SOCIETY OF ACTUARIES

Genetic Algorithms – What They Are, How to Apply Them to Solve Problems, and How to Create Your Own

Maryville University – 7-Mar-2016

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https://github.com/DaveSnell/Genetic-Algorithms

Actuaries
Risk is Opportunity.®

Background and History

- What is a Genetic Algorithm?
- Where did Genetic Algorithms come from?
- How are these being used in other industries?

2

Problem Solving with Genetic Algorithms

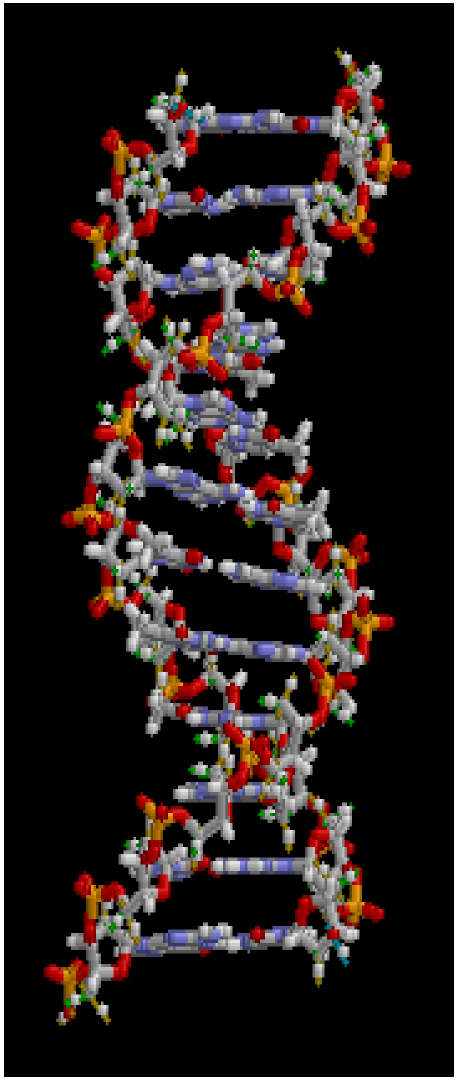
- Why should I use a Genetic Algorithm?
- How do I find a suitable problem?
- What do I need to do to implement a GA?

3

A Genetic Algorithm can be useful for …

- Provider group selection
- Sales representatives and regions
- ERM … beyond CTE
- Stress tests when valuing a block of business
- Traveling Salesperson
- Non-linear equations

4



Genetic Algorithms

Why do we call these Genetic Algorithms?

They mimic our current knowledge of genetics.

We have trillions of cells.

DNA represents a blueprint for a cell.

It is used to generate copies.

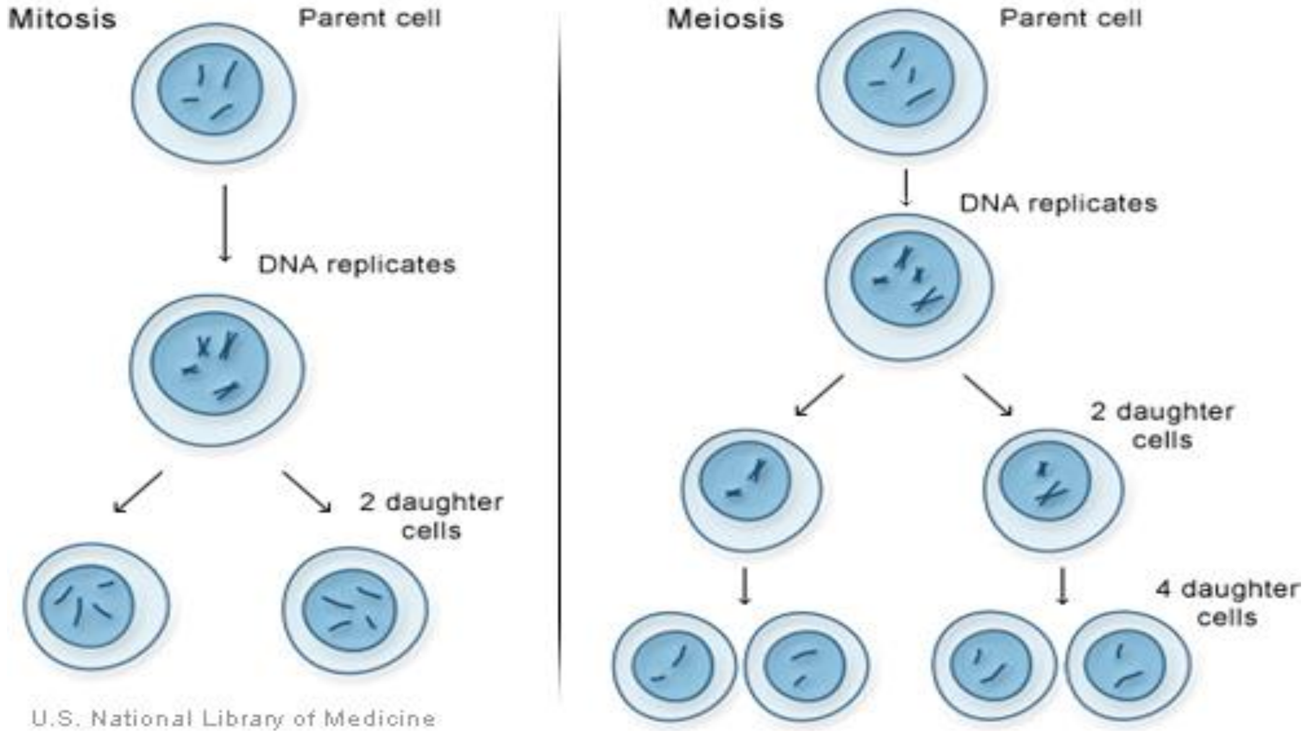
The actual process involves proteins and lots of other biological terms …

and you don’t have to know them to solve problems!

