

Automatic Concept Evolution (ACE)

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ABSTRACT

An evolutionary algorithm can be used by a distributed group of interacting people to produce the solution to a problem. First the problem must be defined. Each member of the group then suggests solutions to the problem. They go on to improve these suggestions by mutation and crossover. They show their preferences by replication and can throw in new suggestions if they think of them. An experiment involving seven people using this algorithm to choose a name for it will be described. The successes and limitations of this experiment will be discussed. A more experiment will be proposed.

Categories and Subject Descriptors

J.5 Arts and Humanities; K.3 Computers and Education; or K.3.1 Collaborative learning; 1.2.m Artificial Intelligence

General Terms

Algorithms, Experimentation, Human Factors.

Keywords

Human Based Evolutionary Computing

1. INTRODUCTION

Automatic Concept Evolution (ACE) [1] has had an interesting history over the last 4 years. It originated from an idea of the author to apply an evolutionary algorithm to arbitrate between a group of geographically dispersed individuals, the staff of EvoNet: the European Network of Excellence in Evolutionary Computing, to cooperatively solve a problem. The resulting algorithm is a Human Based Genetic Algorithm [2]. The staff of EvoNet were always looking for innovative ways to apply EC to real world problems and promote Evolutionary Computing under the EvoNet banner. Once the problem has been defined, each member of a group suggests solutions to the problem. They then go on to improve the suggestions by “mutation” and “crossover”. They can show their preferences for solutions to problems already suggested by “replication” and can “create” new suggestions when they arise.

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2. AUTOMATIC CONCEPT EVOLUTION

The idea was simple: by applying the evolutionary processes of “natural selection” and “genetic inheritance” the algorithm would ensure the optimum solution to a given problem from a pool of possible solutions.

2.1 The Algorithm

The algorithm has seven steps as follows:

1. A problem is defined.
2. Participants create an initial population by suggesting solutions.
3. Participants suggest candidates for the next population using an evolutionary operator to produce each.
4. Suggested solutions to the problem in the previous population are weighted according to their contribution to the candidates for the next population.
5. Candidates’ solutions for the next population are weighted according to the weights of their parents, if the have any, and a proportion of the new population is probabilistically chosen from them according to their weights.
6. A proportion of the new population is randomly chosen from candidates with no parents.
7. If a final solution has not been found the procedure is repeated from step 3 with the new population else it is stopped.

2.2 Implementation

All communication between the author, who organized and participated in the experiment, and the other participants, was done by email. All calculations were done by the author mostly by hand but sometimes with the aid of a calculator.

3. THE EXPERIMENT

3.1 The Problem

The problem was defined as finding a name for this algorithm.

3.2 The Participants and the Initial Population

Once the problem had been defined, each member of the group suggested a number of solutions to the problem. The participants were Mij Kelley, Jen Willies, Chris Osbourne, Luis Hercog, Doug Willies (generation 2), Rob Stevens (from generation 5)

and the author (all generations except 5). The initial population was largely created by Mij Kelley, who produced the first twelve members, supported by the author, who produced the other eight members. The initial population was as follows:

1. Ideas pool
2. New ideas generator algorithm
3. Co-operative thinker
4. New ideas machine
5. Ideas interface
6. Ideas synthesiser
7. Creative collaborator
8. Memetic algorithm
9. EvoNet oracle
10. Community interactive thinking
11. Automated mind merger
12. Interactive evolver of ideas
13. Ideas adapter
14. The game of thought
15. Thought processor
16. The evolution of ideas
17. Dialectic machine
18. Genetic synthesiser
19. Meme machine
20. Proposition engine

3.3 Evolutionary Operators and Suggestions for the Next Population

Participants went on to improve the pool of suggestions by “mutation” and “crossover”. They were able to show their preferences for solutions already suggested by “replication” and could “create” new suggestions as they thought of them. The evolutionary operators were described to the participants as:

x Crossover - choose two members of the population and combine them to form a new suggestion.

