

Stochastic optimization algorithms

Lecture 8, 20180919

Evolutionary algorithms:
LGP and IEC

NOTE

- If you have not yet picked up your comments for the IPP, please do so in the break. I bring the comments also to the lecture on Friday.
- Do check the FAQ (on the course web page) frequently!

Today's learning goals

- After this lecture you should be able to
 - Describe linear genetic programming (LGP) and discuss the differences between LGP and GAs.
 - Apply LGP in a function fitting task.
 - Describe interactive evolutionary computation (IEC)

Genetic programming

- Evolves computer programs (varying size)
- (Standard) genetic programming (GP): Applied to tree-like structures:

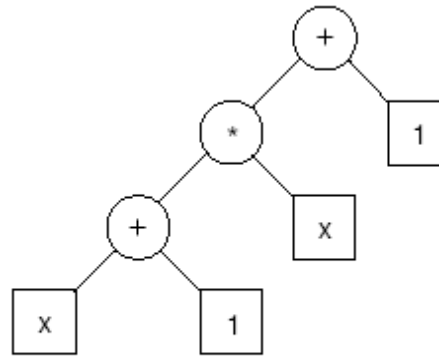


Figure 3.16: A GP tree, which can be evaluated to give $f(x) = (x + 1)x + 1$.

Linear genetic programming

- **Linear genetic programming (LGP):** Evolves computer programs consisting of sequences of elementary instructions. Here we shall only consider LGP.
- Central concepts: Registers and instructions.

Registers and instructions

- Registers: Two kinds:
 - **Variable registers** r_i
 - **Constant registers** c_i
- Instructions:
 - Set of allowed operators = **instruction set** (e.g. $\{+, -, *, /\}$)
 - **Protected definitions**: Makes sure that all chromosomes can be evaluated.

Registers and instructions

- In LGP one evolves sequences of instructions of the form

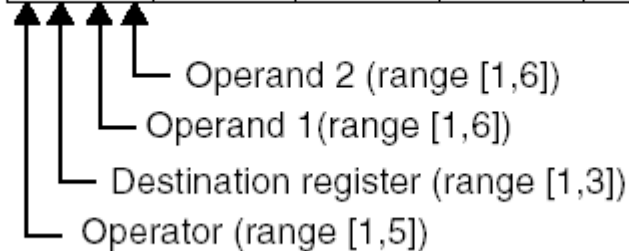
`<Destination register> := <operand1> <operator> <operand2>`

- At initialization, set constant registers once and for all.
- New constants can be built (and stored in variable registers) during a run.

Decoding and evaluation

MISPRINT! (Also in Fig. 3.20): Should be: 5 1 1 5

1	2	1	4	1	3	2	2	3	1	2	3	5	1	5	1	1	1	1	4
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---



Decoding and evaluation

- Set the variable registers to appropriate values. For example, if one is evolving a function $f(x)$ one may assign x to r_1 and set all other registers to 0.
- The next step is to run through the LGP program, and then take the contents of one of the variable registers as the function value.
- A detailed example (function fitting) will be given below.

