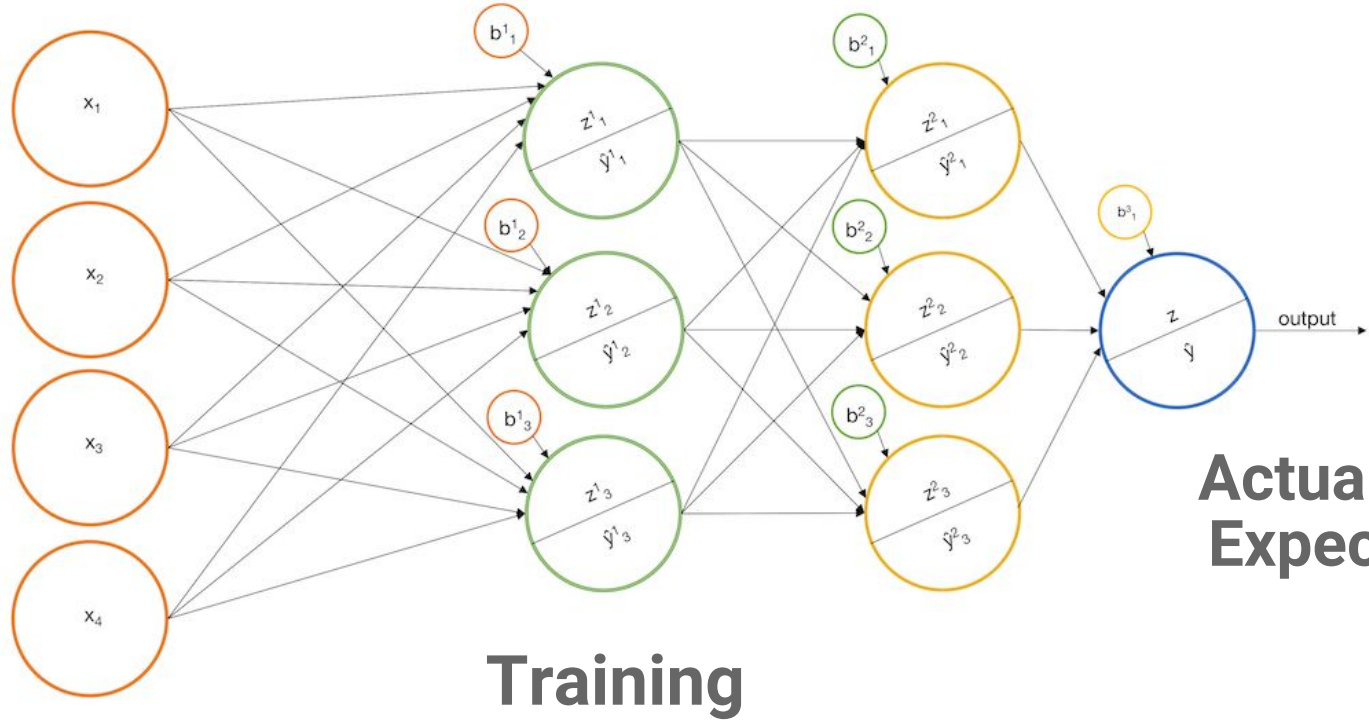
Neural Networks

Features



AI \Leftrightarrow Testing

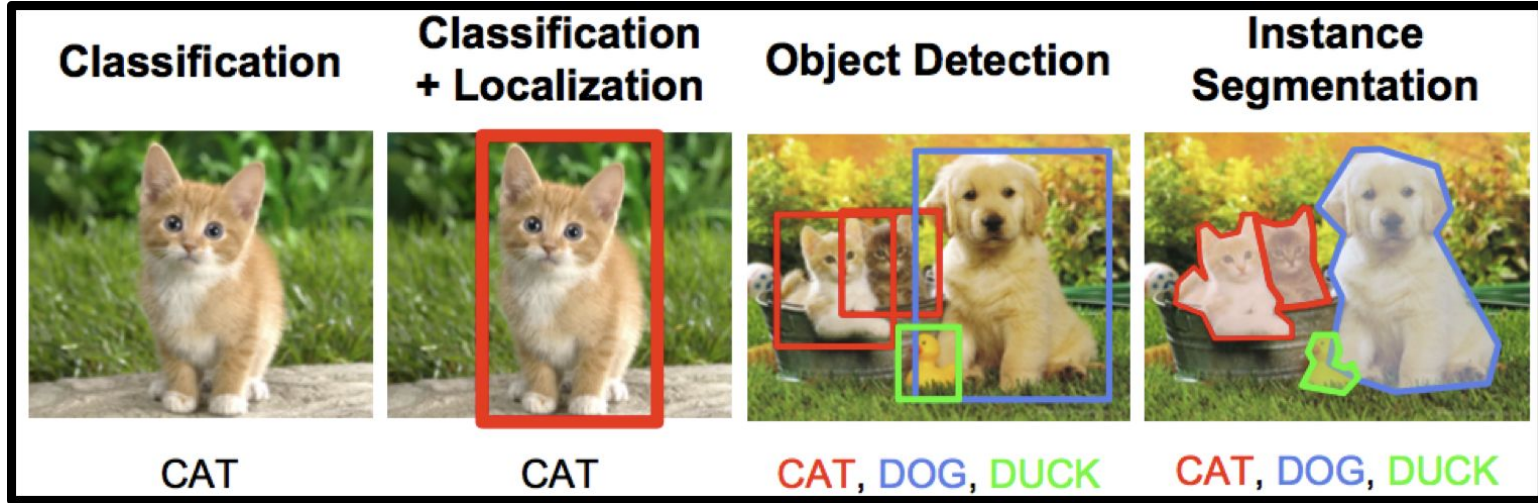
Test
Inputs



Actual vs.
Expected

Research: Object Recognition

Different types of problems:



Applying: Object Recognition

Recognize webpage components

Create New Task

Name

Please enter a name for this task.

