How to program your way out of a paper bag

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https://github.com/doctorlove/paperbag

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Why do we ask this?

- “can't even … out of a paper bag”
  - Couldn't find their way out of a paper bag with a map
- http://www.bored.com/findcliches/stupidpeople.htm
  - A few photons short of a hologram/holodeck
  - Couldn't hit water if he fell out of a boat
  - Doesn't know which side the toast is buttered on
- Angry? Surprised? By lack of ability or knowledge

Fizz Buzz

What is fizz buzz?

1, 2, fizz, 4, buzz, fizz, 7, 8, fizz, buzz, 11, fizz, 13, 14, fizzbuzz, …

What has fizz buzz got to do with paper bags?

Google

fizzbuzz paperbag

Web Images Maps Shopping More Search tools

About 3,700 results (0.35 seconds)

[**Fizz Buzz** Test](#)
c2.com/cgi/wiki?**FizzBuzz**Test
24 Dec 2012 – The "**Fizz-Buzz** test" is an interview question designed to help filter out the **...** who can't seem to program their way out of a wet **paper bag**.

[Coding-Out-of-a-Wet-**Paper-Bag**/**FizzBuzz** at master · gregburek **...**](#)
https://github.com/gregburek/Coding...**Paper-Bag**/.../**FizzBuzz**
Coding-Out-of-a-Wet-**Paper-Bag** - As inspired by Jeff Atwood's post [1] about the inability of programmers to code and solve real world problems, this repo **...**

[clayton/**fizzbuzz** · GitHub](#)
https://github.com/clayton/**fizzbuzz**
fizzbuzz. Contribute to **fizzbuzz** development by creating an account on GitHub. **...** job candidates who can't seem to program their way out of a wet **paper bag**.

[Coding Horror: Why Can't Programmers.. Program?](#)
www.codinghorror.com/.../why-cant-programmers-p...

by Jeff Atwood
26 Feb 2007 – An example of a **Fizz-Buzz** question is the following: **...** that we're tired of talking to candidates who can't program their way out of a **paper bag**.

Fizz buzz

+	-
Can write code	
Can talk through problem solving	Sod all to do with paper-bags
Can spot edge cases	
Can demonstrate communication skills	
Might be a good kata	

Bring back the paper bag #1

How could we do this programmatically?

Let’s try drag and drop in html

DragAndDrop.html

DandD2.html

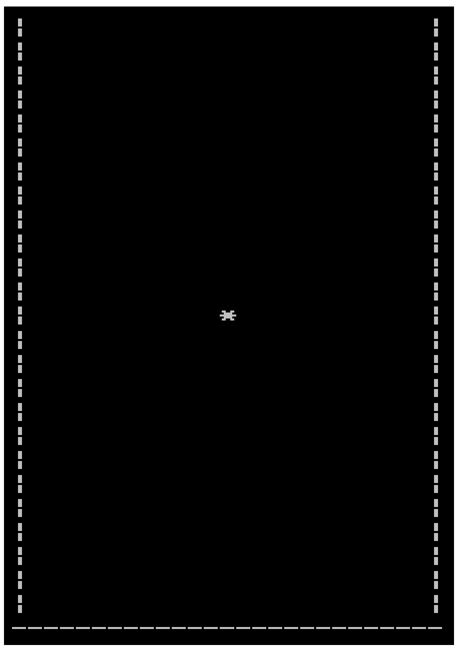
#fail

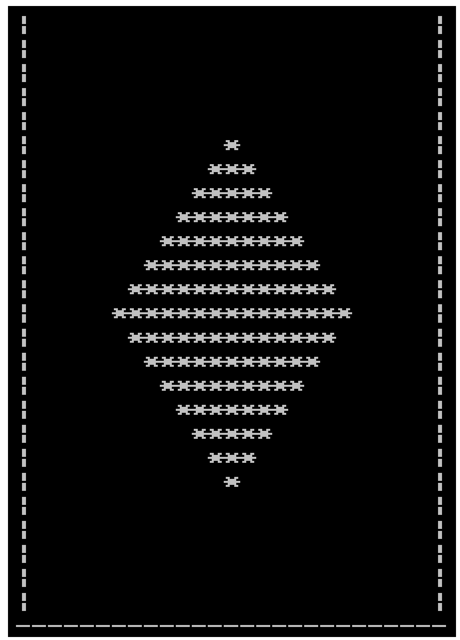
Have we *programmed* our way *out* of a paper bag?

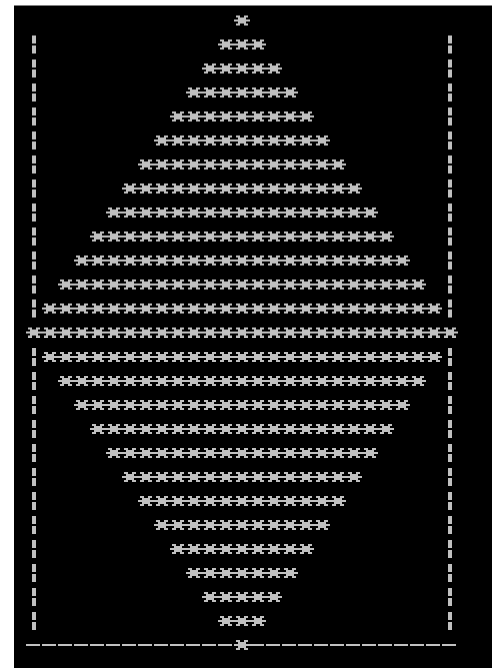
1. No, we ended up in a paper bag
2. No, the user had to move the ant

Bring back the paper bag #2

Time for some ASCII art in C#







[..\..\paperbag\expanding\expanding.exe](..\..\paperbag\expanding\expanding.exe)

Expanding.cs

```
public void Go()
{
    Setup();
    while (Update())
    {
        Draw();
    }
    Draw();

    Console.WriteLine("\nDone");
}
```

```
private void Setup()
{
   _buffer = new char[_width*_width];

   for (int row = 0; row < _width; ++row)
   {
       if (row <= _edge || row > _edge + _bagWidth)
           FillEmptyRow(row);
       else if (row == _edge + _bagWidth)
           FillBagBase(row);
       else
           FillBagRow(row);
   }
   int centre = (_edge + _bagWidth / 2) * _width
                + _edge + _bagWidth / 2; ;
   _buffer[centre] = '*';
   Draw();
}
```

```
private bool Update()
{
  bool breached = false;
  char[] newBuffer = _buffer.ToArray();
  for (int i = 0; i < _buffer.Length; ++i)
  {
    if (Above(i) == '*' || Below(i) == '*'
             || Left(i) == '*' || Right(i) == '*')
    {
       if(_buffer[i] == '|' || _buffer[i] == '-')
         breached = true;
       newBuffer[i] = '*';
    }
  }
  _buffer = newBuffer;
  return !breached;
}
```

```
private void Draw()
{
  int line = 0;
  Console.SetCursorPosition(0, line++);
  for (int i = 0; i < _buffer.Length; ++i)
  {
    Console.Write(_buffer[i]);
    if (i%_width == 0)
      Console.SetCursorPosition(0, line++);
  }
  Thread.Sleep(500);
}
```

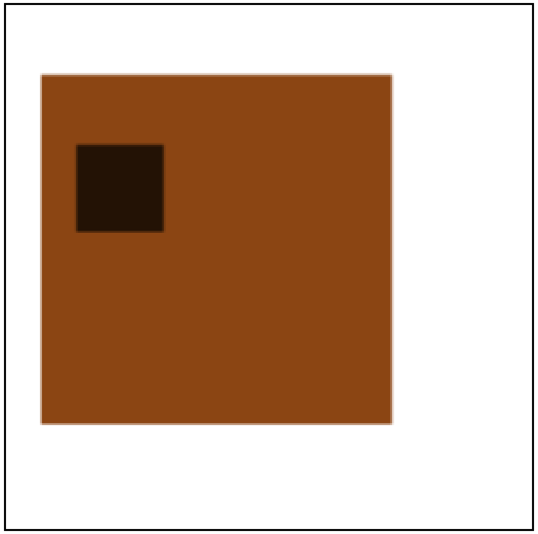
Success?

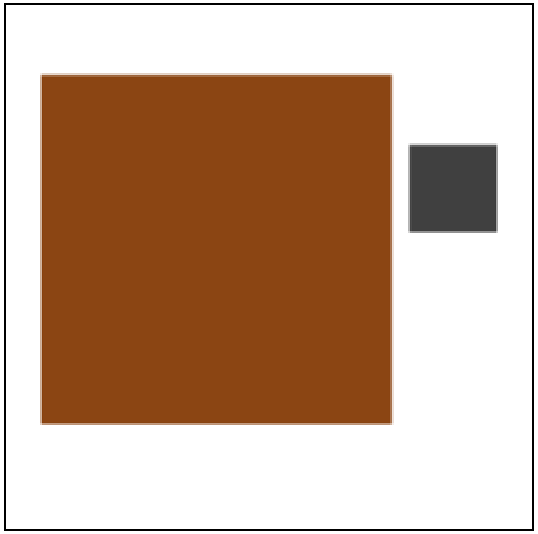
Have we *programmed* our way *out* of a paper bag?

1. Yes, we ended up out of a paper bag
2. Is changing our size cheating?
3. Is busting out of the side cheating?
4. Would the bag being wet make a difference?

Bring back the paper bag #3

- Let's have more pictures, and a spot of JavaScript
- First an animation demo
  - canvas_doodle.html (uses canvas_doodle.js)





Animation in JavaScript

```
function action(x) {
    draw(x);
    x = update(x);
    if (x < 110) {
      id = setTimeout(function() {
                action(x);
              }, 100);
    }
    else {
      stop();
    }
}
```

Draw and Update

```
function draw(x) {
  var canvas = document.getElementById('tutorial');
  if (canvas.getContext) {
    var ctx = canvas.getContext("2d");
    ctx.clearRect(0, 0, canvas.width, canvas.height);
    ctx.fillStyle = "rgb(169, 130, 19)";
    ctx.fillRect (10, 20, 100, 100);
    ctx.fillStyle = "rgba(0, 0, 0, 0.75)";
    ctx.fillRect (10 + x, 40, 25, 25);
  }
}

function update(x) {
    return x + 5;
}
```

Success?

Have we programmed our way out of a paper bag?