Decoding and evaluation

- Example: $x=1 \Rightarrow$

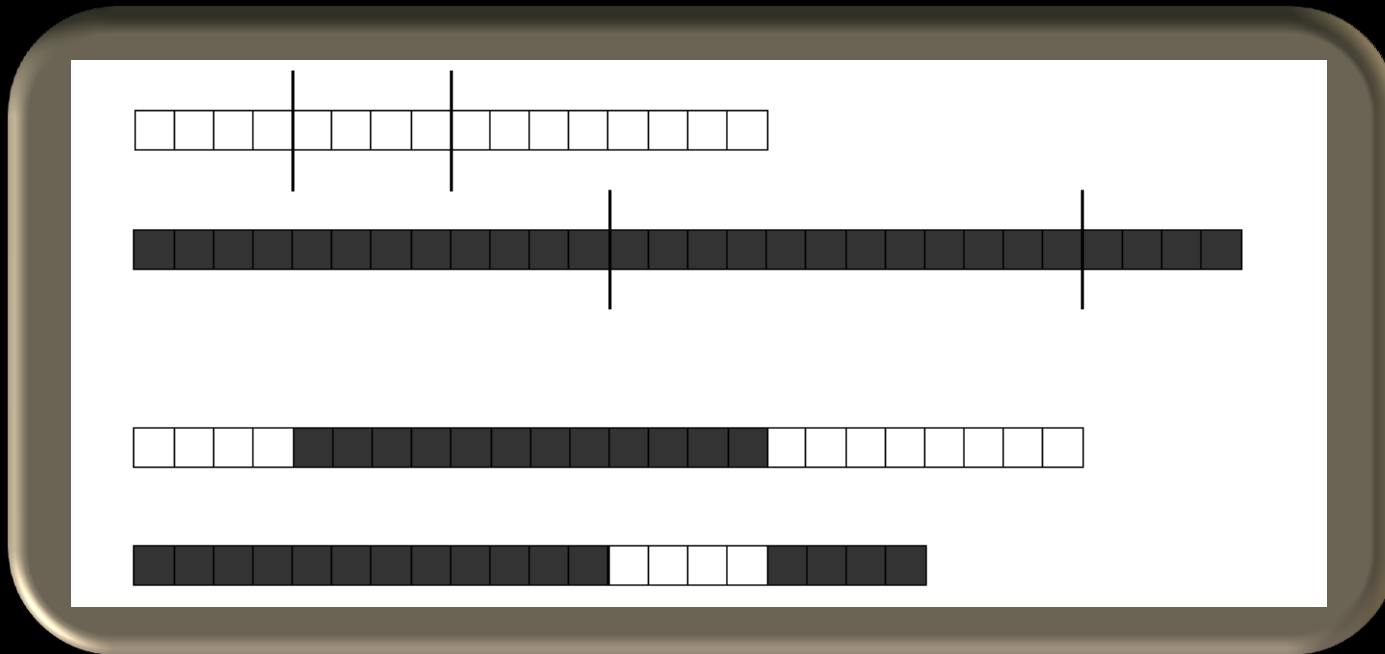
MISPRINT! : Should be: 5 1 1 5

Genes	Instruction	Result
1, 2, 1, 4	$r_2 := r_1 + c_1$	$r_1 = 1, r_2 = 2, r_3 = 0$
1, 3, 2, 2	$r_3 := r_2 + r_2$	$r_1 = 1, r_2 = 2, r_3 = 4$
3, 1, 2, 3	$r_1 := r_2 \times r_3$	$r_1 = 8, r_2 = 2, r_3 = 4$
5, 1, 5, 1	if ($r_1 > c_2$)	$r_1 = 8, r_2 = 2, r_3 = 4$
1, 1, 1, 4	$r_1 := r_1 + c_1$	$r_1 = 9, r_2 = 2, r_3 = 4$



Evolutionary operators

- In LGP, selection takes place just as in a GA.
- Crossover in LGP, however, uses two crossover points and is non-length preserving:



Evolutionary operators

- Mutations are essentially as in a GA, but one must take into account that different genes may have different range, depending on whether they encode a destination register, an operand, or an operator.

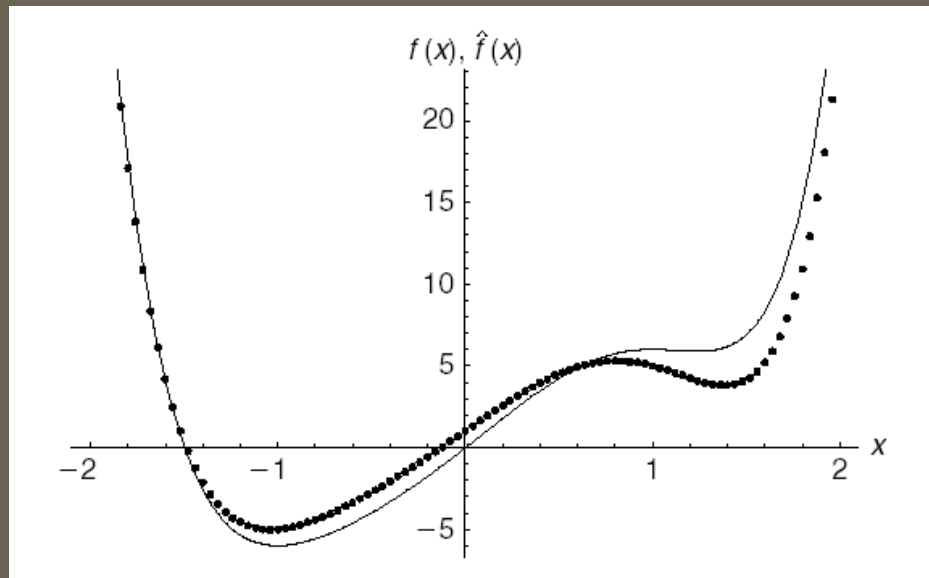
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Function fitting with LGP

- Consider Example 3.11.
- The aim is to find (using LGP) the functional form of a function $f(x)$, based on a set of samples of that function.