Estimated time budget (in hours)

 hours
Time budget must be a valid integer.
Time budget must be 1 hour or greater.

Estimated money budget (in dollars)

 .00
Money budget must be a valid integer.
Money budget must be greater than or equal to \$50.
Money budget must less than or equal to \$100,000.

Steps:

Collect Examples

Label Examples

Train Model

Predict

Applying: Object Recognition

Complex example

The image shows a screenshot of an Amazon shopping cart interface with several key elements highlighted by black boxes and labeled with text and lines:

- SEARCH BOX**: A large white input field in the top navigation bar.
- SEARCH BUTTON**: A magnifying glass icon in a yellow box to the right of the search box.
- CART ICON**: A shopping cart icon with a '1' in a yellow box in the top right navigation bar.
- PRODUCT**: A large black box surrounding the product listing for "Artificial Intelligence: A Modern Approach (3rd Edition)" by Stuart Russell. The listing includes a book cover, title, author, "Hardcover", "In Stock", "prime" logo, "Prime member exclusive" status, a "This is a gift" checkbox, and "Delete" and "Save for later" links.
- PRICE**: A red box around the price "\$102.97" in the product listing.
- CHECKOUT**: A yellow button labeled "Proceed to checkout" in the cart summary box.
- Subtotal (1 item): \$102.97**: A red text label at the bottom right of the cart summary box.

Other visible elements in the interface include a language dropdown set to "EN", navigation links for "Departments", "Browsing History", "Today's Deals", "Gift Cards", "Registry", "Sell", "Account & Lists", and "Orders".


Applying: Object Recognition

ML-based element selection raises level of abstraction

Test scripts are reusable across applications

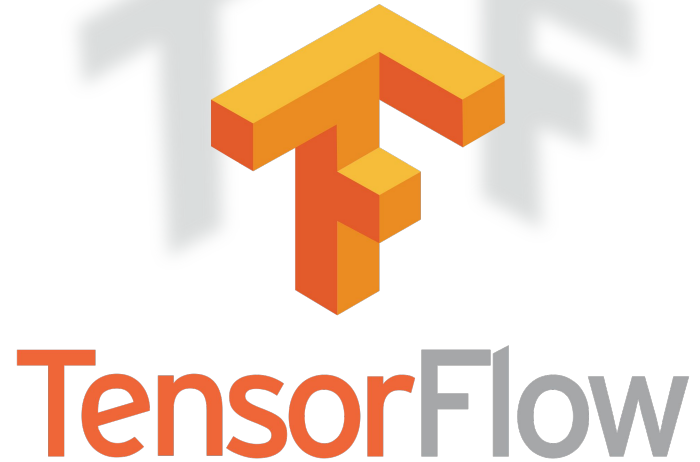
Self-healing test scripts that are resilient to styling changes to SUT

The image shows a screenshot of an Amazon shopping cart interface. At the top, there is a search bar with a dropdown menu set to 'All'. A label 'SEARCH BOX' points to the search input field, and a label 'SEARCH BUTTON' points to the magnifying glass icon. Below the search bar is a navigation bar with links for 'Departments', 'Browsing History', 'Today's Deals', 'Gift Cards', 'Registry', and 'Sell'. The main content area is titled 'Shopping Cart' and contains a table with columns for 'Price' and 'Quantity'. A single item is listed: 'Artificial Intelligence: A Modern Approach (3rd Edition)' by Stuart Russell, priced at '\$102.97'. A label 'PRICE' points to the price value. The quantity is '1'. Below the table, a label 'PRODUCT' points to the item name. At the bottom right, the subtotal is shown as 'Subtotal (1 item): \$102.97'.

	Price	Quantity
 Artificial Intelligence: A Modern Approach (3rd Edition) by Stuart Russell Hardcover In Stock prime Prime member exclusive <input type="checkbox"/> This is a gift Learn more Delete Save for later	\$102.97	1

Subtotal (1 item): \$102.97

Object Recognition: Getting Started!