5

Mitosis & Meiosis

Genetics that you don’t have to know 1



Our Elites correspond to Mitosis

The rest of the new generation are analogous to Meiosis

Genetics that you don't have to know 2

Copy, copy, copy…

Mitosis – exact copies

Meiosis – copy portions from two parents

Mutation – inexact copy – rarely lives

Over time - a long time - we evolve

… taller, less hairy, and more adept at making tools.

Genetic Algorithms (How twins are made)

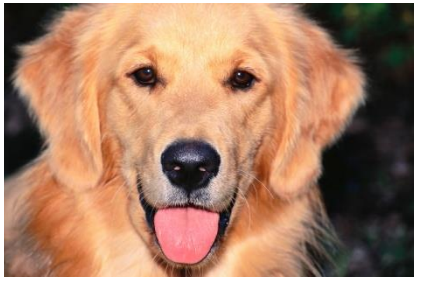
Genetics that you don't have to know 3

8

Very basic genetics

Genetics that you don't have to know 4

- Humans have about 25,000 genes made from A-T and C-G pairs
- DNA strand – double helix of two strands – each about 1.8 meters
- In meiosis, the strand separates into 46 chromosomes (in 23 pairs)
- Alleles (forms of a gene) help determine physical or behavioral traits



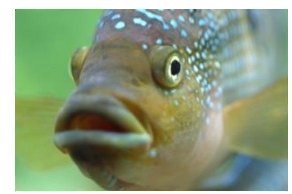
9

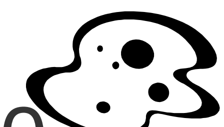
Does the size of a Genome determine species dominance?

NO! – It’s all in how you use it!

Genetics that you don’t have to know 5

- Human ,200,000,000 3.2Gb





- Lungfish130,000,000,000 130Gb

Where is the Research being done on Genomes?

All over the world; but especially …

National Institutes of Health (NIH)

The Genome Institute at Washington University

“*This is why I go to work!”*

RMS – rhabdomyosarcoma

-Frederick S. Huang, MD

Genetics that you don’t have to know 6

Genetic Algorithms

- ❖**Randomly assign the gene string for 100 robots.**

```
43422505540265266062350432441155466146130640400510
04166624610505301230565521330350534334223063122042
44006112664132621314402343314424211646536440311521
01520462315536646262334412410120463361312223511662
01656342565541226634336152133445205013645522131160
```

Link to Actuarial Qualification!

- ❖ Run them through 100 tests with random (or chosen) inputs.
- ❖ Score each robot and eliminate losers (survival of the fittest).
- ❖ Assign mating rights to survivors per test scores.
- ❖ Pick parents, and pair them off to produce the next generation (splitting gene string at arbitrary point)

Parent F (52.80 points): 54335351253404 315142153601520652551511513145155663
Parent M (45.60 points) :54335351525534 633242153604216362551511503145155625

Child A: 54335351253404 633242153604216362551511503145155625
Child B: 54335351525534 315142153601520652551511513145155663

Red genes are from parent M

Blue genes are from parent F

- ❖**Randomly mutate a few genes (actions)**
- ❖**Repeat for 100 (or 1,000 or 10,000) generations**

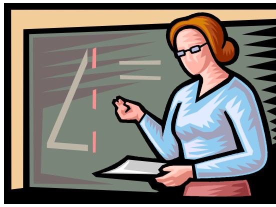
Genetics that you
don't have to know 7

12

Genetic Algorithms (cont.)

- **Randomly assign the gene string for 100 robots.**

```
43422505540265266062350432441155466146130640400510
04166624610505301230565521330350534334223063122042
44006112664132621314402343314424211646536440311521
01520462315536646262334412410120463361312223511662
01656342565541226634336152133445205013645522131160
```



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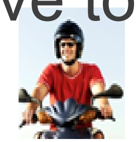
Genetics that you
don't have to know 8

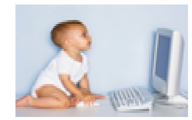
13

Meiosis in action - Genetics 0.001

Genetics that you don’t have to know 9








Gene	Parent 'M'		Parent 'F'		Child1		Child2		Child3		Child4	
1	Dad	Mom	Dad	Mom	Dad's Dad	Mom's Dad	Dad's Mom	Mom's Mom	Dad's Dad	Mom's Mom	Dad's Mom	Mom's Dad
2	Dad	Mom	Dad	Mom	Dad's Mom	Mom's Mom	Dad's Mom	Mom's Dad	Dad's Mom	Mom's Mom	Dad's Mom	Mom's Dad
3	Dad	Mom	Dad	Mom	Dad's Dad	Mom's Mom	Dad's Mom	Mom's Mom	Dad's Mom	Mom's Mom	Dad's Mom	Mom's Dad
4	Dad	Mom	Dad	Mom	Dad's Dad	Mom's Dad	Dad's Dad	Mom's Mom	Dad's Mom	Mom's Mom	Dad's Mom	Mom's Mom
5	Dad	Mom	Dad	Mom	Dad's Mom	Mom's Mom	Dad's Mom	Mom's Dad	Dad's Dad	Mom's Mom	Dad's Mom	Mom's Mom
6	Dad	Mom	Dad	Mom	Dad's Dad	Mom's Mom	Dad's Dad	Mom's Dad	Dad's Dad	Mom's Mom	Dad's Dad	Mom's Mom
7	Dad	Mom	Dad	Mom	Dad's Mom	Mom's Dad	Dad's Mom	Mom's Mom	Dad's Mom	Mom's Dad	Dad's Dad	Mom's Dad
8	Dad	Mom	Dad	Mom	Dad's Mom	Mom's Dad	Dad's Mom	Mom's Dad	Dad's Dad	Mom's Mom	Dad's Dad	Mom's Mom
9	Dad	Mom	Dad	Mom	Dad's Dad	Mom's Dad	Dad's Dad	Mom's Dad	Dad's Dad	Mom's Dad	Dad's Mom	Mom's Mom
...												
5,000	Dad	Mom	Dad	Mom	Dad's Mom	Mom's Mom	Dad's Dad	Mom's Mom	Dad's Dad	Mom's Mom	Dad's Mom	Mom's Mom
5001	Dad	Mom	Dad	Mom	Dad's Mom	Mom's Dad	Dad's Mom	Mom's Dad	Dad's Mom	Mom's Dad	Dad's Dad	Mom's Dad