1. Yes ☺
2. But it’s a bit boring – it does the same thing every time
3. Let’s introduce some randomness
   - One beasty, several, a cluster, a heuristic

Basic algo

```
function init() {
  id = setTimeout(action, 100);
}

function action() {
  update();
  draw();
  if (in_bag()) {
    id = setTimeout(action, 100);
  }
}
```

Update

```
beast = beasties[index];

var new_x_move = bag_width * 0.2 * (-0.5 +
                 Math.random());
var new_y_move = bag_width * 0.2 * (-0.5 +
                 Math.random());
beast.x += new_x_move;
beast.y += new_y_move;

beasties[index] = beast;
```

K nearest neighbour

```
function knn(items, index, k) {
    var results =[];
    for (var i=0; i<items.length; i++) {
        if (i !==index) {
            var neighbour = items[i];
            var distance =
                   Math.sqrt(neighbour.x*neighbour.x
                   + neighbour.y*neighbour.y);
            results.push( new distance_index(distance, i) );
        }
    }
    results.sort( function(a,b) {
                       return a.distance - b.distance;
                  }
                );
    var top_k = Math.min(k, results.length);
    return results.slice(0, top_k);
}
```

Beasties

- paperbag.html
  - one random
- paperbag_many.html
  - all random
- paperbag_many_follow.html
  - k nearest neighbours (knn)
- paperbag_many_follow_up.html
  - heuristic = “go up”

Success?

Have we *programmed* our way *out* of a paper bag?

1. Yes, we ended up out of a paper bag
2. Yes, the program moved the “ants”
3. No, knn was a disaster, unsurprisingly

But, can they get better at it?

We have a heuristic – go up

Time for some machine learning


LEARNING
OUTPUT
NEURAL
WEIGHTS
TRAINING
NETWORK
ERROR
NEURON
NODE
INPUT
ALGORITHM
FUNCTION
USED
ACTIVATION
INSTANCES
BACKPROPAGATION
UNIT
ATTRIBUTE
WEIGHT
SET
PATTERN
PATTERNS
ALSO
UNITS
LAYER
HIDDEN
DECISION
ARTIFICIAL
NETWORKS
RECURRENT
NODES
BACKPROP
SURFACE
EXAMPLE
VALUE
OUTPUTS
USING
TREE
NET
PASS
CLASS
ID3
CASE
VALUES
ALGORITHMS
RULE
AXON
MACHINE
SEE
BIOLOGICAL
PERCEPTRON
TOTAL
LANGUAGE
STEP
INFORMATION
CONNECTION
CONNECTIONS
SQUASHING
CALLED
ONE
NEURONS
DATA
ESTIMATE
DIFFERENT
PARTICULAR
ATTRIBUTES
EXAMPLES
OBSERVATION
MOMENTUM
WAY
FIRST
SYSTEM
INSTANCE
ENOUGH
STATE
SMALL
TERM
PART
BACKWARD
INPUTS
BRANCH
LEARNING
WEIGHTED
POINT
JUST
SPACE
CORRESPONDING
SIMPLE
FIRE
LIKE
TIME
CURRENT
SUM
GIVEN
TASKS
ASSOCIATED
ARTICLE
DELTA
INDUCTION
MAY
LARGE
TERMED
TARGET
MINIMUM
CRITERION
TASK
NOTATION
CLASSIFICATION
HYPOTHESIS
SYNAPSES
REPRESENT
CONNECTED
GRADIENT
THRESHOLD
FEEDFORWARD
LOCAL
TWO
NUMBER
SOMETIMES
CLASSES
SYSTEMS
STOPPING
EXPECTED
SINGLE
ERRORS
DESCENT
XOR
EXCITATORY
LEAF
NEW
RATE
LOG2
ACTUAL
YELLOW
FOLLOWS
E.G
I.E
SIZE
REFERRED
SEQUENCE
PROBLEM
OBTAINED
COMPUTE
TEST
RED


OUTPUT
LEARNING
TRAINING
INPUT

Will this help us program our way out of a paper bag?

Overview

Expert systems

Statistical methods

Artificial neural networks

Inductive data mining

“randomness”

Expert systems

- Human expert knowledge can be used
- Knowledge is transparent and causal
- New data cannot be used
- The output is often qualitative
- Different experts will often provide differing rules, so the knowledge is subjective

Example expert systems

- Dendral and MetaDendral
  - http://en.wikipedia.org/wiki/Dendral
  - ftp://reports.stanford.edu/www/pub/cstr.old/reports/cs/tr/78/649/CS-TR-78-649.pdf
- DEREK by Lhasa
  - https://www.lhasalimited.org/derek_nexus/
- FxCop?
- Lint?
- Pex?

“An early motivation for our work was to explore the power of existing AI methods, such as heuristic search, for reasoning in difficult scientific problems.

Another concern has been to exploit the AI methodology to understand better some fundamental questions in the philosophy of science, for example the processes by which explanatory hypotheses are discovered or judged adequate”

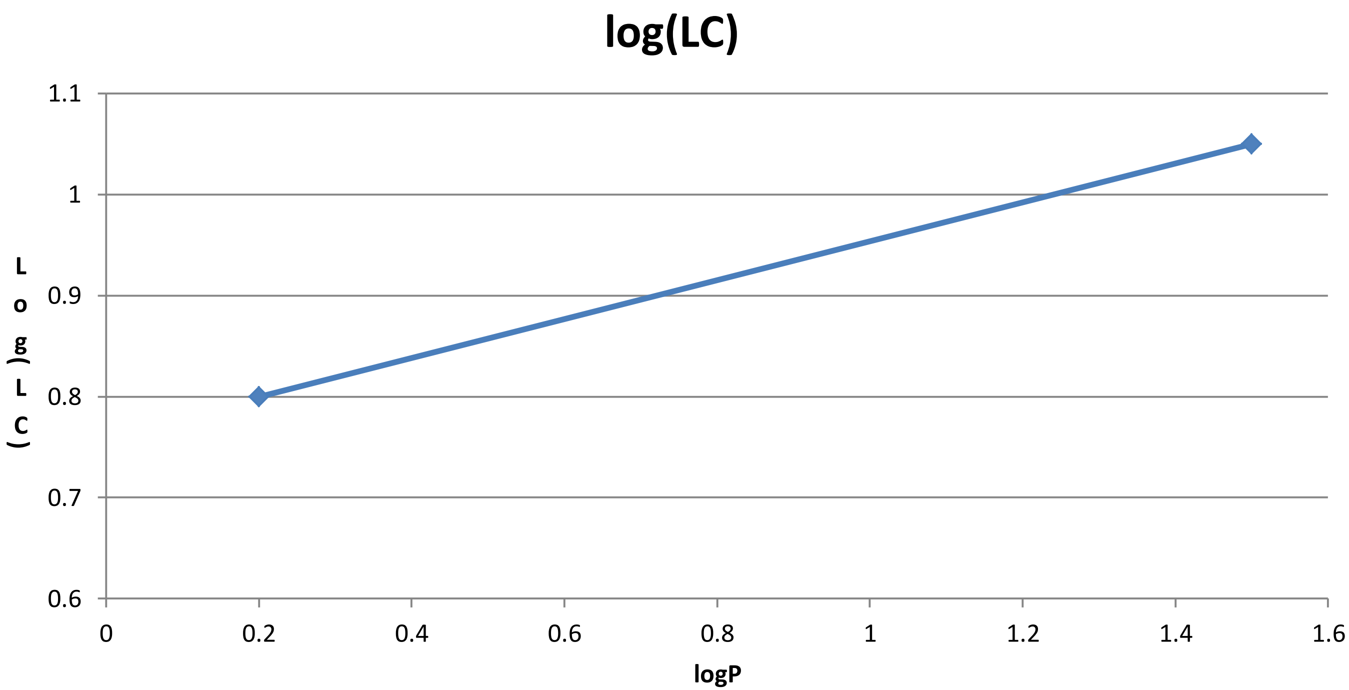
‘Dendral and Meta-Dendral: Their applications dimension’ Buchanan and Feigenbaum, 1978?

http://aitopics.org/sites/default/files/classic/Webber-Nilsson-Readings/Rdgs-NW-Buchanan-Feigenbaum.pdf
ftp://reports.stanford.edu/www/pub/cstr.old/reports/cs/tr/78/649/CS-TR-78-649.pdf

Statistical methods

- Data driven methods, so are more objective than expert systems.
- Quantitative predictions can be generated.
- The models are usually linear and sometimes black-box.
- Human knowledge cannot be used

Regression



EPA toxicity QSAR “ECOSAR” programme

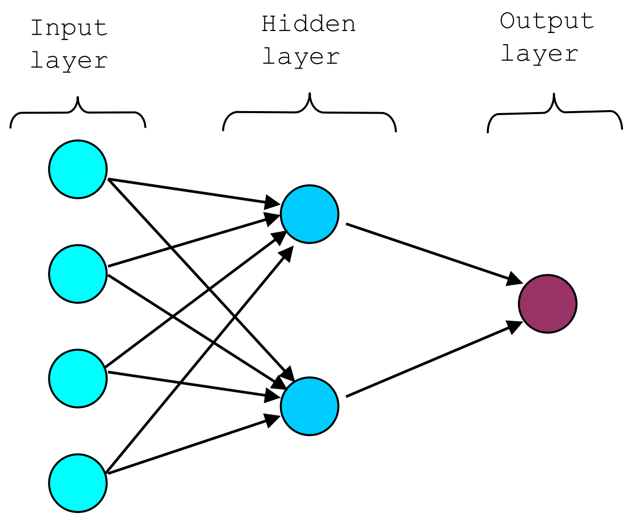
•http://ihcp.jrc.ec.europa.eu/our_labs/computational_toxicology/information-sources/qsar-document-area/Final_report_BRE_partB.pdf page 12

•**N=2, r^2 = 1.0.**

Artificial neural networks

- Data driven methods.
- Quantitative predictions can be generated.
- The model is non-linear, and easy to set up and train.
- The model is largely a black-box.
- Human knowledge cannot be used.
- They cannot handle a large number of inputs e.g. training cases <= input variables.