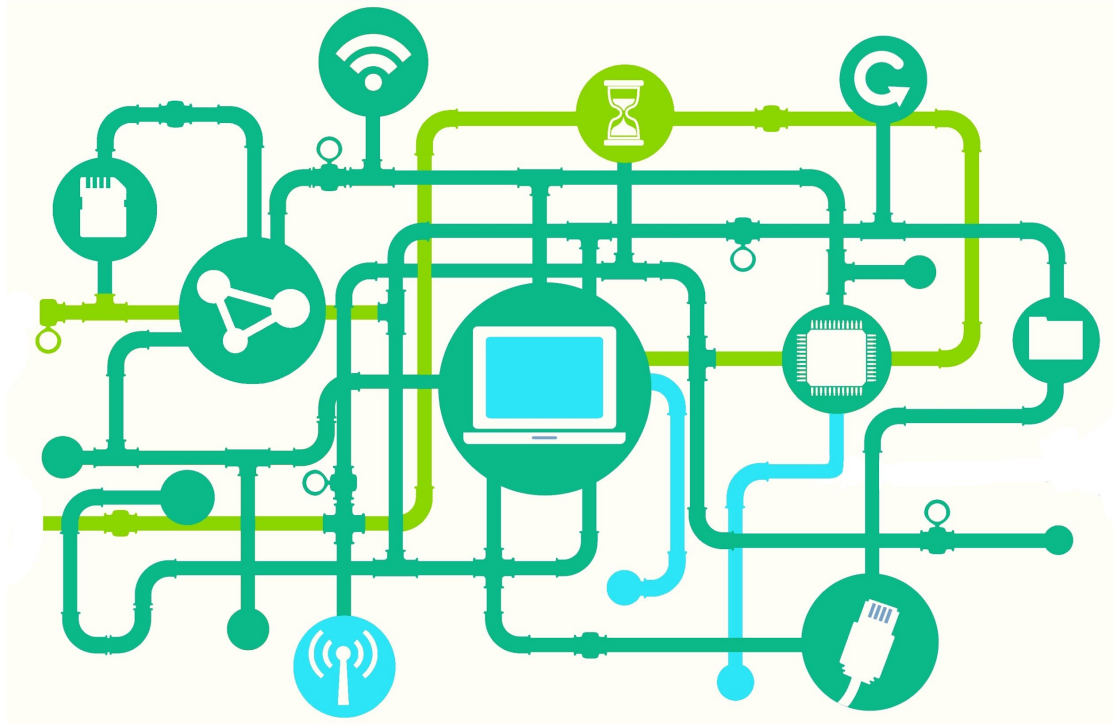


Can Detect Objects, Now What?

Having the ability to detect objects using ML is a step in the right direction

Bug classification

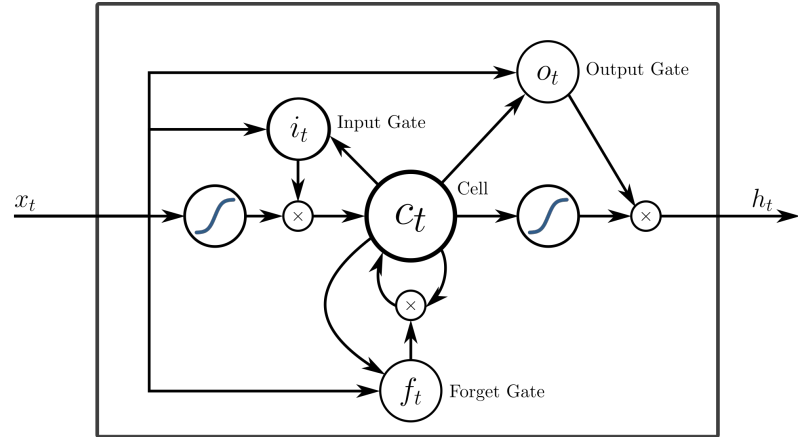
But, how do we capture how these objects interact?



Research: Text Generation

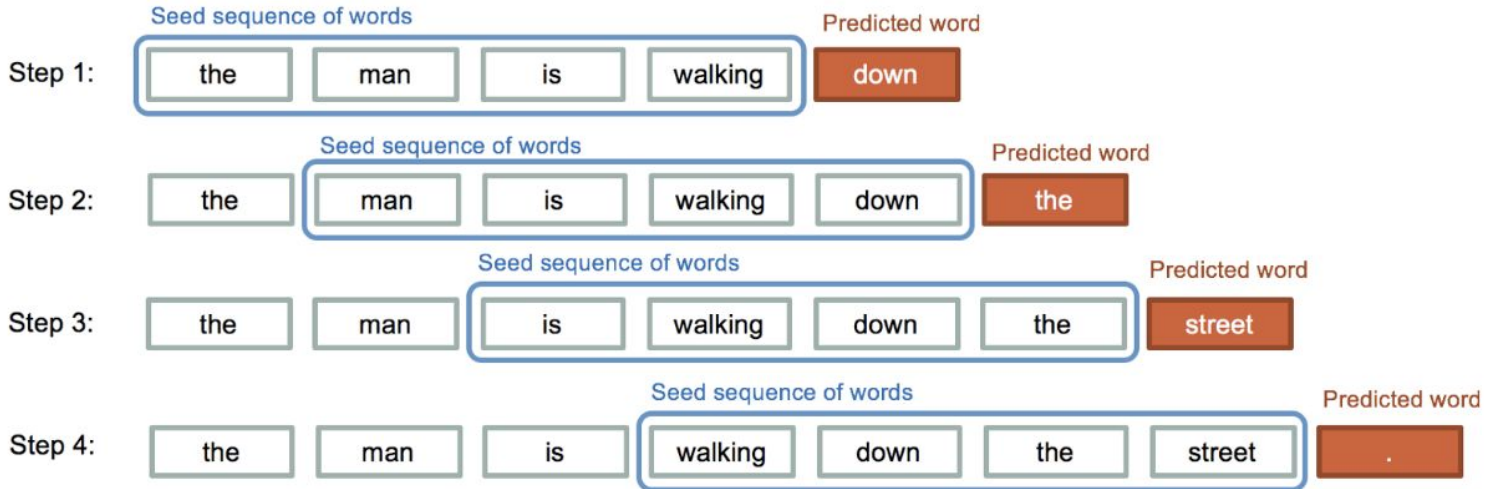


Text Generation with LSTM Recurrent Neural Nets
Jason Brownlee, Ph.D.
machinelearningmastery.com