Parent genes prior to meiosis – each person gets one set from Dad and another set from Mom

set of genes from Dad

set of genes from Mom

Note that each child gene is from two of the four grandparents: one on Mom’s side, one on Dad’s side (excluding mutations)

14

Genetic Algorithms are not limited to two parents (or even four grandparents)

Genetics that you might want to know 10

Potential Parent	Gene 1	Gene 2	Gene 3	…	Gene Ꞷ
1	A	as	1		X
2	B	rt	0		Y
3	C	gh	0		Y
4	D	iu	1		Y
5	E	mn	1		X
6	F	iu	0		X
7	G	ew	1		Y
8	H	t6	1		X
9	I	u8	0		Y
…					
N	Z	9m	1		X
Child	C	t6	1	…	X
parent:	3	8	7		6

Your 'genes' can have vastly different characteristics and components.

A 'child' can have genes drawn from several different parents.

15

Yet another version of the Traveling Salesperson problem … with a few twists:

Distances vary between cities

Some cities are worth more than others to visit

NE Road Trip

City	1	2	3	4	5	6	7	8
Weight	1	1	4	2	1	2	2.5	1

City	City Num.	Albany, NY	Augusta, ME	Boston, MA	Bridgeport, CT	Concord, NH	Greewich, CT	Hartford, CT	Montpelier, VT
Albany, NY	1	0	326	170	156	142	154	111	167
Augusta, ME	2	326	0	164	310	153	339	256	192
Boston, MA	3	170	164	0	153	68	182	99	179
Bridgeport, CT	4	156	310	153	0	198	29	56	250
Concord, NH	5	142	153	68	198	0	227	144	114
Greewich, CT	6	154	339	182	29	227	0	85	279
Hartford, CT	7	111	256	99	56	144	85	0	194
Montpelier, VT	8	167	192	179	250	114	279	194	0

2nd trip to same city = 1/2
3rd trip to same city = 1/10
4th+ trip to same city = 0

max. mileage
1000

					mileage	visits	visit count	visit factor
starting point (evening arrival)	1	value	cost	adjusted value	row col	1	1	1
	1	1	0	1	6 C	1	2	0.75
	7	2.5	111	2.5	12 C	1	3	0.533333333
	6	2	85	1.5	11 I	2	4	0.4
	5	1	227	0.75	10 H	2	5	0.32
	6	2	227	1.5	11 G	2	6	0.266666667
	3	4	182	3	8 H	2	7	0.228571429
	4	2	153	2	9 E	1	8	0.2
	3	4	153	3	8 F	2	9	0.177777778
	5	1	68	0.75	10 E	2	10	0.16
	points	19.5	1206	16				
		mileage penalty		-206				
		total score		-190				

Start Genetic Algorithm for this sample problem

There is a mileage penalty in the scoring algorithm

You can visit a city more than once (but for less credit)