m Mutation - choose one member of the population and alter it slightly.

r Replication - choose one member of the population to go forward to the next generation

c Creation - suggest a new solution to the problem

Candidates for the next population were suggested by participants as follows:

3.3.1 Mij's suggestions for generation 2

Mij's suggestions for generation 2 were as follows:

x 4. New ideas machine & 20. Proposition engine

Ideas engine

x 7. Creative collaborator & 18. Genetic synthesiser

Genetic collaborator

x 12. Interactive evolver of ideas

& 15. Thought processor

Interactive thought processor

m 7. Creative collaborator

Collaborative thinking machine (“quite a big mutation this, maybe I should have used method ‘c’”)

r 16. The evolution of ideas

c Brain-racker

c Conceptual optimisation

3.3.2 Jen's suggestions for generation 2

Jen's suggestions for generation 2 were as follows:

x 11. Automated mind merger

& 12. Interactive evolver of ideas

automated ideas evolver

x 4. New ideas machine & 13. Ideas adapter

new ideas adapter

m 2. New ideas generator algorithm

ideas generator

r 6. ideas synthesiser

c gene machine

3.3.3 Chris's suggestions for generation 2

Chris's suggestions for generation 2 were as follows:

x 12. Interactive evolver of ideas

& 15. Thought processor

Thought Evolver

x 7. Creative collaborator & 8. Memetic algorithm

Memetic Collaborator

m 6. Ideas synthesiser

Ideas Blender

m 6. Ideas synthesiser

Ideas Consolidator (iCON)

r 3. Co-operative Thinker

c Evolutionary Thought Compiler (“Etc” or “Etcetera”)

c Evolutionary Concept Aggregator

3.3.4 Doug's suggestion for generation 2

Doug's suggestion for generation 2 were as follows:

x 13. Ideas adapter & 12. Interactive evolver of ideas

ideas evolver

m 8. Memetic algorithm

conjecture algorithm

m 19. Meme machine

meme fountain

m 15. Thought processor

thought popper

c *concept pump*

3.3.5 The author's suggestions for generation 2

The author's suggestions for generation 2 were as follows:

x 14. The game of thought & 16. The evolution of ideas

The game of ideas

x 8. Memetic algorithm & 19. Meme machine

memetic machine

m 3. Co-operative thinker

Co-operative thinking machine

c *Evothinking*

c *Evointeraction*

3.3.6 Luis's suggestion for generation 2

Luis's suggestion for generation 2 were as follows:

x 6. Ideas synthesiser

& 12. Interactive evolver of ideas

Creative ideas synthesiser

x 13. Ideas adapter & 15. Thought processor

Ideas processor

x 13. Ideas adapter & 15. Thought processor

Thought Adapter

c *Mimic*

c *Chamaleon*

c *Cephalopod*

3.4 Assignment of Fitness to Parents

Suggested solutions to the problem in the previous population are weighted according to their contribution to the candidates for the next population. This results in a scoring for members of the initial population as follows:

1. Ideas pool = 0
2. New ideas generator algorithm $m = 1$
3. Co-operative thinker $m r = 2$
4. New ideas machine $x x = 1$
5. Ideas interface = 0
6. Ideas synthesiser $x m m r = 3.5$
7. Creative collaborator $x x m = 2$
8. Memetic algorithm $x x m = 2$
9. EvoNet oracle = 0
10. 10. Community interactive thinking = 0
11. Automated mind merger $x = 0.5$
12. Interactive evolver of ideas $x x x x x = 2.5$
13. Ideas adapter $x x x x = 2$

14. The game of thought $x = 0.5$

15. Thought processor $x x x x m = 3$

16. The evolution of ideas $x r = 1.5$

17. Dialectic machine $r = 1$

18. Genetic synthesiser $x = 0.5$

19. Meme machine $x m = 1.5$

20. Proposition engine $x = 0.5$

3.5 Assignment of Fitness to Children

Candidates' solutions for the next population were weighted according to the weights of their parents, if they have any, and a proportion of the new population is chosen from them according to their weights.