Feed-forward neural network



$y = f(w_0 + \sum w_i x_i)$

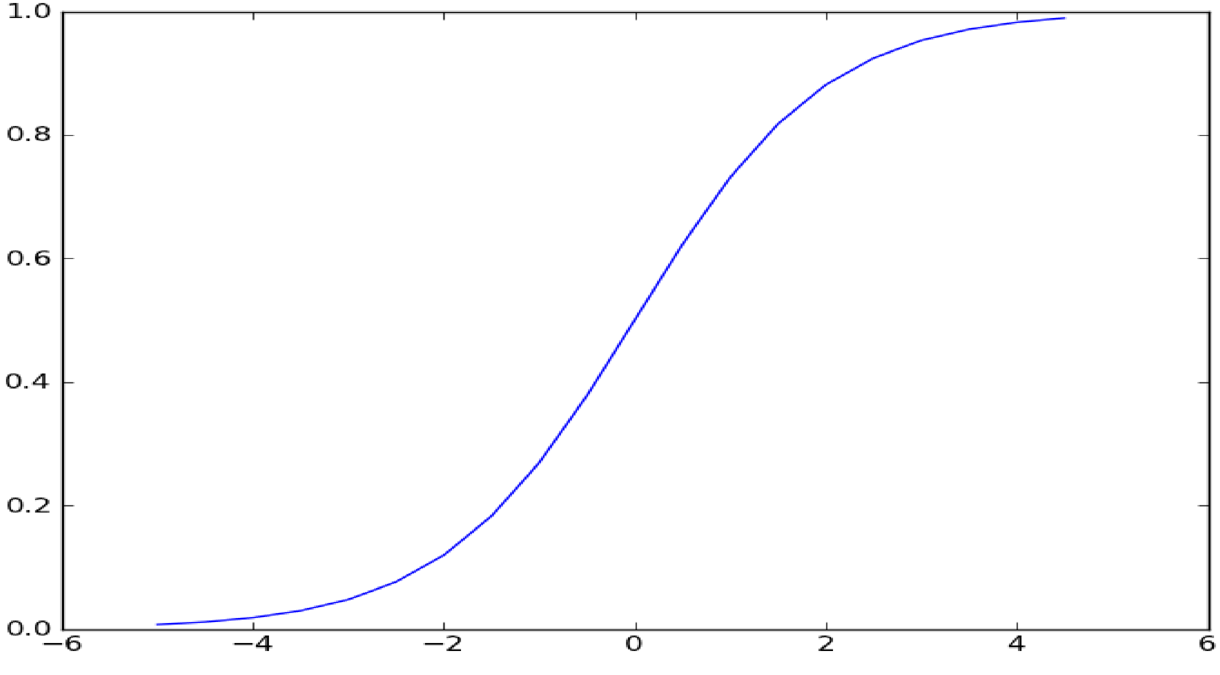
Initial random weights

Choose f, say sigmoid function

Change weights in each epoch to minimise difference between predicted y and actual value

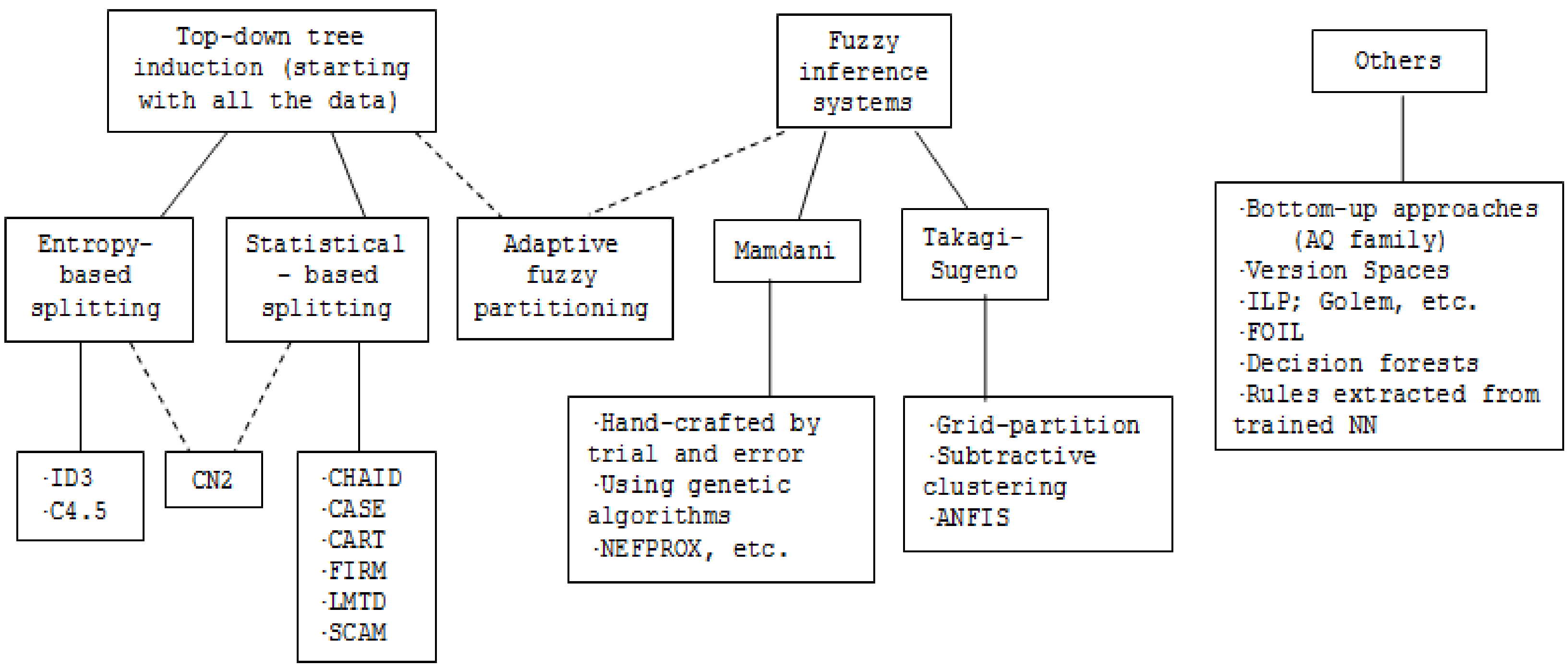
Sigmoid curve

$$S(t) = \frac{1}{1+e^{-t}}$$



Inductive data mining

- Data and human knowledge can be used simultaneously.
- The model automatically generates transparent and “causal” rules or trees.
- It can handle many inputs and noise.
- Results can be inaccurate, complicated, or not generalise well.


Top-down tree induction (starting with all the data)
Fuzzy inference systems
Others
Entropy-based splitting
Statistical - based splitting
Adaptive fuzzy partitioning
Mamdani
Takagi-Sugeno
·Bottom-up approaches (AQ family)
·Version Spaces
·ILP; Golem, etc.
·FOIL
·Decision forests
·Rules extracted from trained NN
·ID3
·C4.5
CN2
·CHAID
·CASE
·CART
·FIRM
·LMTD
·SCAM
·Hand-crafted by trial and error
·Using genetic algorithms
·NEFPROX, etc.
·Grid-partition
·Subtractive clustering
·ANFIS

Randomness

- E.g. Genetic algorithms, Monte-Carlo simulation, swarm “optimisation”
- Usually quantitative
- Data-driven
- Might need an a priori model or heuristic, and values for parameters

Types of ML

Name	Inputs	Learning	instance-based (lazy) learning	Randomness	Output
regression	numeric	supervised	false	no	Numeric
k-th nearest neighbours	numeric	unsupervised	true	no	data points
kohonen neural network	numeric	unsupervised	false	no	Clusters
feedforward nn	numeric	supervised	false	no	Numeric
recurrent nn (eg Hopfield)	binary	reinforcement	true	no	State
C4.5 or See5	categoric	supervised	false	no	decision tree
CART	any	supervised	false	no	Tree
genetic algorithm	any	unsupervised	false	yes	Solution
dendral	numeric	hypothesis formation	false	no	expert system (possible chemical structures)
ACO	spatial	unsupervised	false	yes	best 'path'

ML as tree using See5

- Which techniques are suitable for programming your way out of a paper bag?
- Can we make a decision tree of ML techniques?
- No – it’s supervised
- i.e. needs a target

How to make a tree

- Training data (rows)
- Inputs (columns: x values)
- Target output
- Choose an input to split on
  - Entropy
    - Info content = $-\sum \text{frequency}(\text{class}(j))/|S| * \log_2(\text{class}(j)/|S|)$
    - Compare info content set for potential splits
    - Which attributes give most information gain?
- Split the training data down each node
- Repeat
- Test

Example (golf)

	Inputs (attributes)				*Output (target)*
	Outlook	Temp	Humidity	Windy	Play (positive) / Don't Play (negative)
Training Data	sunny	85	85	false	Don't Play
	sunny	80	90	true	Don't Play
	overcast	83	78	false	Play
	rain	70	96	false	Play
	rain	68	80	false	Play
	rain	65	70	true	Don't Play
	overcast	64	65	true	Play
	sunny	72	95	false	Don't Play
	sunny	69	70	false	Play
	rain	75	80	false	Play
	sunny	75	70	true	Play
	overcast	72	90	true	Play
	overcast	81	75	false	Play
	rain	71	80	true	Don't Play

By hand

- 14 training cases
- Play v. Don’t Play: Info(9/14, 5/14)

  $(9/14*\log_2(9/14)+5/14*\log_2(5/14)) = 0.94$
- Outlook (sunny, 5), (overcast, 4), (rain, 5)
  - Always play when it’s overcast
- Try outlook

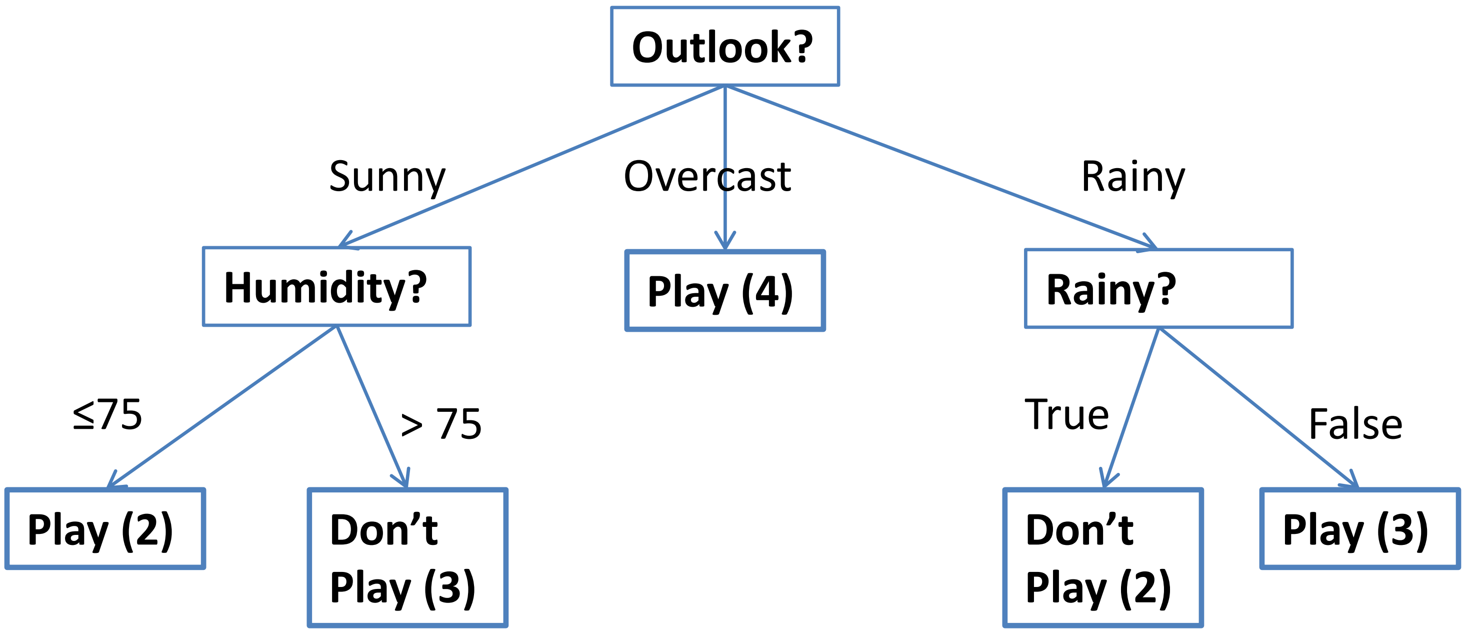
  (5/14*Info(sunny)+4/14*Info(overcast)+5/14*info(rain)) =0.694