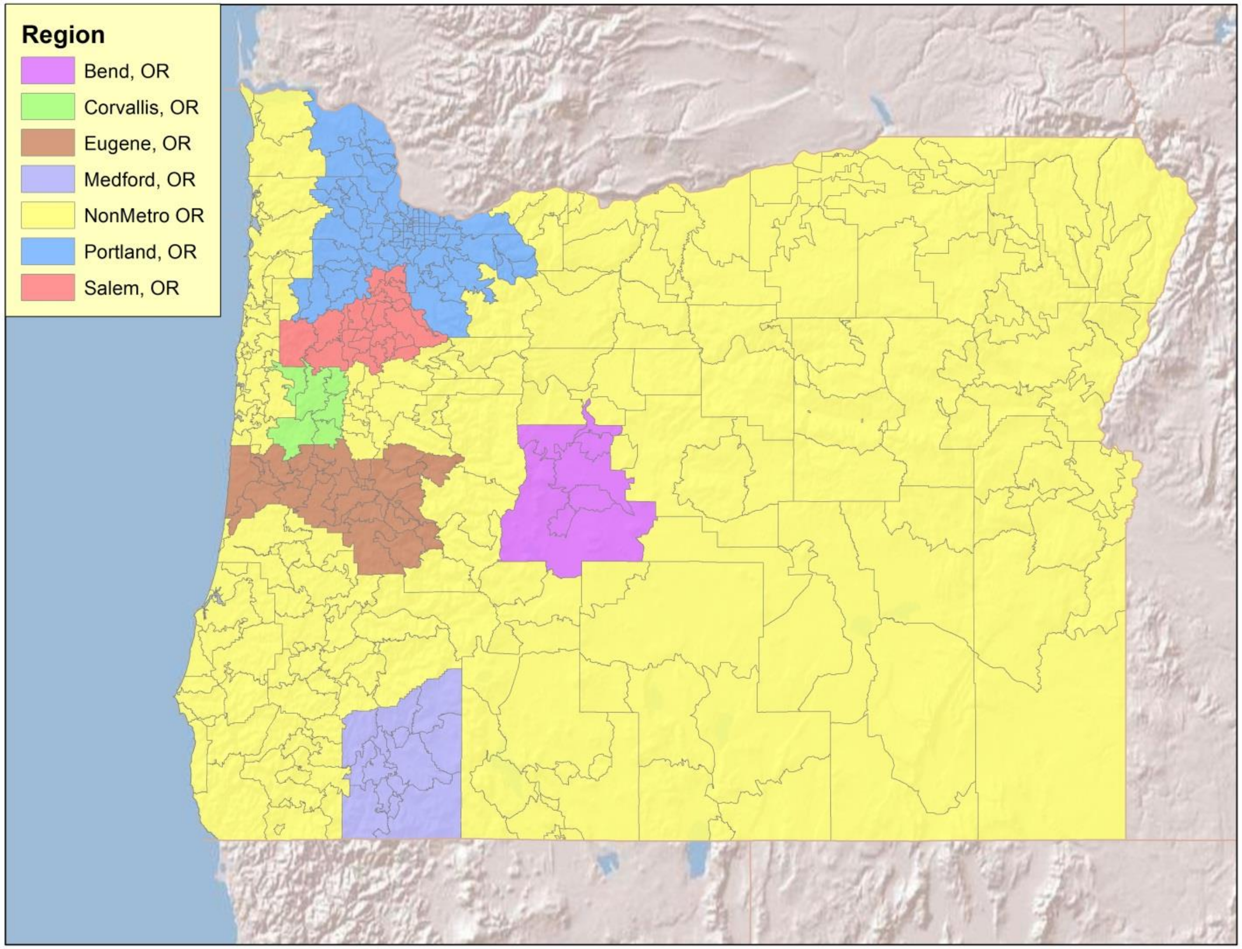
We don't want to exceed 1,000 miles

Let’s see a real world actuarial example:

- Health Provider Network
- 500 potential providers for this example
- Each provider offers up to 36 specialties
- Each specialty has a relative cost
- Each Provider has a relative cost
- You have to provide a sufficient number of practitioners for each of the specialty choices
- You want to minimize overall cost
- More than 10 to the 150th possible solution sets

17

Example: Personnel Assignments



18

Example: Personnel Assignments

- We have 15 people to assign to 7 areas based on their preferences:

	Area Preference (Ranked 1-7)						
Employee	Portland	Salem	Eugene	Corvallis	Medford	Bend	NonMetro
Laura	2	5	4	1	3	6	7
Renee	6	2	7	4	3	1	5
Timothy	1	7	5	4	3	2	6
Robert	2	7	1	3	5	4	6
Adam	4	3	7	2	1	6	5
Jamie	6	1	5	7	2	3	4
Ana	6	4	5	7	1	3	2
Jessica	1	6	4	2	3	5	7
John	6	5	3	2	7	4	1
Anthony	3	5	1	7	2	4	6
Lisa	3	6	4	5	7	2	1
Donna	3	4	7	1	6	5	2
Claude	1	4	2	5	3	7	6
Deborah	3	6	7	4	1	2	5
David	1	6	4	7	2	3	5

19

Provider Network Cost Optimization

Each provider group is in (1) or out (0) of network.

5				Specialties:	Chiropractic	Pathology	Cardiovascular Disease	Family Practice	Obstetric
6				Cost	0.97	0.92	0.90	0.89	
7				Count Minimum	5	5	5	20	
8				Current Count	79	42	70	356	
9					125	62	82	597	
10		Total							
11					1	2	3	4	
12	Health System	In	Rela	Total Provider	Chiropractic	Pathology	Cardiovascular Disease	Family Practice	Obstetric
13	Provider # 1	1	0.77	M(G13:AP13)	0	23	24	64	
14	Provider # 2	1	0.90	355	1	12	26	83	
15	Provider # 3	1	0.79	287	0	0	9	66	
16	Provider # 4	0	1.13	228	0	0	0	65	
17	Provider # 5	0	0.89	216	0	0	11	67	
18	Provider # 6	0	1.36	137	0	0	0	0	
19	Provider # 7	0	1.50	129	3	17	0	10	
20	Provider # 8	0	1.32	85	0	0	0	18	
21	Provider # 9	0	1.33	38	0	0	0	0	
22	Provider # 10	0	1.08	37	0	1	0	0	
23	Provider # 11	1	1.04	35	0	0	0	0	
24	Provider # 12	0	0.73	35	0	0	0	0	
25	Provider # 13	0	1.16	34	0	0	0	0	
26	Provider # 14	0	1.32	28	0	0	0	0	
27	Provider # 15	0	1.12	27	0	0	0	4	
28	Provider # 16	1	1.03	27	0	0	0	18	
29	Provider # 17	1	0.78	26	0	0	0	0	
30	Provider # 18	0	1.22	26	0	0	0	0	
31	Provider # 19	1	1.55	25	0	0	0	1	
32	Provider # 20	1	0.84	21	0	0	0	13	

Each provider group can have multiple specialists; and has a relative cost.

500 Providers for this example; but could have thousands. Lots of specialties. Could have 2^500 (> 10^150) solution sets … might take a while by traditional methods. ☺

20

Provider Network Cost Optimization (continued)

Genetic Algorithm Presentation

Provider Network Fitness Function

Count of Contracts (Provider Groups) Used:	325
Included Providers (Specialists):	2,885
Relativity to Overall Network:	0.8966
Adequate Network:	Yes

Click Here to start genetic algorithm for solution set. You can modify parameters on the Parameters sheet.

Specialty	Available Providers	Required Providers	Selected Providers	Requirement Met	Relativity	Specialty Weight
Hospital	16	5	11	Yes	0.89	47.1%
Family Practice	597	20	438	Yes	0.90	7.7%
Physical Therapy	506	5	243	Yes	1.00	3.9%
Internal Medicine	376	20	296	Yes	0.89	3.8%
Obstetrics/Gynecology	277	5	195	Yes	0.88	3.8%
Pediatrics	351	5	249	Yes	0.95	3.4%
Orthopedic Surgery	147	5	100	Yes	0.88	3.2%
Hematology /Oncology	97	5	58	Yes	0.86	2.8%
Chiropractic	125	5	87	Yes	0.98	2.7%
Diagnostic Radiology	174	5	101	Yes	0.87	2.5%
Dermatology	61	5	47	Yes	0.81	2.1%
Ophthalmology	120	5	111	Yes	0.86	1.3%
Otolaryngology	52	5	45	Yes	0.82	1.3%
Gastroenterology	40	5	34	Yes	0.89	1.2%
Pathology	62	5	41	Yes	0.90	1.1%
Podiatry	44	5	32	Yes	1.01	1.0%
Acupuncturist	65	5	39	Yes	0.94	0.9%
Urology	44	5	32	Yes	0.93	0.9%
General Surgery	65	5	46	Yes	0.84	0.8%
Rheumatology	21	5	16	Yes	0.86	0.8%
Neurology	94	5	86	Yes	0.91	0.8%

Instructions | Summary | Provider_List | DNA | Parameters

Each specialty area must have adequate coverage.