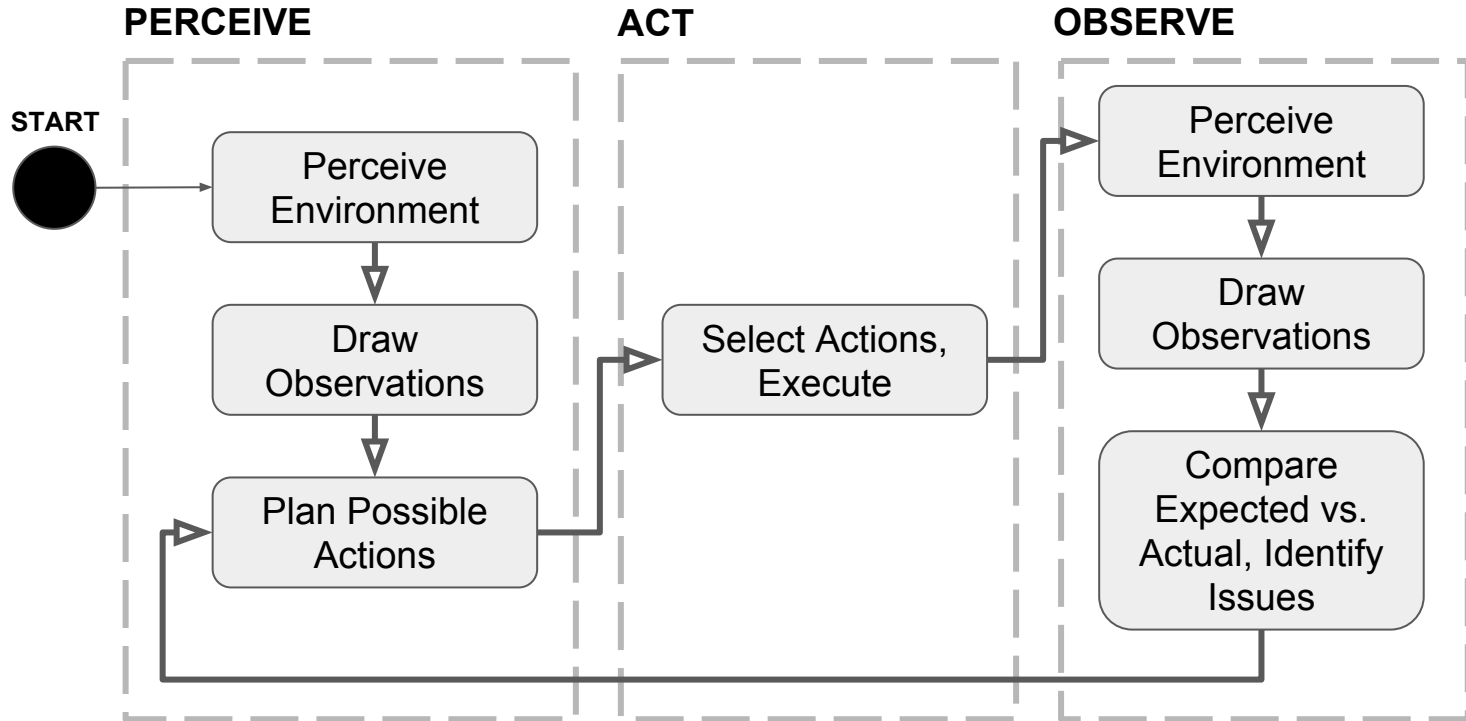
Research: Text Generation

Sentences are generated by training an ML system to predict “next words”:



Applying: Text Generation

Can we model testing as a “sequence”? (Test Flow)



Applying: Text Generation

Can we model these sequences (test flows) using a language?

First Name* **Please enter first name.** Last Name* **Please enter last name.**

Your First Name Your Last Name

Company

Company SUBMIT

Observe Required TextBox FirstName **Input** BLANK FirstName Click Commit **Observe** ErrorMessage

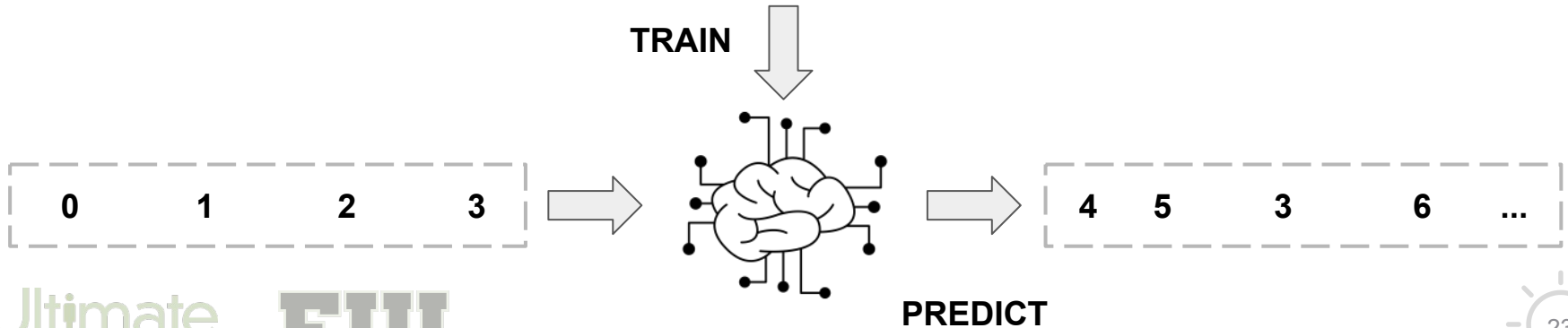
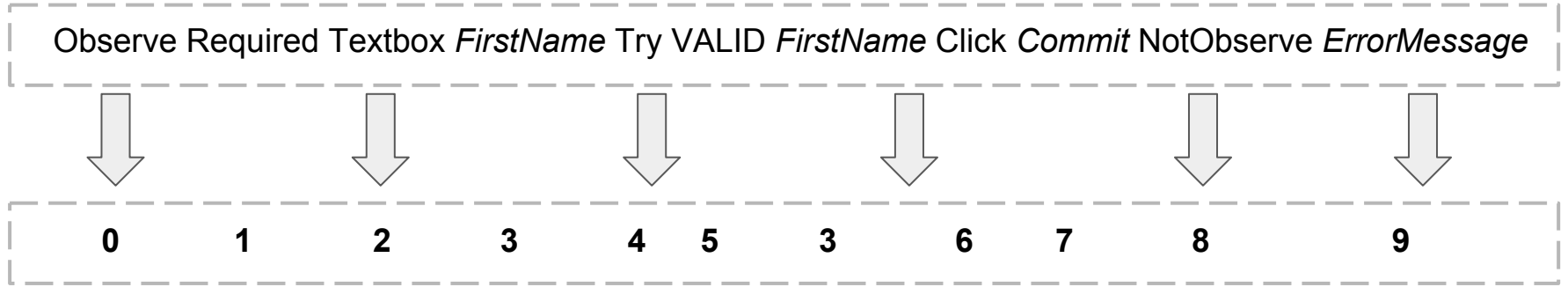
PERCEIVE