  Info gain = 0.94 – 0.694 = 0.246
- Try windy

  (8/14*Info(not windy)+6/14*info(windy)) =0.892

  Info gain = 0.94 – 0.892 = 0.048

Decision Tree



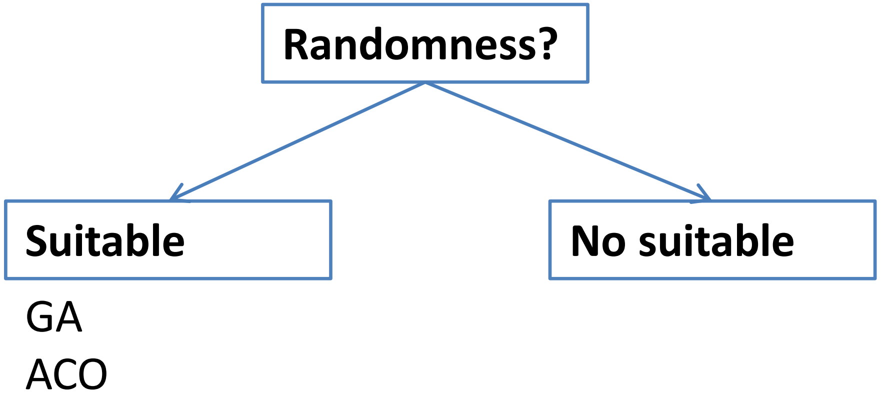
Target for See5

Name	Inputs	Learning	instance-based (lazy) learning	Randomness	Output	**Out of paper bag?**
regression	numeric	supervised	false	no	Numeric	**no**
k-th nearest neighbours	numeric	unsupervised	true	no	data points	**no**
kohonen neural network	numeric	unsupervised	false	no	Clusters	**no**
feedforward nn	numeric	supervised	false	no	Numeric	**no**
recurrent nn (eg Hopfield)	binary	reinforcement	true	no	State	**no**
C4.5 or See5	categoric	supervised	false	no	decision tree	**no**
CART	any	supervised	false	no	Tree	**no**
genetic algorithm	any	unsupervised	false	yes	Solution	**yes**
dendral	numeric	hypothesis formation	false	no	expert system	**no**
ACO	spatial	unsupervised	false	yes	best 'path'	**yes**

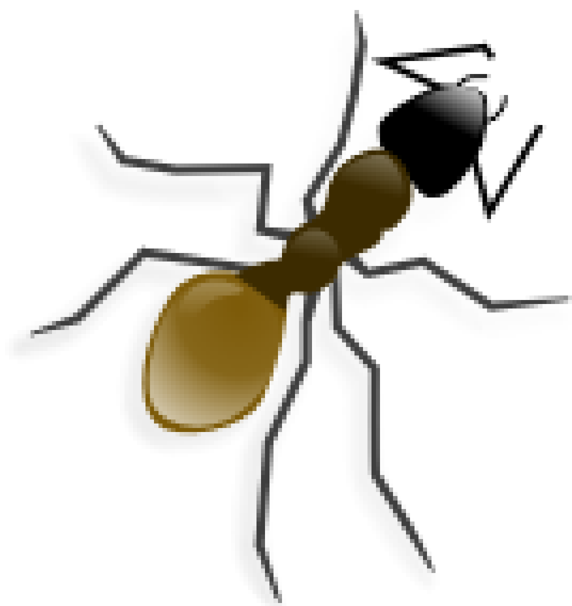
Which ML?

Decision tree:

- randomness = yes: yes (2)
- randomness = no: no (8)



So, why the ant before?



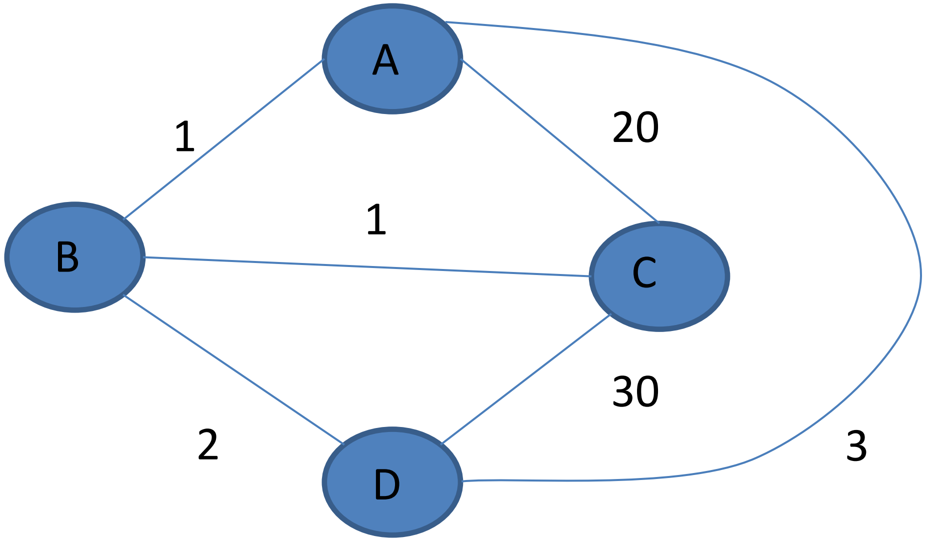
algorithm
problem
colony
optimization
ant
pheromone
ants
algorithms
Ant
solution
solutions
edit
migration
trail
method
routing
path
food
problems
state
search
system
behavior
first
pheromones
scheduling
route
Swarm
paths
shortest
deposited
intelligence
iteration
attractive
time
evaporation
Colony
one
methods
source
probability
technique
Stigmergy
System
colleagues
convergence
best
space
moves
Problem
network
use
two
move
Dorigo
Vehicle
model
Swarming
chosen
find
transition
amount
trails
swarm
distribution
global
assignment
follow
published
possible
Pheromone
used
Set
annealing
ACO
edge
based
vehicle
also
less
feedback
thus
Thus
MMAS
Algorithms
shorter
many

Aside

Machine learning and data mining frequently requires some form of pre-processing

ant
ants
Ant
solution
solutions
problem
algorithm
colony
optimization
pheromone
algorithms
edit
migration
trail
method
routing
search
system
behavior
route
path
food
first
pheromones
problems
scheduling

Travelling salesperson problem



Start at A, chose shortest each time: A -> B -> C -> D = 1 + 1 + 30 = 32

Start at A, think: A -> D -> B -> C = 3 + 2 + 1 = 6

Start at C, think: C -> B -> A -> D = 1 + 1 + 3 = 5

ACO for TSP

- Move some ants randomly, remembering the trail
- Lay pheromones along each trail
- For each epoch
  - Move the ants again, guided by the pheromones
    - E.g. roulette wheel selection
  - Update the pheromones
    - Evaporate a bit (subtract)
    - Emphasis on the better paths (add)
- Report the best path

ACO in C#

```
int numCities = 60; int numAnts = 4; int maxTime = 1000;
int[][] dists = MakeGraphDistances(numCities);
int[][] ants = InitAnts(numAnts, numCities);
int[] bestTrail = BestTrail(ants, dists);
double bestLength = Length(bestTrail, dists);
double[][] pheromones = InitPheromones(numCities);
int time = 0;

while (time < maxTime) {
    UpdateAnts(ants, pheromones, dists);
    UpdatePheromones(pheromones, ants, dists);
    int[] currBestTrail = BestTrail(ants, dists);
    double currBestLength = Length(currBestTrail, dists);
    if (currBestLength < bestLength) {
        bestLength = currBestLength;
        bestTrail = currBestTrail;
    }
    ++time;
}
```

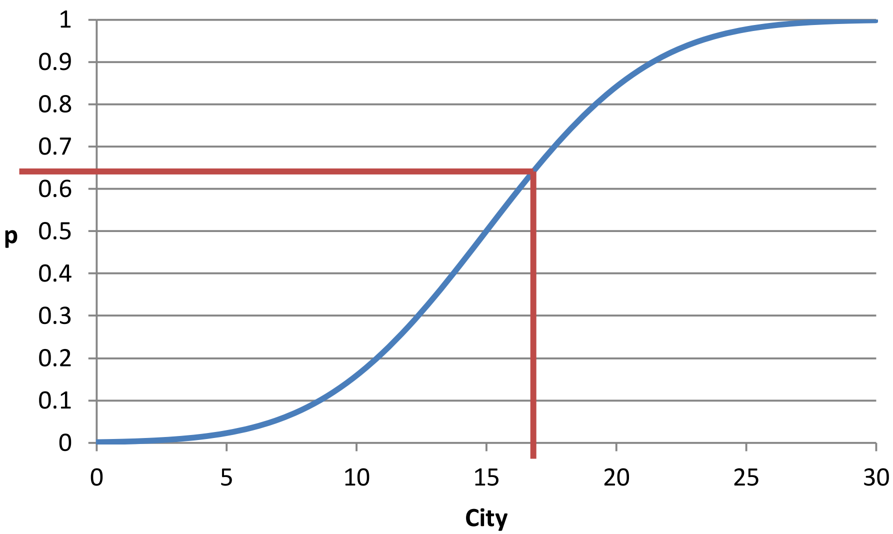
http://msdn.microsoft.com/en-us/magazine/hh781027.aspx

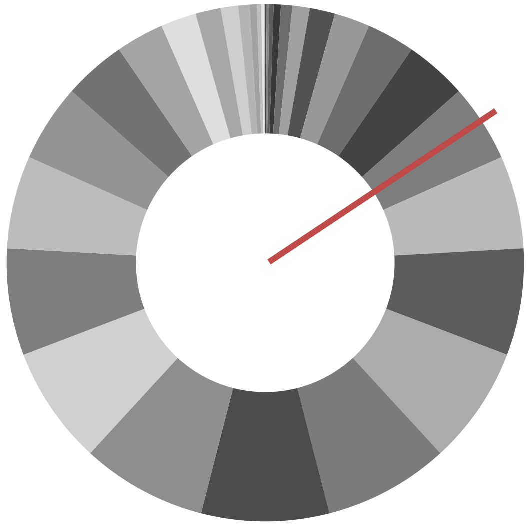
James McCaffery

Update ants

```
// For ant k at cityX
double[] probs = MoveProbs(k, cityX, visited,
      pheromones, dists);

// roulette wheel
double[] cumul = new double[probs.Length + 1];
for (int i = 0; i < probs.Length; ++i)
      cumul[i + 1] = cumul[i] + probs[i];

double p = random.NextDouble();

for (int i = 0; i < cumul.Length - 1; ++i)
      if (p >= cumul[i] && p < cumul[i + 1])
            return i;
```

