

# Case Study of Evolutionary Methods

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(Introduction to) Evolutionary Computation  
Lecture 12, 9/11/2008  
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# Previous Lecture

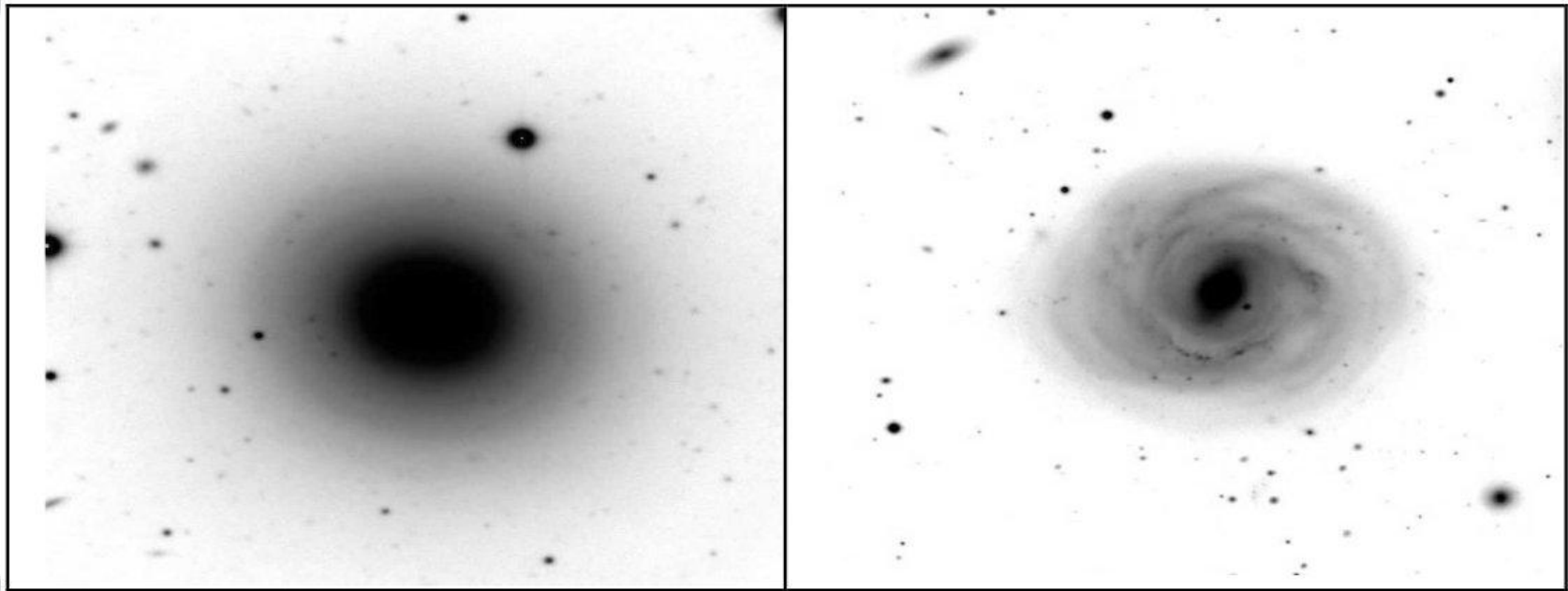
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- Genetic Programming
  - Evolutionary algorithms with tree representation
    - Tree-crossover, tree-mutation, tree-generation
    - Ideal for some applications
    - Bloat
  - Automatic generation of programs
    - Tree-, list-, network-based representations

# Case Study: Galaxy Brightness

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- Astrophysics application
  - Problem: find a formula for the radial brightness of a typical galaxies



Negative images of typical elliptical and spiral galaxy

# Traditional Approach

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- Guesswork...