21

Some problems just don't fit well into classical methods of solution:

Assume you have three equations:

- $y_1 = a * e * g + h + d^a$
- $y_2 = |h|! - |d|!$
- $y_3 = ((\sin(a)) + b) * \log(b + c)) + \cos(\min(c, d)) * (e - f + g * h)$

Oh yeah!
We are math folks, so this might be too easy by itself!

Find a combination of ***a, b, c, d, e, f, g, h*** such that the standard deviation of y_1, y_2, and y_3 is minimized.

Let's add some constraints to make it more interesting!

a has to be an integer from 1 to 10
b is a real number from 0 to 15
c is a real number from 1 to 3
d is a real number from 0.5 to 7
e is a real number from -10 to 50
f is an **even** integer from -20 to 40
g is a real number from 0 to 18
h is a real number from 3 to 12

How to attack a really monstrous problem (continued … expressed as an Excel sheet)

	A	B	C	D	E	F	G
4		Variable Value	ValueOK	Min	Max	Int?	Conditions
5	a	5.00	TRUE	1	10	Y	=IF(F5="Y",IF(AND(varA>=D5,varA<=E5,varA=INT(varA)),TRUE,FALSE),IF(AND(varA>=D5,varA<=E5),TRUE,FALSE))
6	b	7.50	TRUE	0	15	N	=IF(F6="Y",IF(AND(varB>=D6,varB<=E6,varB=INT(varB)),TRUE,FALSE),IF(AND(varB>=D6,varB<=E6),TRUE,FALSE))
7	c	2.00	TRUE	1	3	N	=IF(F7="Y",IF(AND(varC>=D7,varC<=E7,varC=INT(varC)),TRUE,FALSE),IF(AND(varC>=D7,varC<=E7),TRUE,FALSE))
8	d	3.00	TRUE	0.5	7	N	=IF(F8="Y",IF(AND(varD>=D8,varD<=E8,varD=INT(varD)),TRUE,FALSE),IF(AND(varD>=D8,varD<=E8),TRUE,FALSE))
9	e	20.00	TRUE	-10	50	N	=IF(F9="Y",IF(AND(varE>=D9,varE<=E9,varE=INT(varE)),TRUE,FALSE),IF(AND(varE>=D9,varE<=E9),TRUE,FALSE))
10	f	30.00	TRUE	-20	40	Y	=IF(F10="Y",IF(AND(varF>=D10,varF<=E10,varF=INT(varF),MOD(varF,2)=0),TRUE,FALSE),IF(AND(varF>=D10,varF<=E10),TRUE,FALSE))
11	g	9.00	TRUE	0	18	N	=IF(F11="Y",IF(AND(varG>=D11,varG<=E11,varG=INT(varG)),TRUE,FALSE),IF(AND(varG>=D11,varG<=E11),TRUE,FALSE))
12	h	8.00	TRUE	3	12	N	=IF(F12="Y",IF(AND(varH>=D12,varH<=E12,varH=INT(varH)),TRUE,FALSE),IF(AND(varH>=D12,varH<=E12),TRUE,FALSE))

use ctrl ~ to toggle formula view

	G	H
16	1,151.00	=varA*varE*varG+varH+varD^varA
17	40,314.00	=FACT(ABS(varH))-FACT(ABS(varD))
18	(19.41)	=((SIN(varA))+varB)*LOG(varB+varC)+COS(MIN(varC,varD))*(varE-varF+varG*varH)
19	22,956.10	<== we want to minimize the standard deviation of the three results above

Click here to try an extended form of the Genetic algorithm program

This is an example of a problem that the Excel Solver cannot handle. We have three equations above (in cells G16:G18) and we wish to minimize the standard deviation of them in cell G19.

The constraints on input variables appear in table range C5:E12 where each of the eight variables has an allowable minimum, maximum, and type (integer or real). Note that variable f must also satisfy the condition that it is an even integer. This type of constraint is difficult, at best, to work into the Solver.

samples to try manually:

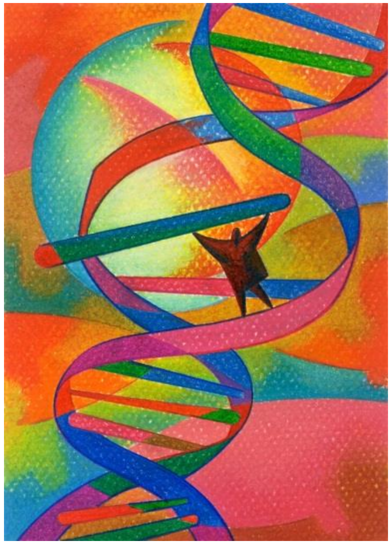
	A	B
28	a	5.00
29	b	7.50
30	c	2.00

Region_Staffing / Instructions / Default_Parameters / DNA / SalesTrip / EquationSolver

23

Looking Behind the Curtain

- Stepping through the code for our examples
- Learning to ~~fish~~ evolve

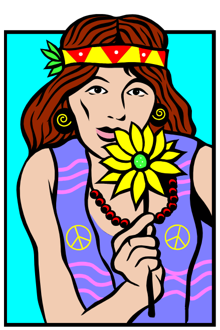


https://github.com/DaveSnell/Genetic-Algorithms

24

Criteria that make a problem suitable for a genetic algorithm

- **The problem involves a lot of variables - to some extent, the more variables there are, the better this technique applies.**
- **Each variable can take on potential values to produce different solutions.**
- **We can substitute a value for each of the variables and that particular combination of individual values can be thought of as a solution set.**
- **The problem can be quantified in some manner so that any two solution sets can easily be compared to see which is better.**