Roulette wheels





MoveProbs

```
double[] taueta = new double[numCities]; double sum = 0.0;
for (int i = 0; i < taueta.Length; ++i) {
    if ((i == cityX) || (visited[i] == true))
      // Prob of moving to self is zero
      // Prob of moving to a visited node is zero
      taueta[i] = 0.0;
    else {
      taueta[i] = Math.Pow(pheromones[cityX][i], alpha) *
        Math.Pow((1.0 / Distance(cityX, i, dists)), beta);
      //cap or floor if too big or too small
    }
    sum += taueta[i];
}

//Normalise :   probs[i] = taueta[i] / sum;
```

Update Pheromones

```
double length = Length(ants[k], dists);
// length of ant k trail
double decrease = (1.0 - rho) *
    pheromones[i][j];
double increase = 0.0;
if (EdgeInTrail(i, j, ants[k]) == true)
    increase = (Q / length);

pheromones[i][j] = decrease + increase;
// matrix of edges from city i to city j
```

Maths

- Probability

p(K-th ant moves from city x to city y)

$$= \frac{\tau^{\alpha}{}_{xy}\eta^{\beta}{}_{xy}}{\sum \tau^{\alpha}{}_{xy}\eta^{\beta}{}_{xy}}$$

where η is attractiveness of move e.g. $^{1}/_{distance(x,y)}$

- Pheromone

$$\tau_{xy} = (1-\rho)\tau_{xy} + \sum_k \Delta\tau^{k}{}_{xy}$$

with $\Delta\tau^{k}{}_{xy} = \begin{cases} \frac{Q}{L_k} if ant\ k\ uses\ edge\ xy \\ 0 \qquad\qquad otherwise \end{cases}$

ACO for TSP results

- No pictures ☹
- [ACO.exe]()
- Change the code for our pathological case

```
static int[][] MakeGraphDistances(int numCities)
{
  int[][] dists = new int[numCities][];
  dists[0] = new int[] {  0, 1, 20,  3 };
  dists[1] = new int[] {  1, 0,  1,  2 };
  dists[2] = new int[] { 20, 1,  0, 30 };
  dists[3] = new int[] {  3, 2, 30,  0 };
  return dists;
}
```

- [ACOPathological.exe]()

Graphviz

Best trail found:

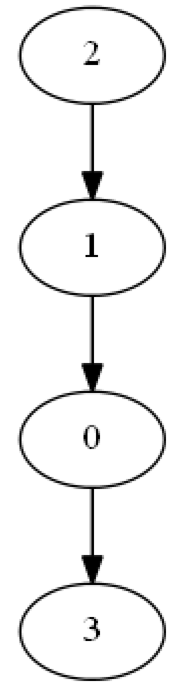
2 1 0 3

Change to:

digraph G {2->1; 1->0; 0->3;}

Run it through dot:

>dot.exe –Tpng
  digraph G {2->1; 1->0; 0->3;}
   > TSPACO.png



Observations

- Cheating! Just reports the best path ever

```
int[] currBestTrail = BestTrail(ants, dists);
double currBestLength = Length(currBestTrail, dists);
if (currBestLength < bestLength) {
      bestLength = currBestLength;
      bestTrail = currBestTrail;
      Console.WriteLine("New best length of " +
            bestLength.ToString("F1"));
}
```

- Do the worst ones get any better?
- Would this work for escaping a paper bag?
  - Let’s make the ants move nearby rather than jumping anywhere

ACO for escaping a paper bag

- Pictures ☺
- Change the distance metric, η?
  - We have a heuristic – “go up”, so use y
- Our problem is really continuous: start inside the bag and stop at the top
- Why don’t the ants update the pheromones as they move? (Another day…)

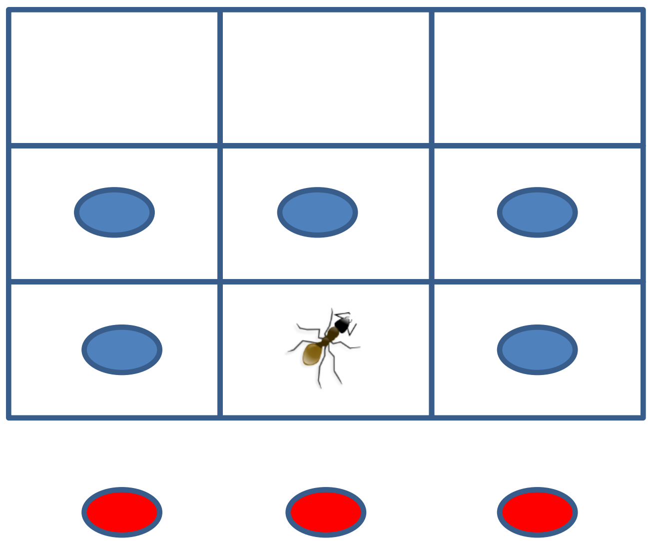
ACO in JavaScript

Pseudo-algorithm

- Let n ants start in the bottom of the bag
- In each epoch
  - All ants step up/down/left/right
    - guided by pheromones
    - ‘til they come out the top
  - Lay pheromones
  - Draw best trail

Shall we have some unit tests?

- “All ants step up/down/left/right”
  - And should not burst out of the bottom of the bag



Jasmine 1.2.0 revision 1337005947 finished in 0.02s

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Passing 18 specs

next_pos
- should not be below bag
- should not be beside bag
- should not return to a previous point

random_trail
- should start at bottom of bag
- should end above bag

make_trails
- should return same number of trails as ants

find_best
- should find the only trail if there is just one
- should find the shortest trail when it is first
- should find the shortest trail when it is last

contains
- should not contain a item when it is empty
- should contain a item when it is the only item

add_new_pheromones
- should contain each point in a new trail

nearest_pheromones
- should find the only item if just one exists
- should report -1 if none are near enough

cumulative_probability
- should give the sum of tau eta when there is one point
- should give the sum of tau eta when there is a non-zero weight and the rest are zero

roulette_wheel_choice
- should return a position
- should go to best pheromone point if all other points have zero probability

```
describe("next_pos", function() {

  it("should not be below bag", function() {
    var width = 4;
    for (var i = 0; i < width; ++i)
    {
      var pos = { x: i, y :0 };
      var next = next_pos(width, pos, []);
      expect(next.y >= 0).toBe(true);
    }
  });

});
```

Update

```
function update(pheromones, height, width) {
  var trail, i;
  var updated = evapourate(pheromones);

  for( i = 0; i < trails.length; ++i) {
    trail = trails[i];
    pheromones =
       add_new_pheromones(height, pheromones,
                                     trail);
  }

  trails = new_trails(pheromones, height,
     width, ants);
}
```

Recap

$$\tau_{xy} = (1-\rho)\tau_{xy} + \sum_k \Delta\tau^k{}_{xy}$$

= (evapourate old) + (lay new)

with $\Delta\tau^k{}_{xy} = \begin{cases} \frac{Q}{L_k} if ant\ k\ uses\ edge\ xy \\ 0 \qquad otherwise \end{cases}$

Pheromone evapouration

```
function evapourate(pheromones) {
  var evapouration = 0.75;
  var updated = [], new_pos;

  for(i = 0; i < pheromones.length; ++i) {
    new_pos = {x: pheromones[i].x, y: pheromones[i].y,
           weight: evapouration * pheromones[i].weight};
    updated.push( new_pos );
  }
  return updated;
}
```

Pheromone addition

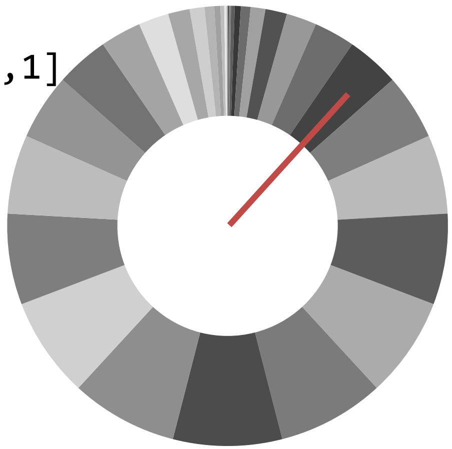
```
function add_new_pheromones(height, pheromones, trail) {
  var i, pos, new_pos;
  var Q = 2.0 * height;
  var L = Q/trail.length;

  for (i = 0; i < trail.length; ++i) {
    pos = trail[i];
    index = nearest_pheromone(pheromones, pos);
    if ( index !== -1 ) {
      pheromones[index] = {x: pheromones[index].x,
          y: pheromones[index].y, weight: pheromones[index].weight + L};
    }
    else {
      pheromones.push( {x: pos.x, y: pos.y, weight: L});
    }

  }
  return pheromones;
}
```

Make new trails

```
//For each ant, with var trails = [];
//trails.push
//   (pheromone_trail(width, height, pheromones));

function pheromone_trail(height, width, pheromones) {
    var trail = [], pos = start_pos(width);
    trail.push(pos);

    while (pos.y < height) {
      pos = roulette_wheel_choice(width, pos, trail,
                                  pheromones);
      trail.push(pos);
    }
    return trail;
}
```

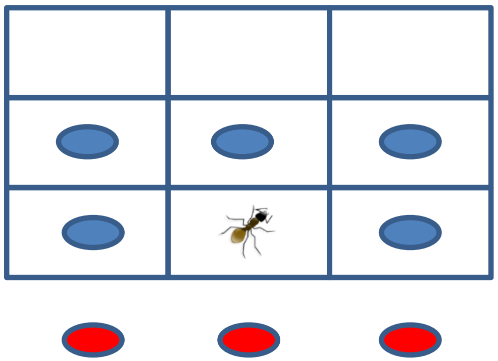
Roulette wheel

```
function roulette_wheel_choice(width, pos, trail, pheromones) {
  var p=0;
  var possible = allowed_positions(width, pos, trail);
  var cumulative = cumulative_probability(possible, pheromones);
  var total = cumulative[cumulative.length-1];
  if (total === 0) {
    p = Math.floor(Math.random() * possible.length);
    return possible[p];
  }

  p = Math.random() * total;

  for (i = 0; i < cumulative.length - 1; ++i) {
    if (p >= cumulative[i] && p <= cumulative[i+1]) {
      //the first place where it is in range, with 1 is in [1,1]
      return possible[i];
    }
  }
}
```



allowed_positions

```
function allowed_positions(width, pos, trail) {
  var possible = possible_positions(width, pos);
  var allowed = [];
  var i = 0;
  for (i = 0; i < possible.length; ++i) {
    if (!contains(trail, possible[i])) {
      allowed.push(possible[i]);
    }
  }
  if (allowed.length === 0) {
      allowed = possible;
  }
  return allowed;
}
```