ACT

OBSERVE

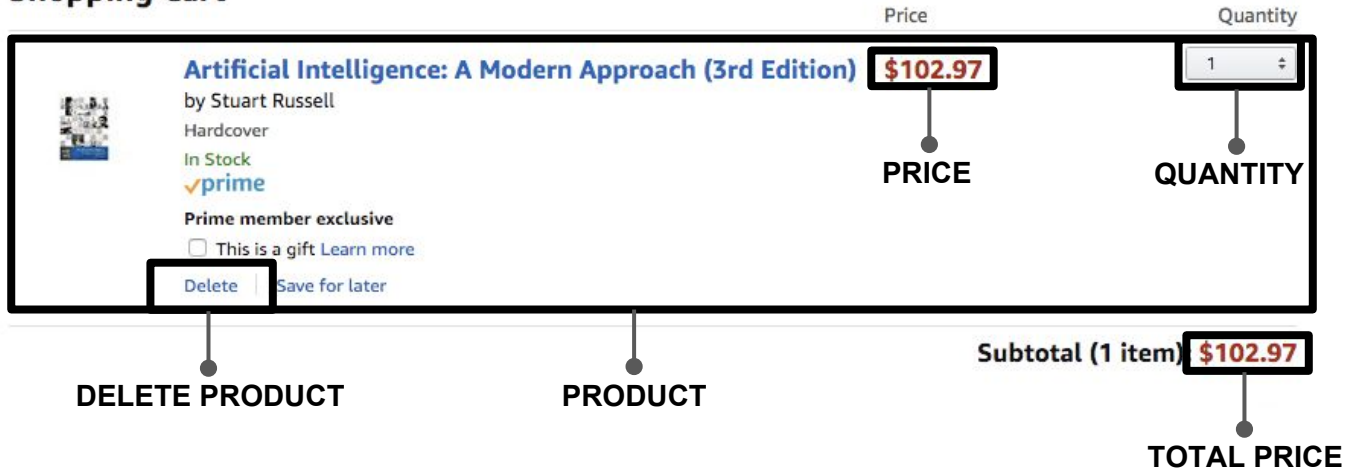
Applying: Text Generation

Can we apply ML techniques to generate test flows?



Applying: Text Generation

Shopping Cart



Observe Screen *ShoppingCart*
Focus *Product In Collection*
Try Click *Delete Product*
Observe *Product Not In Collection*

Observe Screen *ShoppingCart*
Focus *Product In Collection*
Try Increase *Product Quantity*
Observe Increase In *Total Price*

Applying: Text Generation

Train ML system to generate strings in language

Generated strings represent test flows

```
----- Generating text after Epoch: 1
----- Diversity: 0.2
observe required textbox firstname try click commit errormessage errormessage errormessage errormessage

----- Diversity: 0.5
observe required textbox firstname try textbox click commit errormessage errormessage errormessage

----- Diversity: 1.0
observe required textbox firstname try click commit errormessage errormessage commit errormessage

----- Diversity: 1.2
observe required textbox firstname try whitespace try click commit primaryphone commit

----- Generating text after Epoch: 49
----- Diversity: 0.2
observe required textbox firstname try blank firstname click commit observe errormessage

----- Diversity: 0.5
observe required textbox firstname try invalid_xsr firstname click commit observe errormessage

----- Diversity: 1.0
observe required textbox firstname try valid firstname click commit notobserve errormessage

----- Diversity: 1.2
observe required textbox firstname try whitespace firstname click commit observe errormessage
```