- Hubble's law:

- Physically inspired
    - Bad fit...

$$I(r) = \frac{I_0}{\left(\frac{r}{a} + 1\right)^2}$$

- De Vaucouleurs law:

- No physical interpretation
    - Reasonable fit

$$I(r) = I_e e^{-3.33 * \left(\left(\frac{r}{r_e}\right)^{1/4} - 1\right)}$$

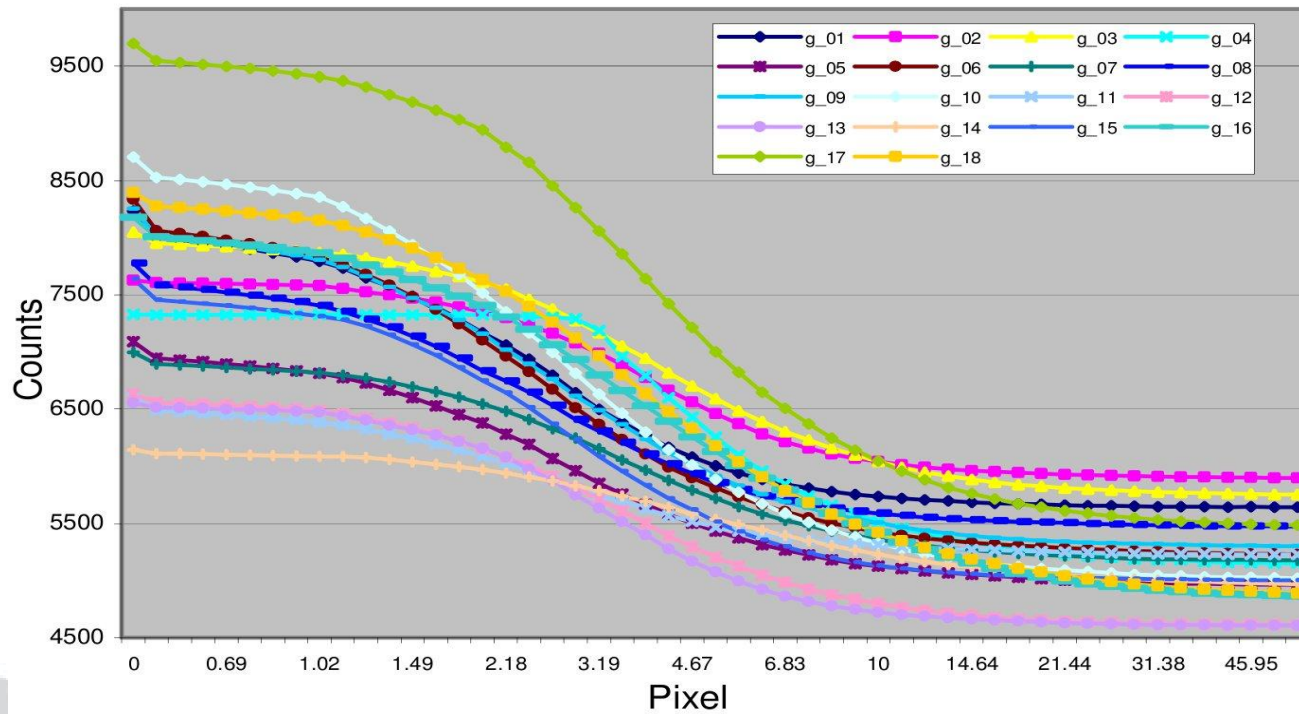
- Come up with a formula

- Use square error fitting to adjust parameters
      - (such as 3.33 above)

# Typical observed profiles

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- 18 elliptical galaxies
  - Coma cluster, near-infrared



# Problems with current approach

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- Lots of new data coming in
  - Great variety of shapes
  - Generalized model?
    - Bulges, shallower vs. steeper profiles
  - Physical interpretation ?

# Evolutionary Approach

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- Suggestions?