Recap

tau eta is $\dfrac{\tau^{\alpha}{}_{xy}\eta^{\beta}{}_{xy}}{\sum \tau^{\alpha}{}_{xy}\eta^{\beta}{}_{xy}}$

where

- τ is the pheromone
- η is attractiveness of move e.g. $^{1}/_{distance(x,y)}$
- α, β are parameters
  - (numbers picked out of the air and experimented with)

cumulative_probability

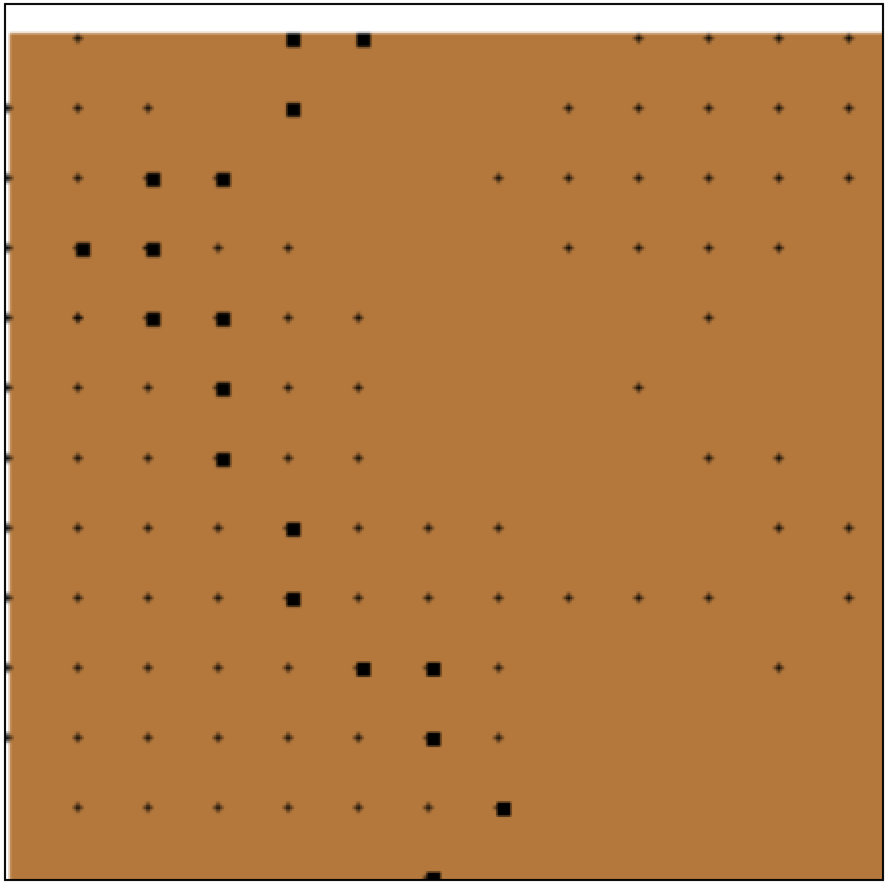
```
function cumulative_probability(possible, pheromones){
  var total = 0.0, index;
  var cumulative = [total];
  for (i = 0; i < possible.length; ++i) {
    index = nearest_pheromone(pheromones, possible[i]);
    if (index !== -1) {
      total = total + taueta(pheromones[index].weight,
                       pheromones[index].y);
    }
    cumulative.push(total);
  }
  return cumulative;
  //not in [0, 1] but choosing random(0, total) is same as dividing by total here
}
```

Tau eta

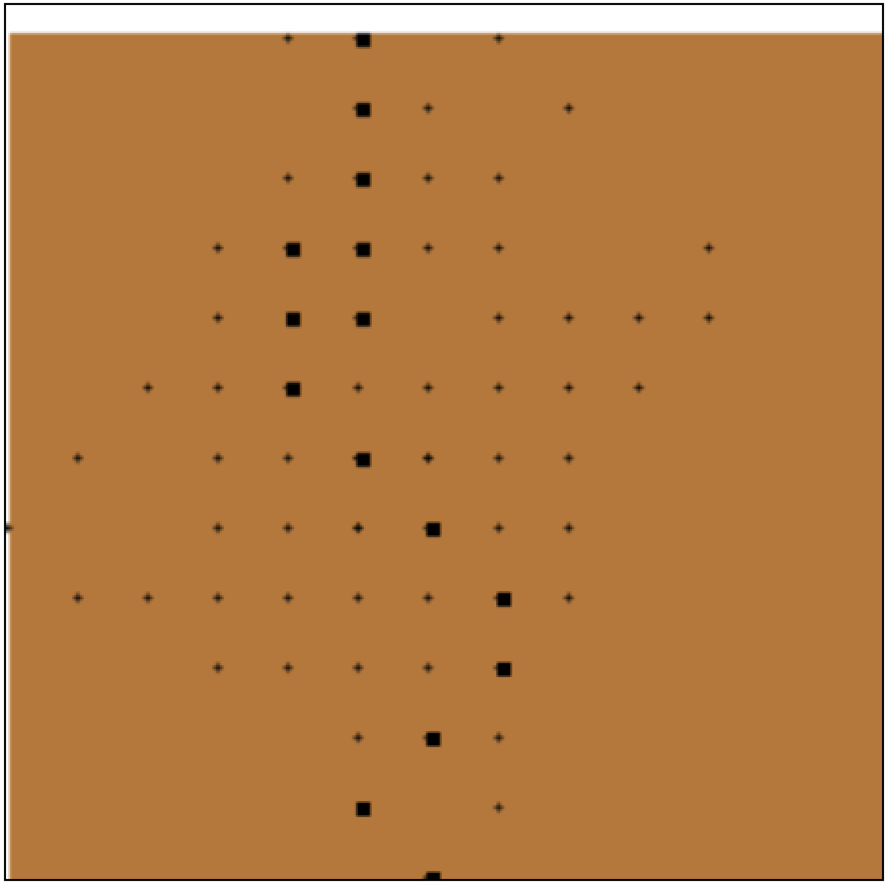
```
function taueta(weight, y) {
  var alpha = 1.0;
  var beta = 3.0;
  return Math.pow(weight, alpha) +
    Math.pow(y, beta);
}
```

Success?

..\..\paperbag\aco_paperbag\aco_paperbag.html



Learning: lighter dots worst, darker dots best



Finished: worst tending to be a bit closer to best

What we have learnt so far

- Fizz buzz doesn't have a paper bag
- A simple JavaScript animation can involve a paper bag we program our way out of
- Machine learning covers many ideas, some of which are suitable for the problem at hand
- We saw an implementation of an ant colony optimisation
  - We could try other pheromone updating schemes

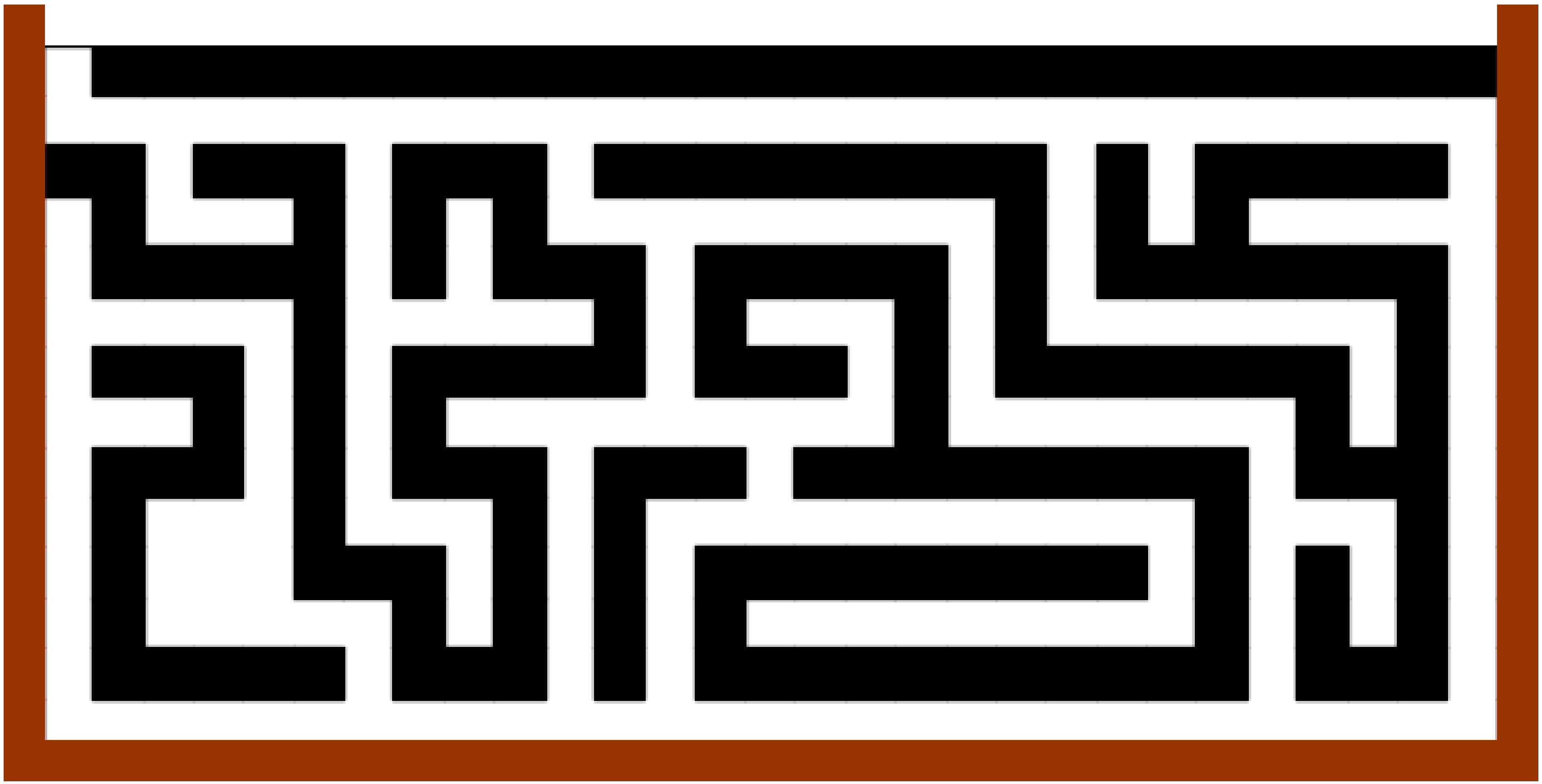
What else can we do?

- When faced with a difficult problem
  - make a cup of tea
  - break your problems into parts and handle them one part at a time
  - remember, “All the greatest and most important problems of life are fundamentally insolvable. They can never be solved, but only outgrown.” Carl Jung
  - try to transform it into a known problem and solve that instead

“The mere formulation of a problem is far more essential than its solution, which may be merely a matter of mathematical or experimental skills. To raise new questions, new possibilities, *to regard old problems from a new angle requires creative imagination* and marks real advances in science.”