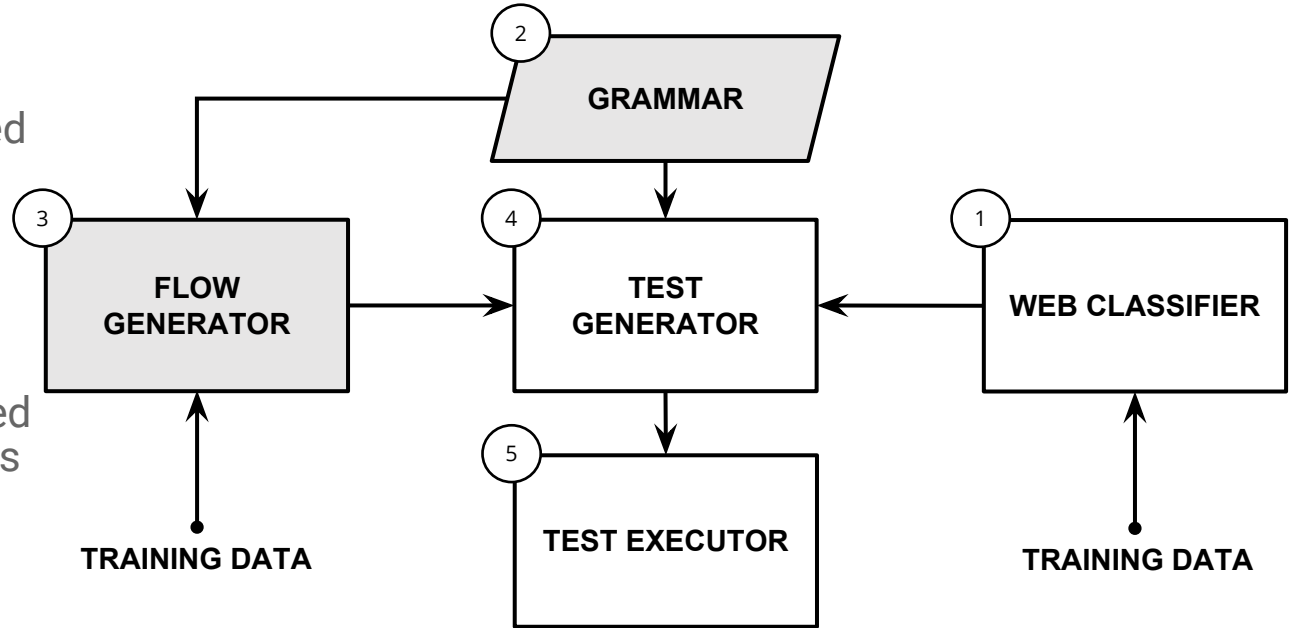
AI-Driven Test Generation

Web classifier trained by human testers

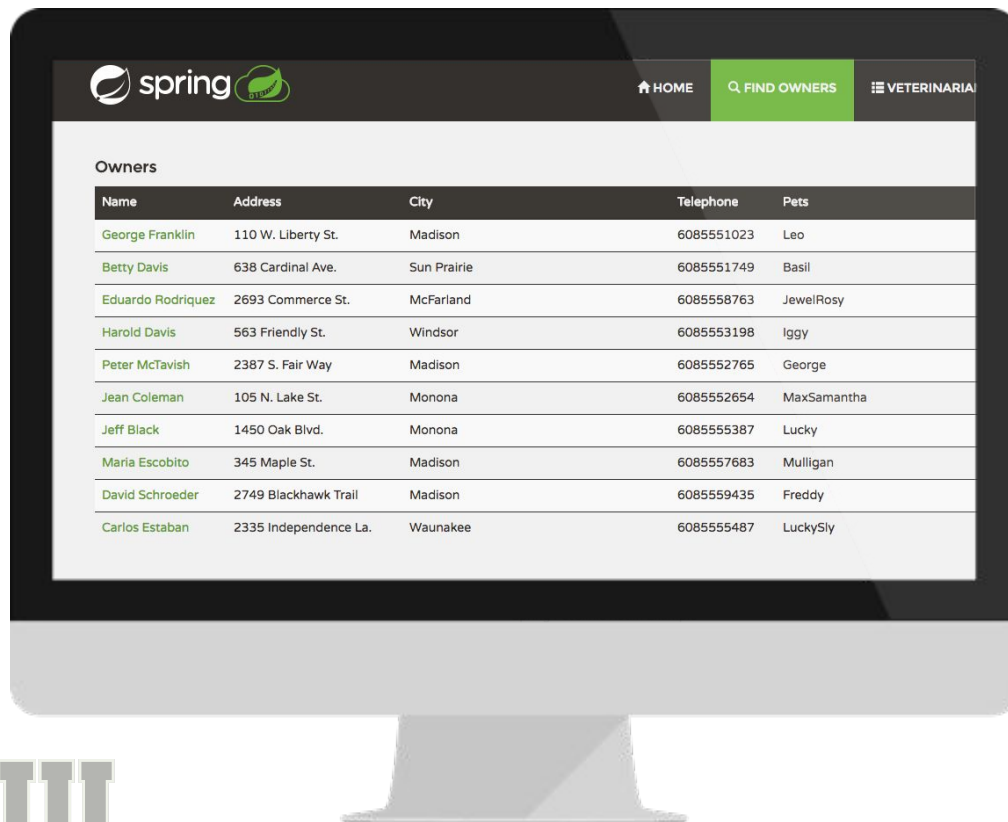
Test flow generator trained by human testers

Test flows refer to web elements via labels (reusable across SUTs)

Language grammar is used to convert generated flows to executable test cases



AI-Driven Test Generation (Demo)



The image shows a computer monitor displaying a web application. The application has a dark header with the 'spring' logo on the left and navigation links for 'HOME', 'FIND OWNERS', and 'VETERINARIA' on the right. Below the header, there is a section titled 'Owners' containing a table with the following data:

Name	Address	City	Telephone	Pets
George Franklin	110 W. Liberty St.	Madison	6085551023	Leo
Betty Davis	638 Cardinal Ave.	Sun Prairie	6085551749	Basil
Eduardo Rodriguez	2693 Commerce St.	McFarland	6085558763	JewelRosy
Harold Davis	563 Friendly St.	Windsor	6085553198	Iggy
Peter McTavish	2387 S. Fair Way	Madison	6085552765	George
Jean Coleman	105 N. Lake St.	Monona	6085552654	MaxSamantha
Jeff Black	1450 Oak Blvd.	Monona	608555387	Lucky
Maria Escobito	345 Maple St.	Madison	6085557683	Mulligan
David Schroeder	2749 Blackhawk Trail	Madison	6085559435	Freddy
Carlos Estaban	2335 Independence La.	Waunakee	6085555487	LuckySly

Agenda

Motivation

AI/Machine Learning

Applying AI to Testing

State of the Art

Breaking into AI



State of the Art



<http://mabl.com>



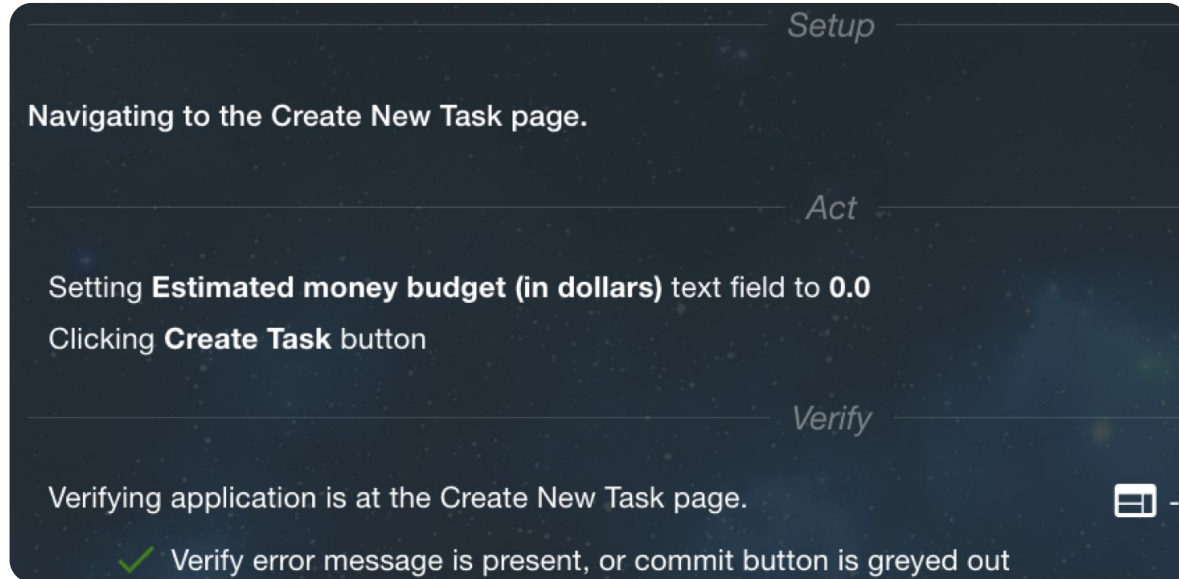
State of the Art

Automatic system exploration



State of the Art

Automatic human-readable test case generation



The screenshot displays a test case in a dark-themed interface. It is divided into three sections: **Setup**, **Act**, and **Verify**. The **Setup** section contains the text "Navigating to the Create New Task page." The **Act** section contains two steps: "Setting **Estimated money budget (in dollars)** text field to **0.0**" and "Clicking **Create Task** button". The **Verify** section contains the text "Verifying application is at the Create New Task page." and a green checkmark icon. Below the checkmark is the text "Verify error message is present, or commit button is greyed out". A small icon of a document with a minus sign is visible in the bottom right corner of the screenshot.

Setup

Navigating to the Create New Task page.

Act

Setting **Estimated money budget (in dollars)** text field to **0.0**
Clicking **Create Task** button

Verify

Verifying application is at the Create New Task page.

✓ Verify error message is present, or commit button is greyed out

State of the Art

Human-trainable knowledge base for domain rules

AIST: AI Domain Expert Seed Rules Inferred Rules Questions Labelling Graph NLP Analysis

Ask Questions Search Expression... 🔍 🗣️ +

ID	Value	Operator	Decision
1	Jasper O.	has a	Car
2	Oliver M.	is never a	STE
3	Mia J.	has one	Car

Open Challenges

Despite the progress that has been made...

How do we reliably generate meaningful test inputs for the infinitely possible combinations?

For deeper domain-specific knowledge, how do we train the bots to know what to expect of a system?

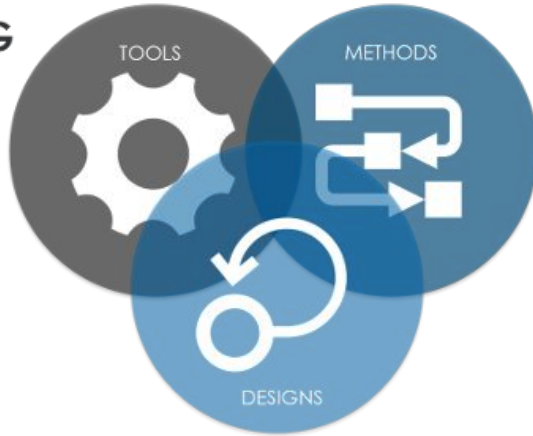
How do we create systems capable of autonomously learning and comparing behavior for intra-domain SUTs?