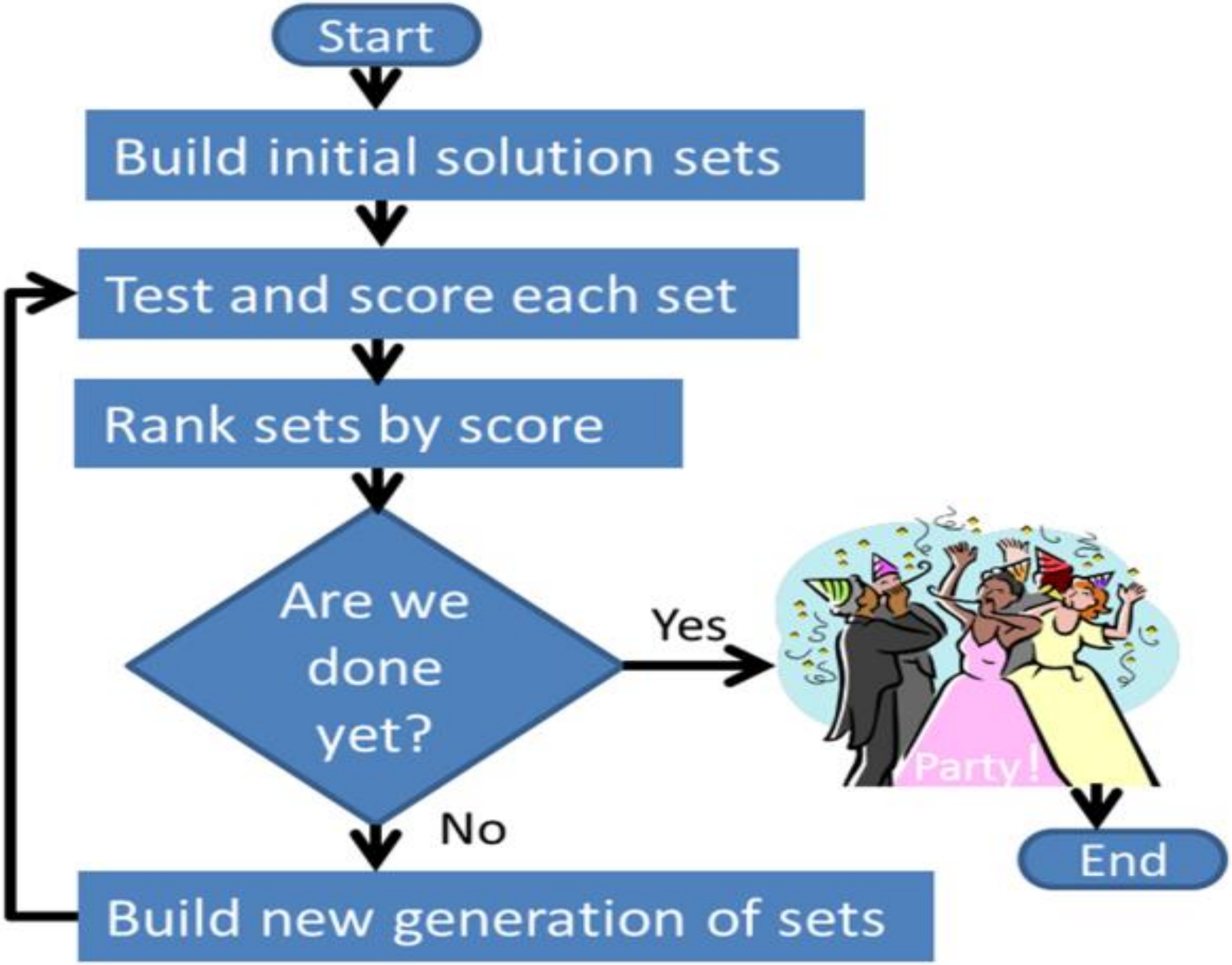
OMG

That is so simple!

Mitosis/meiosis
Single nucleotide polymorphisms
Alleles/ phenotypes
Adenine, Cytosine, Thymine, Guanine

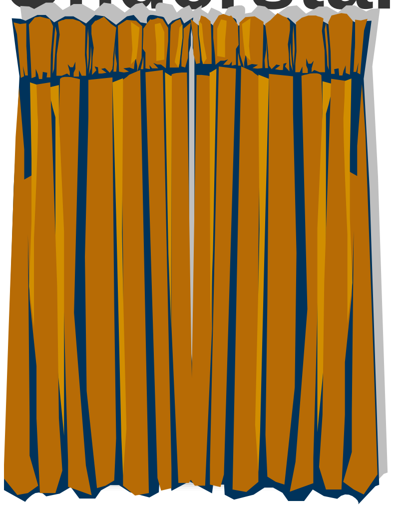
25

How to build a genetic algorithm

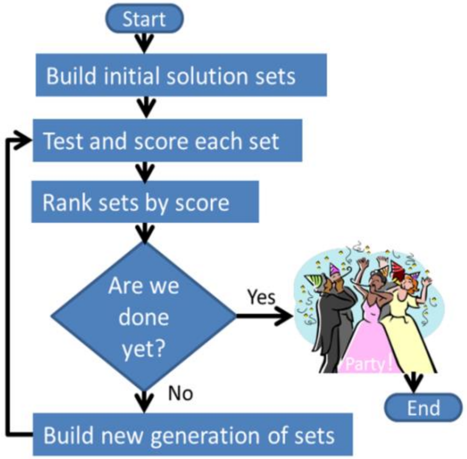


26

Understanding what is behind the curtain



1. Populate a collection of possible solution sets.
2. Test each set of the collection and save the scores obtained.
3. Rank the scores.
4. Build the successive collection (generation) of solution sets.
5. Repeat steps 2 thru 4 until done.