Albert Einstein

Transform it into a known problem and solve that instead

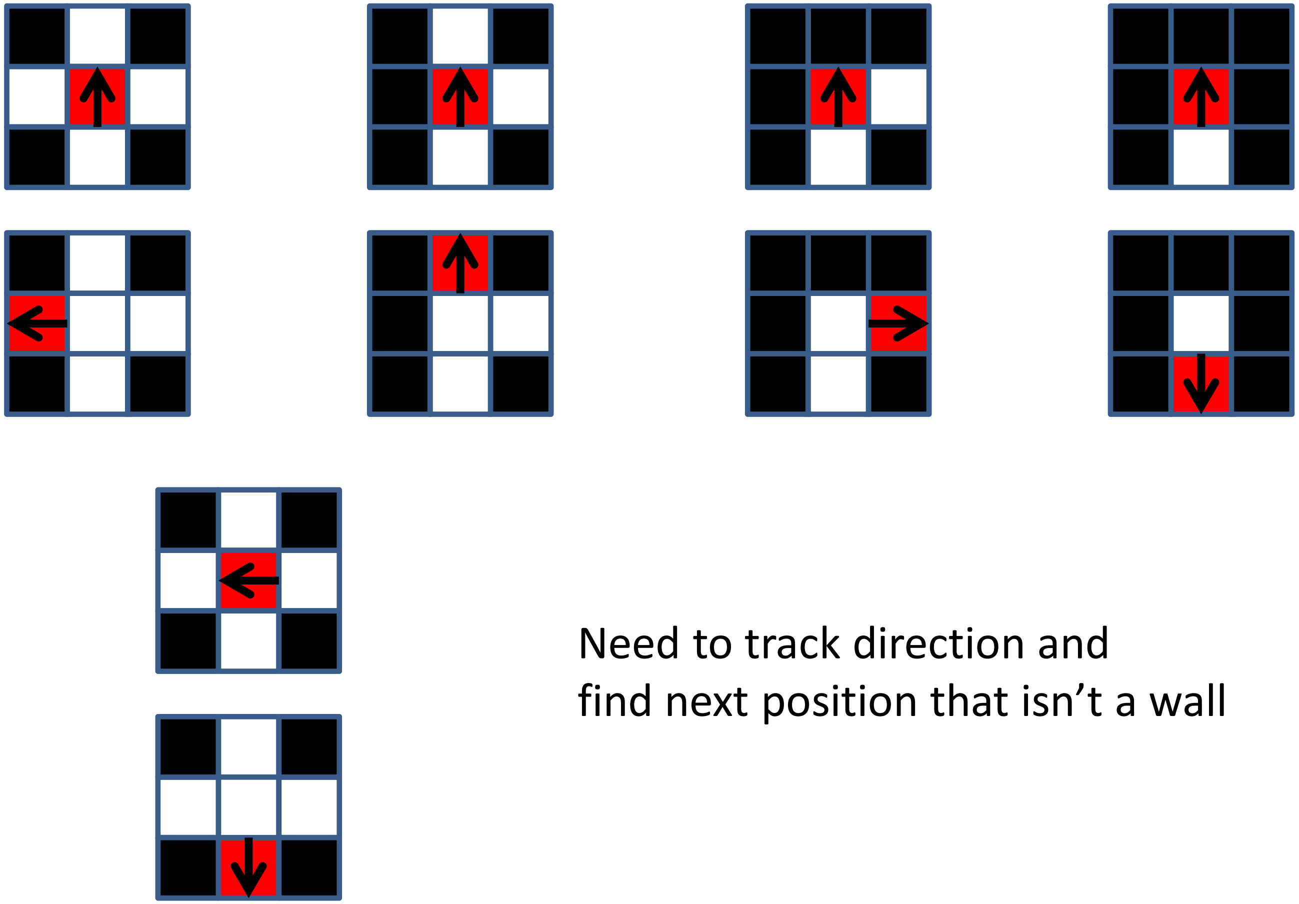


Mazes

- Let’s be lazy and assume we already have a maze
- http://en.wikipedia.org/wiki/Maze_generation_algorithm

```
Z = numpy.zeros(shape, dtype=numpy.int32)
#for rand x, y
Z[y, x] = 1 #make a wall
for j in range(complexity):
    neighbours = []
    if x > 1:             neighbours.append((y, x - 2))
    if x < shape[1] - 2:  neighbours.append((y, x + 2))
    if y > 1:             neighbours.append((y - 2, x))
    if y < shape[0] - 2:  neighbours.append((y + 2, x))
    if len(neighbours):
        y_,x_ = neighbours[rand(0, len(neighbours) - 1)]
        if Z[y_, x_] == 0:#if it’s not a wall
            Z[y_, x_] = 1
            Z[y_ + (y - y_) // 2, x_ + (x - x_) // 2] = 1
            x, y = x_, y_
```

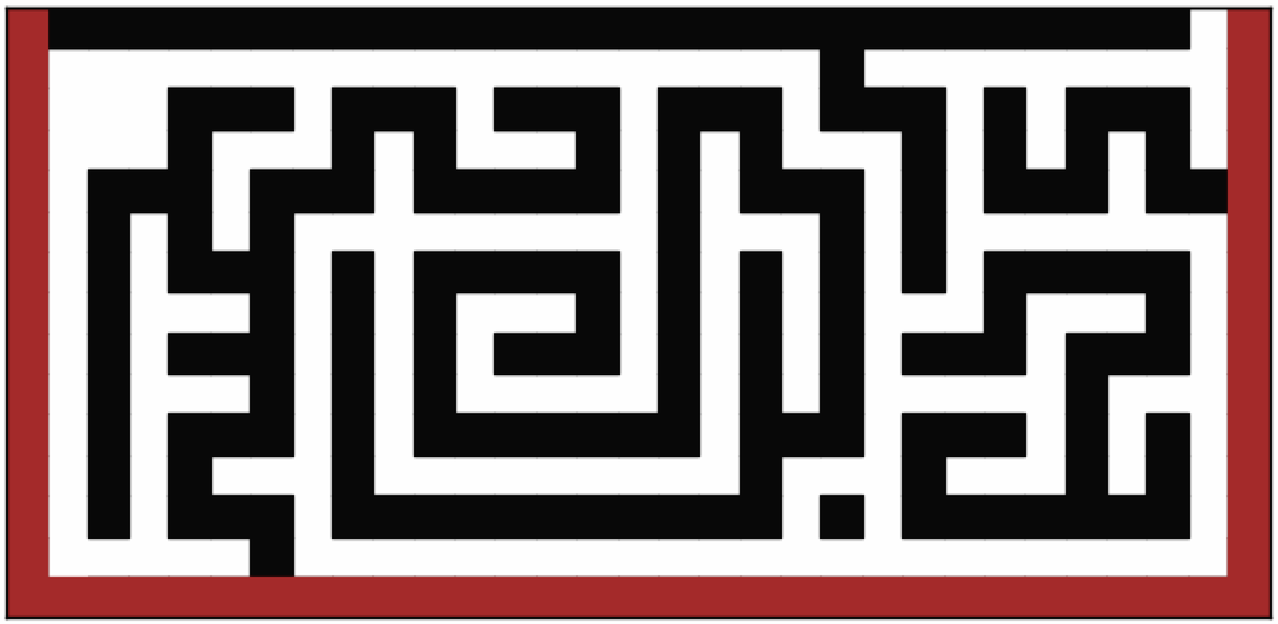
Left-wall follower



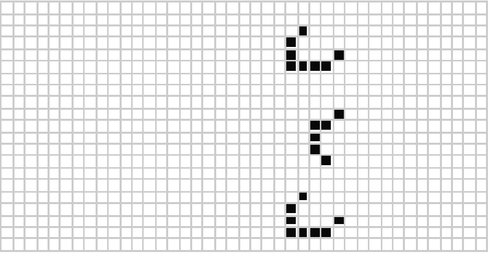
Need to track direction and
find next position that isn't a wall

Next move

```
#find start and append next_move til we come out the end
    facing, row, col = next_move(facing, row, col, maze)
    path.append( (row, col) )
    …

def next_move(facing, row, col, maze):
    l = potential_moves(facing)
    index = 0
    rows = maze.shape[0]
    cols = maze.shape[1]
    while index < len(l):
        if l[index] == 'U' and (row - 1 >= 0) and (maze[row - 1, col] == 0):
            return 'U', row - 1, col
        elif l[index] == 'R' and (col + 1 < cols) and (maze[row, col + 1] == 0):
            return 'R', row , col + 1
        elif l[index] == 'D' and (row + 1 < rows) and (maze[row + 1, col] == 0):
            return 'D', row + 1, col
        elif l[index] == 'L' and (col - 1 >= 0) and (maze[row, col - 1] == 0):
            return 'L', row, col - 1
        index = index + 1
```



Other ideas



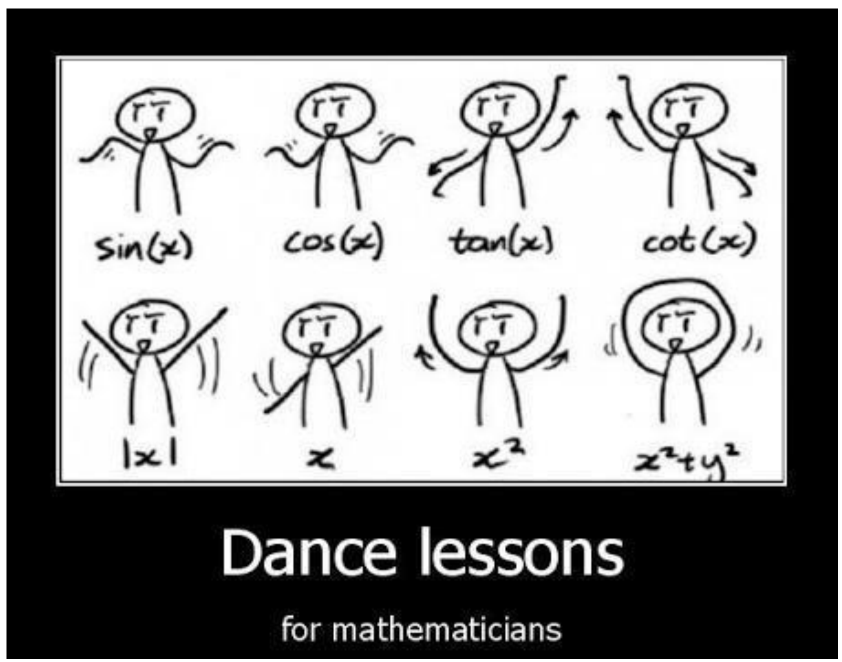
- Cellular automata
  - Langton’s ant (http://en.wikipedia.org/wiki/Langton%27s_ant)

    Squares on a plane are coloured variously either black or white. One square is the "ant". The ant moves according to these rules:
    - At a white square, turn 90° right, flip the colour of the square, move forward one unit
    - At a black square, turn 90° left, flip the colour of the square, move forward one unit
  - Conway’s game of life (http://en.wikipedia.org/wiki/Conway%27s_Game_of_Life)

    Cells are alive or dead. At each time step
    - Any live cell with fewer than two live neighbours dies, as if caused by under-population.
    - Any live cell with two or three live neighbours lives on to the next generation.
    - Any live cell with more than three live neighbours dies, as if by overcrowding.
    - Any dead cell with exactly three live neighbours becomes a live cell, as if by reproduction.