# Representation

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# Fitness Function

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- Hits
  - Number of function points within tolerances
    - (max: 50 points)
    - Depends on tolerances
  - Size penalty
    - Simpler functions are better
    - $F = \text{hits} - w * \text{nodes}$

# GP details

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Target	To find a regression mathematical function based on the galaxy profile given
Terminals	$R, \Re = [-10, 10]$
Non-terminals	$+, -, *, /, \exp, \sin, \cos, \log$
Crossover rate	0.9
Mutation rate	0.01
Population size	6,000
Maximum no. of generations	100
Termination criterion	Generation limit or Time limit, whichever reached first
Selection strategy	Tournament selection, Size = 6
Max depth of individual expressions	17
Hit criterion	0.005
Fitness criterion	Hits – 0.01 * the length of the expression
Max depth of initial individual expressions	6
Maximum run time (hours)	6

# Results

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- 18 models
  - All with fitness 50
  - Different tree structures
- What now?

# Manual Simplification

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- Simplify trees
  - Get rid of unused branches
  - Transform into most compact form
- Parameterize
  - Turn real-valued terminals into parameters

$$f_{g1} = \frac{a+b}{c+r}$$
$$f_{g2} = a' + \frac{b'}{b'+c'*r^2}$$

# Evolutionary Parameter Optimization

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- Representation?
- Crossover, Mutation?
- Fitness?

# Results

Profiles	$\chi^2$ for $f_{g1}$		$\chi^2$ for $f_{g2}$	
	Using hit criteria =0.005	Using hit criteria= 0.002	Using hit criteria =0.005	Using hit criteria = 0.002
1	7.4460	7.8961	11.4012	<b>1.1141</b>
2	9.1809	6.2876	12.8405	<b>1.8633</b>
3	8.7796	5.0199	6.3452	<b>0.7113</b>
4	6.8782	6.8221	2.8035	2.8385
5	4.1948	3.8105	5.7141	<b>0.8685</b>
6	3.1867	2.7282	3.2442	<b>0.7194</b>
7	9.7797	4.8050	17.9798	<b>0.9289</b>
8	6.8756	4.9609	11.0505	<b>0.1353</b>
9	5.8373	5.0018	3.4484	<b>1.0390</b>
10	2.8263	2.8807	<b>1.9078</b>	<b>0.3318</b>
11	34.0802	8.2256	25.2975	7.9733
12	5.8477	5.0861	7.9886	<b>1.5150</b>
13	7.6026	7.6528	10.6681	<b>1.2615</b>
14	9.1534	<b>1.8299</b>	13.8083	<b>1.2896</b>
15	5.9548	5.8170	2.1233	<b>1.2062</b>
16	4.8048	<b>1.98719</b>	3.7705	<b>0.6759</b>
17	2.9778	3.0106	<b>1.3418</b>	<b>0.3138</b>
18	<b>1.2161</b>	<b>1.0233</b>	<b>0.8031</b>	<b>0.0796</b>

$\chi^2 < 2.0$ : good fit

# Critique

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- Functions not evolved for generalization
  - Evolving functions for each profile, then fitting to other functions.
- Evolve generalized functions in one step?
  - Parameter fitting as sub-algorithm?
- Mini project ?

# Humies

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- Awards for Human-Competitive results produced by genetic and evolutionary computation
- \$5000, \$3000, \$3000 awards

# Summary

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- Treat EA's as 'construction toys'
  - Pick representation suitable to the problem
  - Pick operators suitable to representation
  - Pick population, selection, etc suitable for the problem
  - Write custom fitness function
  - Add speciation, constraint handling, etc. as required
- Human-competitive result

# References

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J. Li, X. Yao, C. Frayn, H. G. Khosroshahi, S. Raychaudhury, "An Evolutionary Approach to Modeling Radial Brightness Distributions in Elliptical Galaxies," Proc. of the 8th International Conference on Parallel Problem Solving from Nature (PPSN VIII), Lecture Notes in Computer Science, Vol. 3242, pp.591-601, Springer, September 2004.  
[http://www.cs.bham.ac.uk/~xin/papers/Li\\_ppsn314.pdf](http://www.cs.bham.ac.uk/~xin/papers/Li_ppsn314.pdf)

Humies: <http://www.genetic-programming.org/hc2005/main.html>, any of the papers and presentations, in particular 2007 and 2008 winners and placed.