In the first iteration suggestions for the second population each got the total of the fitness of their parents, if they had any. This resulted in the following fitness for suggestions for the second population:

<i>x</i>	6. & 7. <i>Creative ideas synthesiser</i>	6
<i>x</i>	15. & 12. <i>Thought Evolver</i>	5.5
<i>x</i>	12. & 15. <i>Interactive thought processor</i>	5.5
<i>x</i>	13. & 15. <i>Thought Adaptor</i>	5
<i>x</i>	13. & 15. <i>Ideas processor</i>	5
<i>x</i>	7. & 8. <i>Memetic Collaborator</i>	4
<i>x</i>	13. & 12. <i>ideas evolver</i>	4.5
<i>x</i>	8. & 19. <i>memetic machine</i>	3.5
<i>m</i>	6. <i>Ideas Blender</i>	3.5
<i>m</i>	6. <i>Ideas Consolidator (iCON)</i>	3.5
<i>r</i>	6. <i>ideas synthesiser</i>	3.5
<i>x</i>	11. & 12. <i>automated ideas evolver</i>	3
<i>x</i>	4. & 13. <i>new ideas adapter</i>	3
<i>m</i>	15. <i>thought popper</i>	3
<i>m</i>	7. <i>Collaborative thinking machine</i>	3
<i>x</i>	7. & 18. <i>Genetic collaborator</i>	2.5
<i>m</i>	3. <i>co-operative thinking machine</i>	2
<i>r</i>	3. <i>Co-operative Thinker</i>	2
<i>m</i>	8. <i>conjecture algorithm</i>	2
<i>x</i>	14. & 16. <i>The game of ideas</i>	2
<i>x</i>	4. & 20. <i>Ideas engine</i>	1.5
<i>m</i>	19. <i>meme fountain</i>	1.5
<i>r</i>	16. <i>The evolution of ideas</i>	1.5
<i>m</i>	2. <i>ideas generator</i>	1
<i>r</i>	17. <i>Dialectic machine</i>	1

Suggestions with no parents get no score resulted in no fitness for the following suggestions for the second population:

c *Evolutionary Thought Compiler (Etc)*

c	Evolutionary Concept Aggregator
c	gene machine
c	Brain-racker
c	Conceptual optimisation
c	Cephalopod
c	Chameleon
c	Mimic
c	concept pump
c	EvoThinking
c	EvoInteraction

Eliminating all suggestions with scores < 2 , gave the following 20 members of the next population:

1. Thought Evolver
2. Memetic Collaborator
3. automated ideas evolver
4. new ideas adapter
5. Genetic collaborator
6. Interactive thought processor
7. Thought Adaptor
8. Ideas processor
9. Creative ideas synthesiser
10. ideas evolver
11. The game of ideas
12. memetic machine
13. Ideas Blender
14. Ideas Consolidator (iCON)
15. Collaborative thinking machine
16. conjecture algorithm
17. thought popper
18. co-operative thinking machine
19. Co-operative Thinker
20. ideas synthesiser

3.6 Candidates with no Parents

In the first iteration no new members of the next population were randomly chosen from candidates with no parents.

3.7 Repeating the Process

Since a final solution had not been found the procedure was repeated from step 3 for 5 more iterations.

4. THE FOLLOWING ITERATIONS

In the second iteration some of the participants made comments and asked questions along with their suggestions for the next generation.

4.1 Mij's Suggestions for Generation 3

Together with her suggestions for generation 3 Mij asked the question "Let me know if I've broken the rules here -- I'm assuming I don't have to use ALL of the methods... (From a user's point of view, crossover is quite a hard one to implement, it seems a lot easier to just replicate, mutate or create)." I did not answer this question.