27

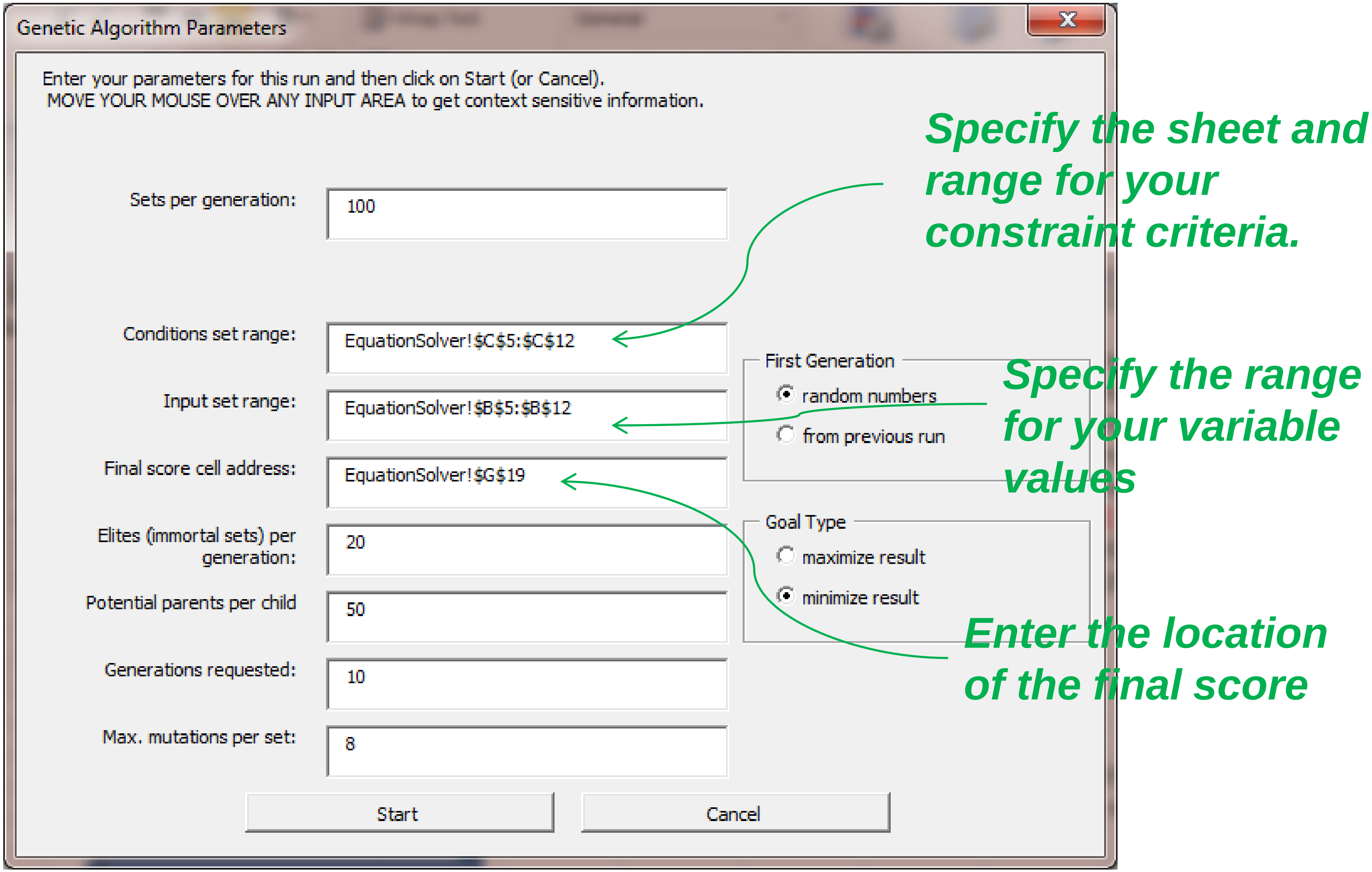
VBA example code

from elsewhere: elites = 20
setsPerGeneration = 100
parentPool = 40
solutionSets is a
2-dimensional array 30 by100

```
Private Sub AddTheChildren()
Dim parent As Integer, var As Long, child As Integer,
children As Integer
  children = setsPerGeneration - elites          (80 = 100 – 20)
    For child = 1 To children                    (start with child set 1)
      For var = 1 To setLength                   (1 to 30 if 30 variables per set)
        parent = Int(parentPool * Rnd()) + 1     (e.g. parent 5 wins
        solutionSets(var, elites + child)         for variable 17 for
                                                  child 1)
                        = solutionSets(var, parent)
      Next var      (so set variable 17 in new solution set 21 = 20 +1 to
    Next child       the value from variable 17 in old solution set 5 )
End Sub 'AddTheChildren
```


28

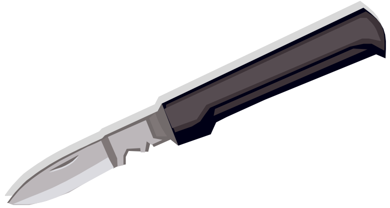
Input Screen for *FREE* workbook

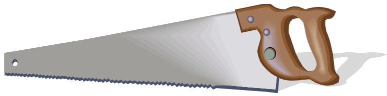


Recap – what did we learn?

- Genetic algorithms can be useful in many diverse types of situations.
- You don’t need to be a math, genetics, or stats wiz or a programmer to understand how to make one.
- You can use the free tool to do a lot of learning just with Excel.
- This is the tip of the iceberg. Join the Forecasting & Futurism section and Health section and tap into a cornucopia of
- new tools and techniques.

New Tools Require New Skills

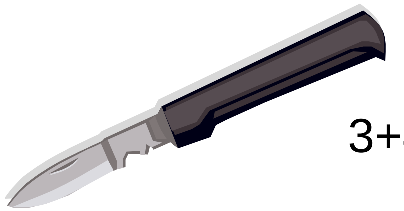




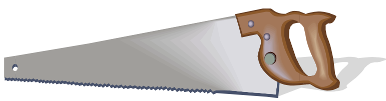
Find this video on YouTube via search term ChainsawAlton (one word).