One step at a time... **together.**



Important Problems

AI TESTING



TESTING AI

AISTA
aitesting.org



SELF-TESTING

Breaking into AI (MOOCs)

Machine Learning

About this course: Machine learning is the science of getting programmed. In the past decade, machine learning has given recognition, effective web search, and a vastly improved understanding of the world. Machine learning is so pervasive today that you probably use it dozens

▼ More

Created by: Stanford University

Stanford
University

Deep Learning Specialization

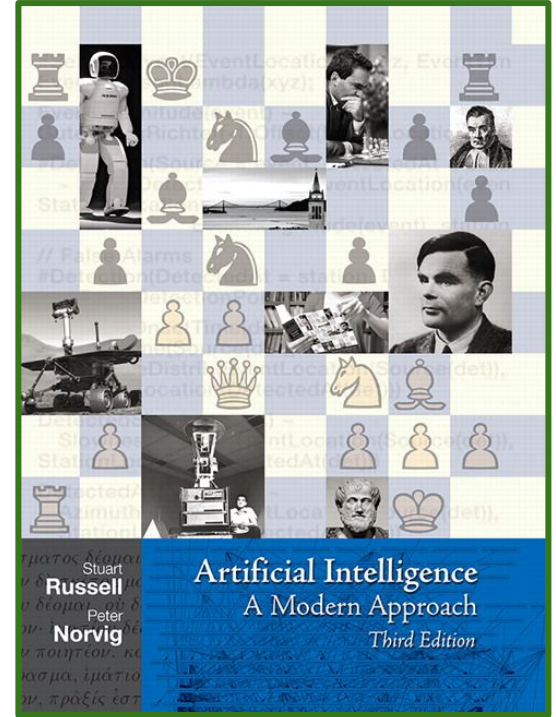
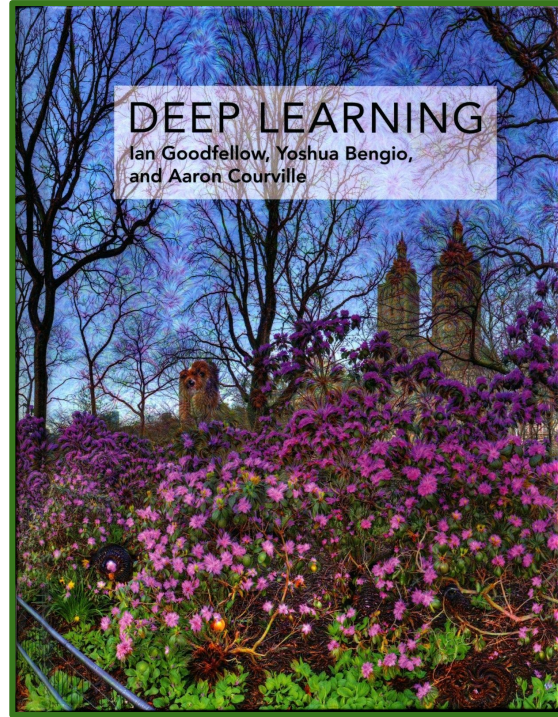
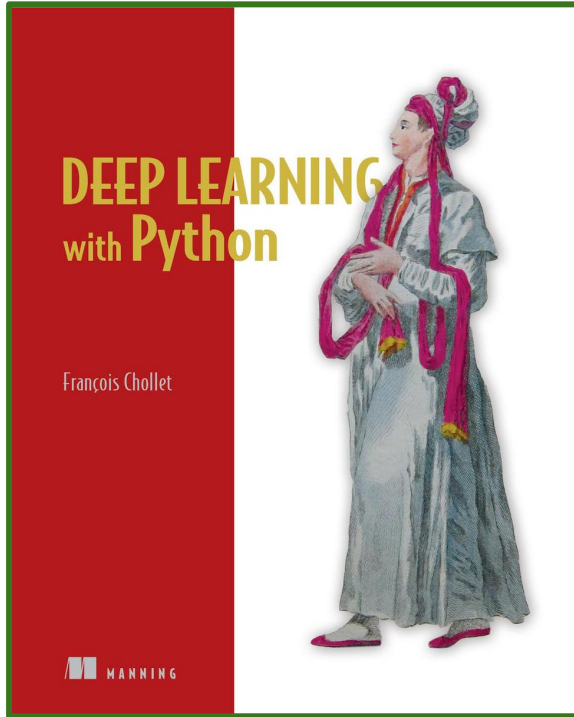
Master Deep Learning, and Break into AI

NANODEGREE PROGRAM

Become a Machine Learning Engineer

In this program you will master Supervised, Unsupervised, Reinforcement, and Deep Learning fundamentals. You will also complete a capstone project in your chosen domain.

Breaking into AI (Books)



Breaking into AI (Presentations)

Jason Arbon, “**AI and Machine Learning for Testers**”, PNSQC 2017

Tariq King, Keynote “**Rise of the Machines: Can Artificial Intelligence Terminate Manual Testing?**”, StarWest 2017

Paul Merrill, “**Machine Learning & How It Affects Testers**”, Quality Jam 2017

Geoff Meyer, Keynote “**What’s Our Job When the Machines Do Testing?**”, StarEast 2018

Angie Jones, Keynote “**The Next Big Things: Testing AI and Machine Learning Applications**”, StarEast 2018

Jason Arbon and Tariq King, “**Artificial Intelligence and Machine Learning Skills for the Testing World**”, StarEast 2018

Closing Remarks

**The Bots Are Here
Ripe New Intersection
Break Into AI, and Get
Involved!**

Acknowledgements

Patrick Alt

Jason Arbon

David Adamo

John Maliani

Keith Briggs

Robert Vanderwall

Justin Phillips

Michael Mattera

Philip Daye

Brian Muras

Keith Stobie

Rick Anderson

Thank you!