4.2 Jen's Comment When Making Suggestions for Generation 3

Together with her suggestions for generation 3 Gen made the following comment: "In doing this exercise, I was trying to decide what we are really trying to do here since I am still a bit unclear what our REAL objective is, either:

evolving ideas by BUILDING UP from distinct particles

a CRYSTALLISING process to filter out or sieve out certain aspects from a mass of ideas

SHAPING an amorphous mass, ie sculpting something large and all over the place into something more precise

And should the name of our "machine" emphasise the input (particular individuals' ideas) or the output (evolved concepts), or the PROCESS itself, or preferably all three?" I made no response to this comment.

4.3 Scoring of Population 2

After everyone had made their suggestions for generation 3 the scoring for population 2 was as follows:

1. Thought Evolver $x \ x \ r = 2$
2. Memetic Collaborator $x = 0.5$
3. automated ideas evolver $m \ m \ x \ m = 3.5$
4. new ideas adapter $= 0$
5. Genetic collaborator $r \ x \ x \ x \ x = 3$
6. Interactive thought processor $r \ x \ m \ x \ x = 3.5$
7. Thought Adaptor $x = 0.5$
8. Ideas processor $x = 0.5$
9. Creative ideas synthesiser $r \ x \ x \ x = 2.5$
10. ideas evolver $= 0$
11. The game of ideas $r = 1$
12. memetic machine $x = 0.5$
13. Ideas Blender $= 0$
14. Ideas Consolidator (iCON for short) $m \ x = 1.5$
15. Collaborative thinking machine $x = 0.5$
16. conjecture algorithm $m = 1$
17. thought popper $r \ x = 1.5$
18. co-operative thinking machine $x = 0.5$
19. Co-operative Thinker $x = 0.5$
20. ideas synthesiser $x \ x = 1$

4.4 Scoring of Suggestions for Population 3

In this iteration I gave each child the *average* score of its parents rather than the *total* score. This resulted in the following fitness for suggestions for the third population:

<i>m</i>	3.	automated concept evolver	3.5
<i>m</i>	3.	Ideas Express	3.5
<i>m</i>	3.	Ideas Tuner	3.5
<i>m</i>	6.	interactive thought builder	3.5
<i>r</i>	6.	Interactive thought processor	3.5
<i>x</i>	5. & 3.	Genetic memetic collaborator	3.25
<i>x</i>	5. & 6.	genetic interactive thought processor	3.25
<i>r</i>	5.	Genetic collaborator	3
<i>x</i>	6. & 9.	Interactive creative ideas synthesiser	3
<i>x</i>	1. & 5.	Genetic thought evolver	2.5
<i>r</i>	9.	Creative ideas synthesiser	2.5
<i>X</i>	9. & 17.	Thought popping synthesiser	2
<i>x</i>	6. & 8.	Evolutionary Thoughts and Ideas Processor (EVO-TIP)	2
<i>r</i>	1.	thought evolver	2
<i>x</i>	5. & 19.	genetic thinker	1.75
<i>x</i>	7. & 9.	Creative Thought Synthesiser	1.5
<i>m</i>	14.	Evolutionary Ideas Consolidator (EVO-iCON)	1.5
<i>r</i>	17.	thought popper	1.5
<i>x</i>	2. & 1.	Memetic thought collaborator	1.25
<i>x</i>	14. & 15.	Collaborative ideas consolidator	1
<i>m</i>	16.	conjector injector	1
<i>r</i>	11.	the game of ideas	1
<i>x</i>	18. & 20.	Co-operative Thought Machine	0.75
<i>x</i>	12. & 20.	memetic synthesiser	0.75
<i>c</i>		Evoparley	
<i>c</i>		Evopowwow	
<i>c</i>		Evoconfab	
<i>c</i>		concept generator	
<i>c</i>		concept sculpture	
<i>c</i>		meiotic concept evolve	
<i>c</i>		EVolutionary Idea Log (EVIL)	

4.5 Population 3

Eliminating all suggestions with scores < 1.5 gave 18 members of the next population. Adding two new creations at random gave the following:

1. Genetic memetic collaborator

2. Genetic thought evolver
3. Interactive creative ideas synthesiser
4. Creative Thought Synthesiser
5. Thought popping synthesiser
6. genetic interactive thought processor
7. genetic thinker
8. Evolutionary Thoughts and Ideas Processor (EVO-TIP)
9. automated concept evolver
10. Ideas Express
11. Ideas Tuner
12. interactive thought builder
13. Evolutionary Ideas Consolidator (EVO-iCON)
14. Genetic collaborator
15. Interactive thought processor
16. Creative ideas synthesiser
17. thought popper
18. thought evolver
19. Evoconfab
20. meiotic concept evolve

4.6 Population 4

Scoring population 3 as before and the suggestions for population 4 as before, eliminating all suggestions for population 4 with scores < 2 gave 19 members of the next population. Adding one new creation at random gave the following:

1. interactive evolver
2. Automated ideas evolver
3. creative thought tuner
4. Evolutionary confabulator
5. Automatic concept evolver (ACE)
6. Evolutionary interactive thinking (EvoIeIT)
7. Evolving Ideas (EvoIdeas)
8. Evolutionary thought (EvoThought)
9. Evolutionary thinking (EvoThink)
10. EvoConflab
11. Evolutionary Thoughts and Ideas Processor (EvoTIP)
12. Evolutionary Ideas Consolidator (EvoICon)
13. concept evolver
14. thought tuner
15. thought streamer
16. Evolutionary Thoughts and Ideas Processor (EVO-TIP)
17. thought popper
18. Creative Thought Synthesiser
19. Interactive thought processor
20. Evo-muse

4.7 Population 5

Scoring population 4 as before and the suggestions for population 5 as before, eliminating all suggestions for population 5 with scores < 1.75 gave 18 members of the next population. Adding two new creations at random gave the following:

1. Evolutionary Thoughts and Ideas Processor (EvoTIP)
2. Deep Thought
3. Interactive Thought Synthesiser
4. Evolutionary Ideas Confabulator (EvoICON)
5. Automatic concept evolver (ACE)
6. Evolutionary Thoughts and Ideas Processor (EvoTIP)
7. Evolutionary thought processor
8. interactive ideas evolver
9. Idea convolver
10. Automatic Concept Evolver (ACE)
11. Evolutionary Thought (EvoThought)
12. Thought Tuner
13. Thought Evolver
14. Automatic concept evolver (ACE)
15. Evolutionary thought tuner
16. Evolutionary thought consolidator
17. Interactive thought processor
18. Evolutionary thought synthesiser
19. eureka engine
20. Darwinator

4.8 Question from Jen

Before producing her suggestions for generation 6 Jen asked: *“just a quickie question: must our selection of 6 for the next generation, each be different, or can they also be duplicates of the same choice, ie 3 of ACE and 3 of EvoTIP?”*

My reply was: *“That is a good question. We don't have a rule on it. Until we do you can do what you like. Just one point on this, if you replicate ACE 3 times and EvoTIP 3 times you are showing no preference for either and will leave the final decision to the other participants which is of course OK if that is what you want to do. You will probably just hasten the end of the game, which is good, but wont TIP the balance in either direction. Of course I still have a few ACEs up my sleeve.”*

Her suggestions for generation 6 were:

- r 13. Thought Evolver
- r 15. Evolutionary thought tuner
- r 19. Eureka Engine
- r 20. Darwinator
- r 5. Automatic concept evolver (ACE)
- r 5. Automatic concept evolver (ACE)

4.9 Question from Mij

Mij also asked a question: *“Actually, I've got an overwhelming urge to begin voting for my favourites, so that's what I'm effectively going to do. Is this cheating? If so, tell me and I'll have another try. In fact, I've just realised (I must be a bit slow) that it is possible to completely undermine the co-operative aspect of the process simply by replicating one's own favoured solution six times in every generation. Why didn't I see this before? I've had some really great suggestions that never even made it into a generation! I should have created multiple copies.... Has everyone else being doing this?”*

I got the feeling that Jen and Mij were discussing their strategies. I did not reply to this question.