31

New Tools Require New Skills

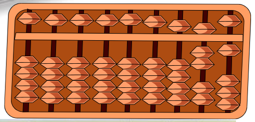


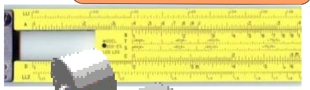
3+4=4+3

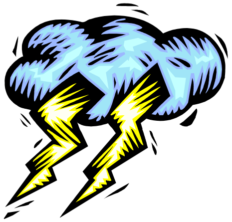


3-4≠4-3

Find this video on YouTube via search term ChainsawAlton (one word).







Complexity
Sciences

32

SOCIETY OF ACTUARIES

Genetic Algorithms – What They Are, How to Apply Them to Solve Problems, and How to Create Your Own

Maryville University – 7-Mar-2016

David L. Snell, ASA, MAAA, FLMI, CLU, ChFC, ARA, ACS, MCP

technology evangelist, RGA Reinsurance Company

https://github.com/DaveSnell/Genetic-Algorithms

Actuaries

Risk is Opportunity.®

New function to read constraints from the spreadsheet

```
Function fn_ValidValue(snpNum As Long) As Double
Dim validValue As Double, bolValid As Boolean, loopCounter As Integer
Dim rowWithValue As Long, rowWithTest As Long, colWithValue As Integer, colWithTest As Integer
Const sheetName = "EquationSolver", maxLoopCounter = 1000
Dim minValue As Double, maxValue As Double, mustBeInt As Boolean
    'plug successive values into cell for the snpNum, and test the ValueOK cell for that snpNum
    Sheets(sheetName).Activate
    With Sheets(sheetName)
        colWithValue = .Range("EquationSolverInputSet").Column
        colWithTest = .Range("EquationSolverConditionsSet").Column
        rowWithValue = .Range("EquationSolverInputSet").Row + snpNum - 1
        rowWithTest = .Range("EquationSolverConditionsSet").Row + snpNum - 1
        minValue = .Cells(rowWithTest, colWithTest + 1)
        maxValue = .Cells(rowWithTest, colWithTest + 2)
        If UCase(.Cells(rowWithTest, colWithTest + 3)) = "Y" Then
            mustBeInt = True
        Else
            mustBeInt = False
        End If
        bolValid = False
        loopCounter = 0
        Do Until (bolValid = True) Or (loopCounter > maxLoopCounter)
            validValue = (maxValue - minValue) * Rnd() + minValue
            If mustBeInt Then
                validValue = Int(validValue)
            End If
            Cells(rowWithValue, colWithValue) = validValue
            .Range("EquationSolverConditionsSet").Calculate
            DoEvents
            If Cells(rowWithTest, colWithTest) = True Then
                bolValid = True
            End If
            loopCounter = loopCounter + 1
        Loop
    End With
    If loopCounter > maxLoopCounter Then
        Debug.Print Now & " unable to find acceptable value for snpNum " & snpNum & " in "; maxLoopCounter & " tries"
    End If
    fn_ValidValue = validValue
End Function 'fn ValidValue
```

This reads the min, max, and int specs from the spreadsheet table and substitutes values, then checks the table for a TRUE condition.

34

Scale of Provider Network Combinations

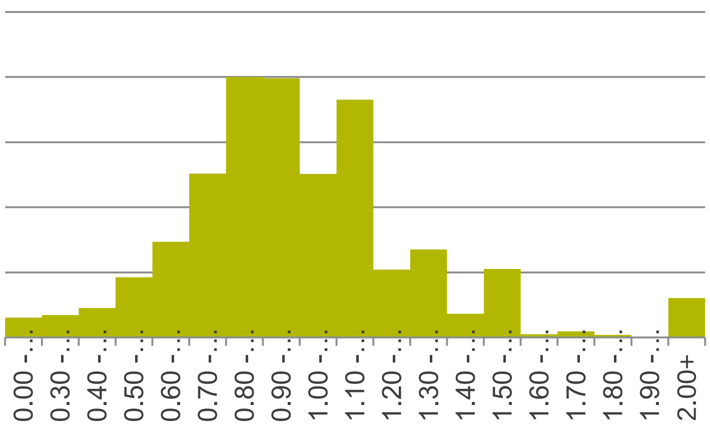
- 100 providers have $2^{100} = 1.27 * 10^{30}$ combinations.
- 500 providers have $2^{500} = 3.27 * 10^{150}$ combinations.
- 1,000 providers have $2^{1,000} = 1.07 * 10^{301}$ combinations.
- For comparison the estimated number of atoms in the observable universe is on the scale of 10^{82}: (http://www.universetoday.com/36302/atoms-in-the-universe/)

35

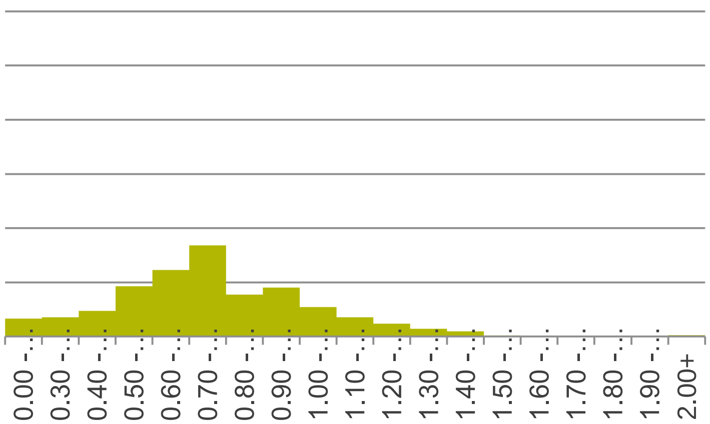
But does it work?

- Overall Network Relativity: 1.00
- GA Produced Relativity: ~~0.72~~ 0.54 (a few days later)

Distribution by Relative Score



GA Distribution by Relative Score



36