Function fitting with LGP

- Procedure:
 - Choose instruction set (e.g. {+, -, *, /})
 - Set constant registers (once and for all)
 - Initialize chromosomes.
 - For each chromosome, run through all data points $x_i, i = 1, \dots, L$.
 - For each point, place the value of x_i in the first register and set the other registers to 0.
 - Run the LGP chromosome, and then take the contents (after evaluation) of (for example) the first register as the estimate $\hat{f}(x_i)$ of the function value $f(x_i)$... (continued on next page)

Function fitting with LGP

- Once all points have been considered, form the error as ...

$$E_{\text{rms}} = \sqrt{\frac{1}{L} \sum_{i=1}^L (f(x_i) - \hat{f}(x_i))^2}$$

- ...and then compute the fitness as $F = 1/E_{\text{rms}}$.
- Then, apply the evolutionary operators as usual etc.

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Interactive evolutionary computation

- In some cases (e.g. design problems) one can use *subjective* evaluation of individuals (rather than (just) an objective fitness function).
- Used in **interactive evolutionary computation (IEC)**.

Interactive evolutionary computation

- Basic algorithm: (see also Fig. 3.23 in the book)

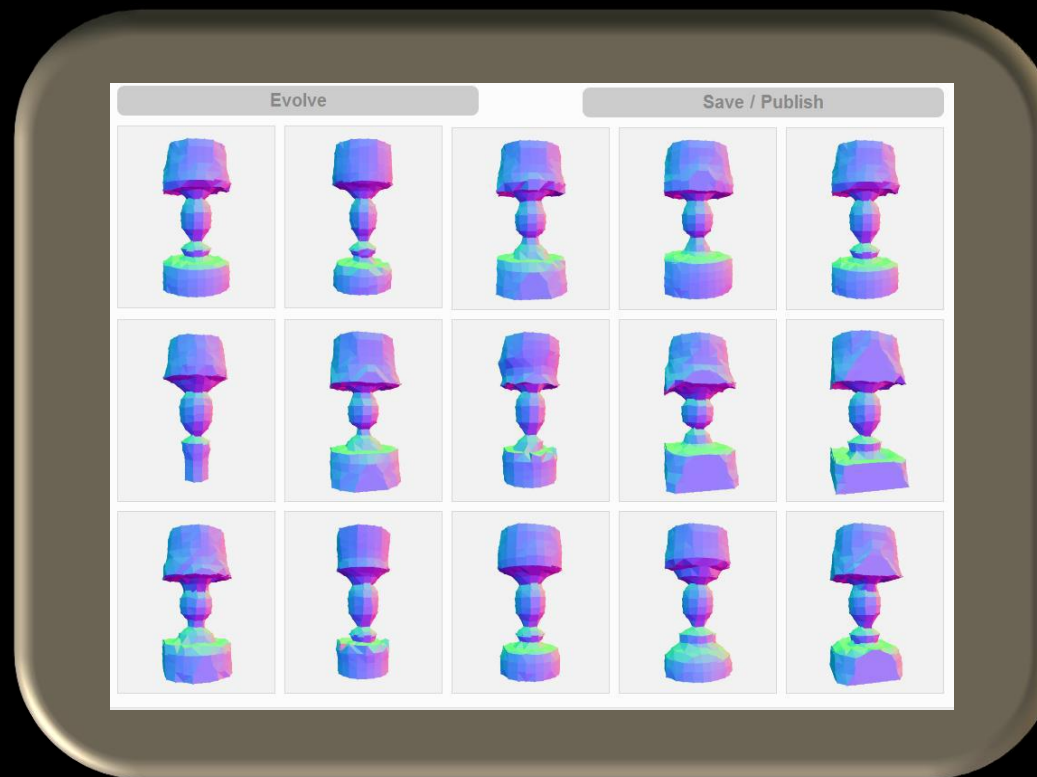
1. Initialize the population by generating (from randomly initialized chromosomes) and displaying N images on a computer screen.
2. Subjectively evaluate the individuals and select the preferred image.
3. Generate the next generation:
 - 3.1. Make an exact copy of the preferred image and place it at the centre of the screen.
 - 3.2. Make $N - 1$ new individuals by mutating the selected individual. Display the $N - 1$ newly generated individuals, surrounding the individual placed at the centre of the screen.
4. Return to step 2, unless any of the displayed images are satisfactory.

Interactive evolutionary computation

- More advanced versions also involve crossover etc.
- Constraint handling (where applicable) can also be implemented, so that the user is only presented with solution candidates that fulfil the constraints, if any.
- Main difficulties:
 - Finding a suitable encoding for the problem at hand.
 - User fatigue.

Interactive evolutionary computation

- Example, See <http://endlessforms.com/>



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Information (HP1)

- Make sure to answer all the questions posed for each problem, and to follow the coding standard.
- Also, note carefully (see the checklist on the web page):
 - Filename (LastName_FirstName ...)
 - Simplifies the sorting of the solutions.
 - Civic registration number (personnummer) in the report
 - Only way to report your grade.
 - Report in PDF format
 - Our (own) plagiarism check is based on PDF format.
 - (The Matlab files are checked for plagiarism as well, of course)