Other ideas…

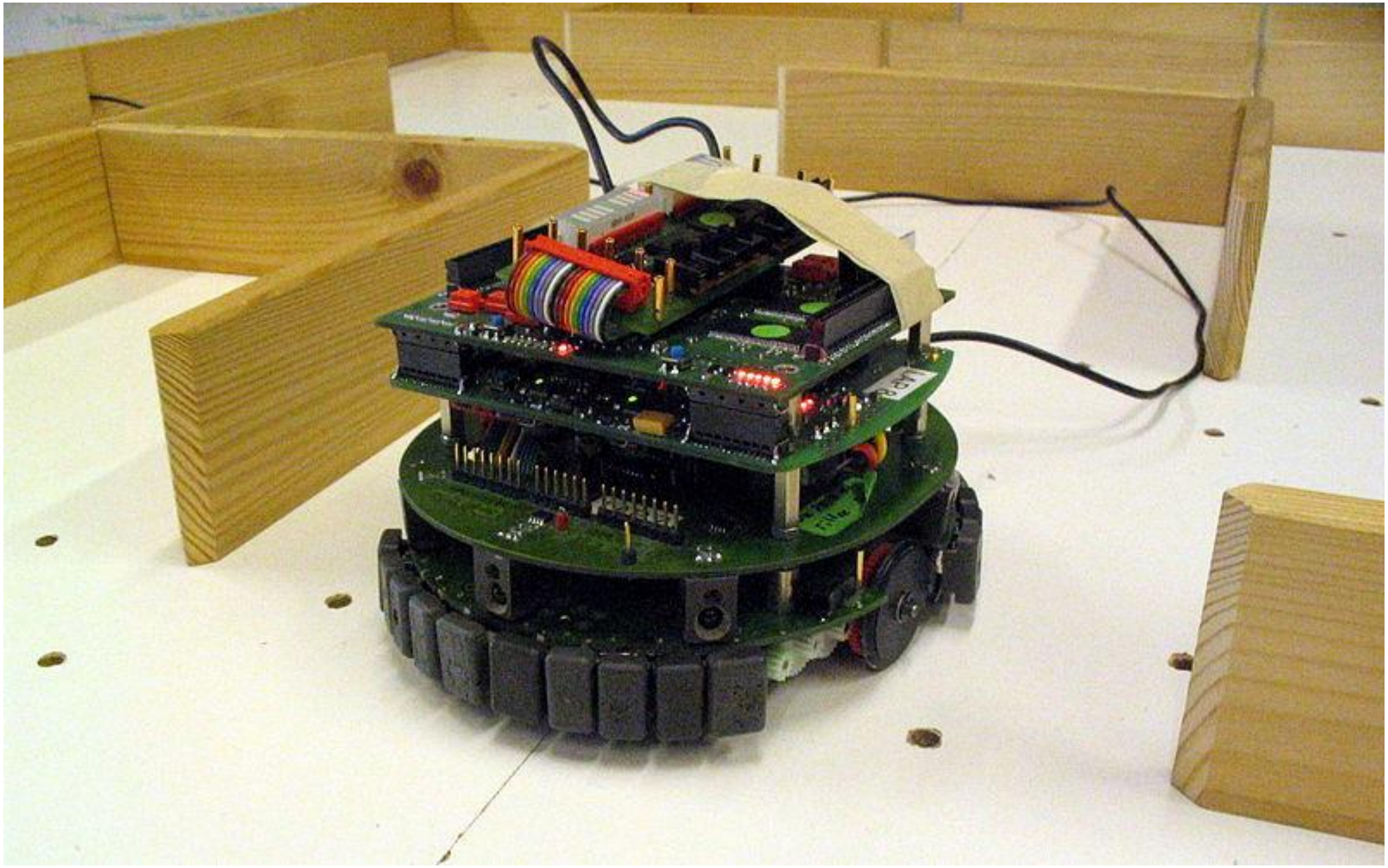
- Other swarm optimisation algorithms
- Monte-Carlo simulations
- Anything that moves in a plane, or space



Is this a software problem?

- All our paper bags are 2D
- Can they move?
- What colour are they?
- Does it make a difference if the bag is wet?
- Lots of maze solving projects on the internet involve robots…

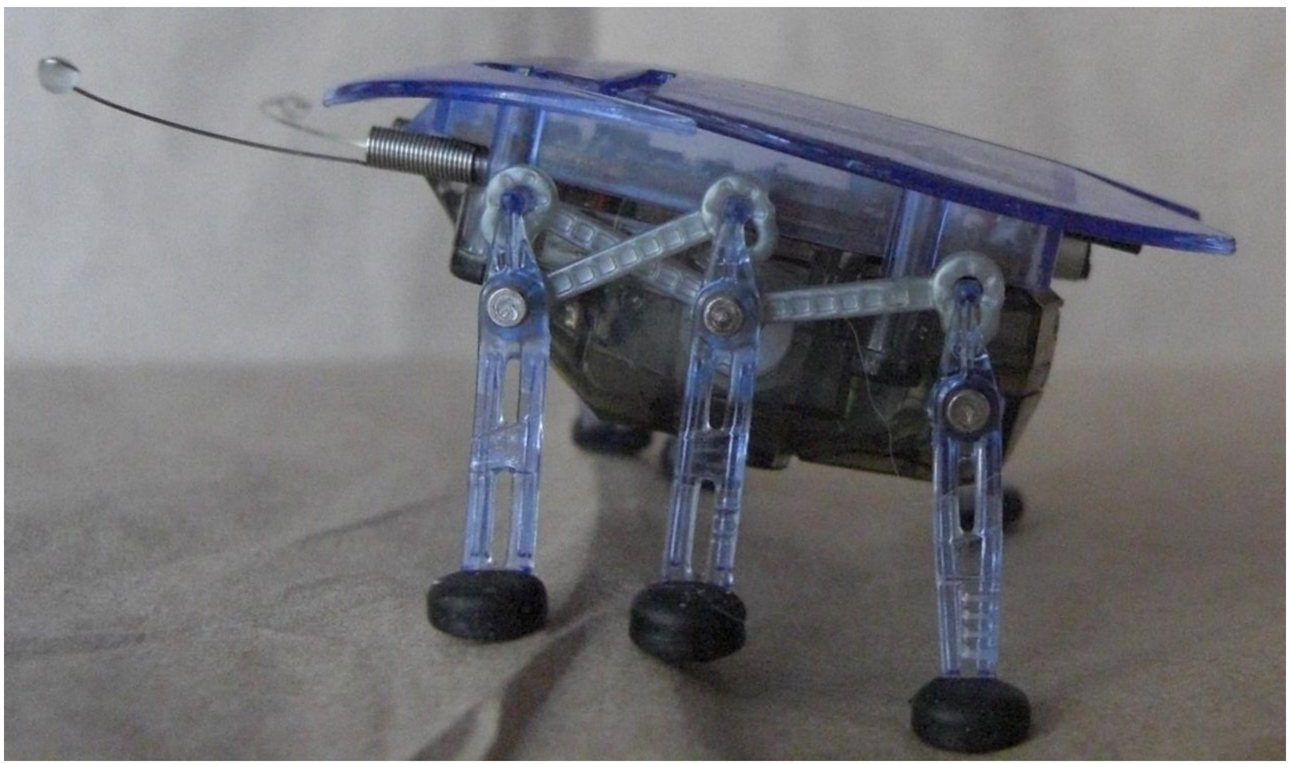
Is it a software problem?



http://upload.wikimedia.org/wikipedia/commons/thumb/f/fe/Cyclope_robot.jpg/800px-Cyclope_robot.jpg

Is this a hardware problem?
(or am I a hardware engineer?)

- My soldering was rubbish
- Hexabug often gets stuck in the bag



Other hardware ideas

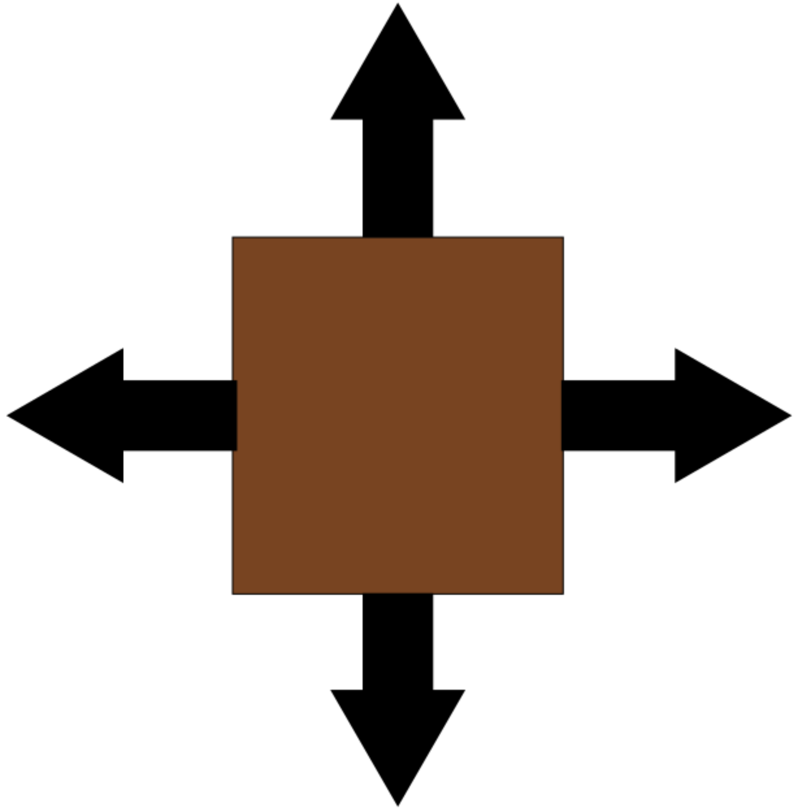
- Raspberry Pi
  - http://www.cl.cam.ac.uk/projects/raspberrypi/tutorials/robot/robot_assembly/
- Learn to build robots

Other ideas

http://upload.wikimedia.org/wikipedia/commons/thumb/c/c7/Explosions.jpg/800px-Explosions.jpg

Conclusion

- Fizz buzz doesn’t involve paper bags
- Drag and drop wasn’t enough fun
- It’s a hard problem: “difficult scientific problem”
- Machine learning provides many ideas
- Is it actually a software problem?
- Can you program your way out of a paper bag?
- Email your attempts to overload@accu.org



This is to certify that
Frances Buontempo
can program her way
out of a paper bag