Her suggestions for generation 6 were:

- r 1. Evolutionary Thoughts and Ideas Processor (EvoTIP)
- r 2. Deep Thought
- r 2. Deep Thought
- r 2. Deep Thought
- r 5. Automatic concept evolver (ACE)
- r 5. Automatic concept evolver (ACE)

4.10 Author's Suggestions for Generation 6

The author, who was as keen as the other participants who had been working on this since generation 1 to bring the experiment to a conclusion, made the following suggestions for population 6:

- r 5. Automatic concept evolver (ACE)
- r 5. Automatic concept evolver (ACE)
- r 5. Automatic concept evolver (ACE)
- x 17. Interactive thought processor & 20. Darwinator
Darwinian thought processor
- r 5. Automatic concept evolver (ACE)
- r 5. Automatic concept evolver (ACE)

4.11 Rob's Suggestions for Generation 6

Because Rob had only joined the experiment at generation 4 he was still fresh and thinking of new ideas for population 6 rather than getting bored and wanting to vote for the winner to finish. His suggestions for population 6 were:

- x 4. Evolutionary Ideas Confabulator (EvoICON)
& 6. Evolutionary Thoughts and Ideas Processor (EvoTIP)

Evolutionary Thoughts and Ideas Confabulator

- x 4. Evolutionary Ideas Confabulator (EvoICON)
& 8. interactive ideas evolver

Interactive Confabulator

- x 13. Thought Evolver & 19. eureka engine

Eureka Evolver

- x 9. Idea convolver & 19. eureka engine

Idea Engine

m 17. Interactive thought processor
interactive Thought evolving machine (ITEM)
 m 19. eureka engine
 meme engine

4.12 Population 6

Scoring population 5 as before and the suggestions for population 6 as before, eliminating all suggestions for population 6 with scores < 2.5 gave 19 members of the next population. Adding one new creation at random gave the following:

1. Evolutionary Ideas Confabulator (EvoICON)
2. Concept evolver
3. Evolutionary Thoughts and Ideas Processor (EvoTIP)
4. Deep Thought
5. Deep Thought
6. Deep Thought
7. Automatic concept evolver (ACE)
8. Automatic concept evolver (ACE)
9. Automatic concept evolver (ACE)
10. Eureka Engine
11. Automatic concept evolver (ACE)
12. Eureka Evolver
13. meme engine
14. Automatic concept evolver (ACE)
15. Darwinian Eureka Engine
16. Automatic concept evolver (ACE)
17. Automatic concept evolver (ACE)
18. Automatic concept evolver (ACE)
19. Automatic concept evolver (ACE)
20. Automatic concept evolver (ACE)

5. RESULTS

5.1 The Winner

The winner of the competition was declared to be “Automatic concept evolver (ACE)” which became the name of the algorithm

5.2 Where Did the Winner Come From?

Tracing the evolution of the winner through the six generations gives the following picture:

Gen 1 Mij c Automated mind merger
 Terry c Interactive evolver of ideas
 Gen 2 Jen $< Mij \times Terry$ automated ideas evolver
 Gen 3 Jen $< m$ Jen automated concept evolver
 Gen 4 Mij $< m$ Jen Automatic concept evolver (ACE)
 Gen 5 (Terry Jen Mij) $< r$ Mij
 Gen 6 (Terry5 Luis Jen2 Mij3) r (Terry Jen Mij)

5.3 Operator frequency over 6 generations

Looking at the frequency of use of the various operators over the 6 generations gives the following picture:

Gen.	1	2	3	4	5	6
c	20	2	2	1	2	0
x	0	11	8	3	8	3
m	0	7	5	12	2	1
r	0	0	5	4	8	16

5.4 What could ACE be used for?

The current idea is to use ACE as an OuLiPoean [3] constraint to aid a group of people to produce literature.

6. ACKNOWLEDGMENTS

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