Cultural Transmission of Information in Genetic Programming

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Sources

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Overview

- Culture and Evolution
- Implementing Culture via Shared Memory
- Examples:
  - Symbolic Regression
  - Wumpus World
- Conclusions

Culture Defined

[Webster's]

1. the act or process of tilling and preparing the earth for crops; cultivation of the soil.

2. the raising, improvement, or development of some plant, animal, or product.

3. the growth of bacteria or other microorganisms in a specially prepared nourishing substance, as agar.

4. a colony of microorganisms thus grown.

5. improvement, refinement, or development by study, training, etc.

6. the training and refining of the mind, emotions, manners, taste, etc.

7. the result of this; refinement of thought, emotion, manners, taste, etc.

8. the concepts, habits, skills, art, instruments, institutions, etc. of a given people in a given period; civilization.

Culture Defined

"By culture I mean the transfer of information by behavioral means, most particularly by the process of teaching and learning. It is used in a sense that contrasts with the transmission of genetic information passed by the direct inheritance of genes from one generation to the next." [Bonner 1980, p. 9]

Culture and Evolution

- The gene pool and the cultural "meme" pool [Dawkins 1976] are separate, interacting systems.
- The ability to use culture can influence biological evolution in several ways [Bonner 1980].
- Genetic changes spread through populations slowly, except in the case of extinctions.
- Cultural changes may spread very quickly.
- The meme pool is less stable than the gene pool.

Culture and Evolutionary Computation

- "Meme-based" adaptive systems in multiplayer games—evolution of memes within individuals [Bankes 1995].
- "Cultural algorithms" in which a "belief space" containing generalizations of individuals helps to guide evolution [Reynolds 1994].
- Straightforward extension of memory mechanisms used by individuals.

Culture Implemented via Shared Memory

- All individuals throughout evolutionary time share a single, global memory system.
- Note: the state of the culture must be returned with the best-of-run individual.

Indexed Memory

- Astro Teller, 1994
- Each individual has an independent memory system
- Read and write functions

Computational Effort

$$I(M,i,z) = M * (i+1) * \left\lceil \frac{\log(1-z)}{\log(1-P(M,i))} \right\rceil$$

- *P(M,i)* = cumulative probability of success by generation *i* with a population size of *M*, calculated over a large number of independent runs.
- *I(M,i,z)* = number of individuals that must be processed to produce a solution by generation *i* (and population size *M*) with probability greater than *z* .A value of *z*=99% is used here.
- Computational Effort = minimum of *I(M,i,z)* for all *i* [Koza, 1992]

Symbolic Regression

- Goal: to find a function, in symbolic form, that fits a data set produced from for
- Function set: +, -, *, %, SIN, COS, EXP, RLOG, [READ, WRITE]
- Terminal set: x, ephemeral random constants
- Total runs: 300 (population size 1000, 51 gens/run, 20 fitness cases)
- y=x4+x3+x2+x

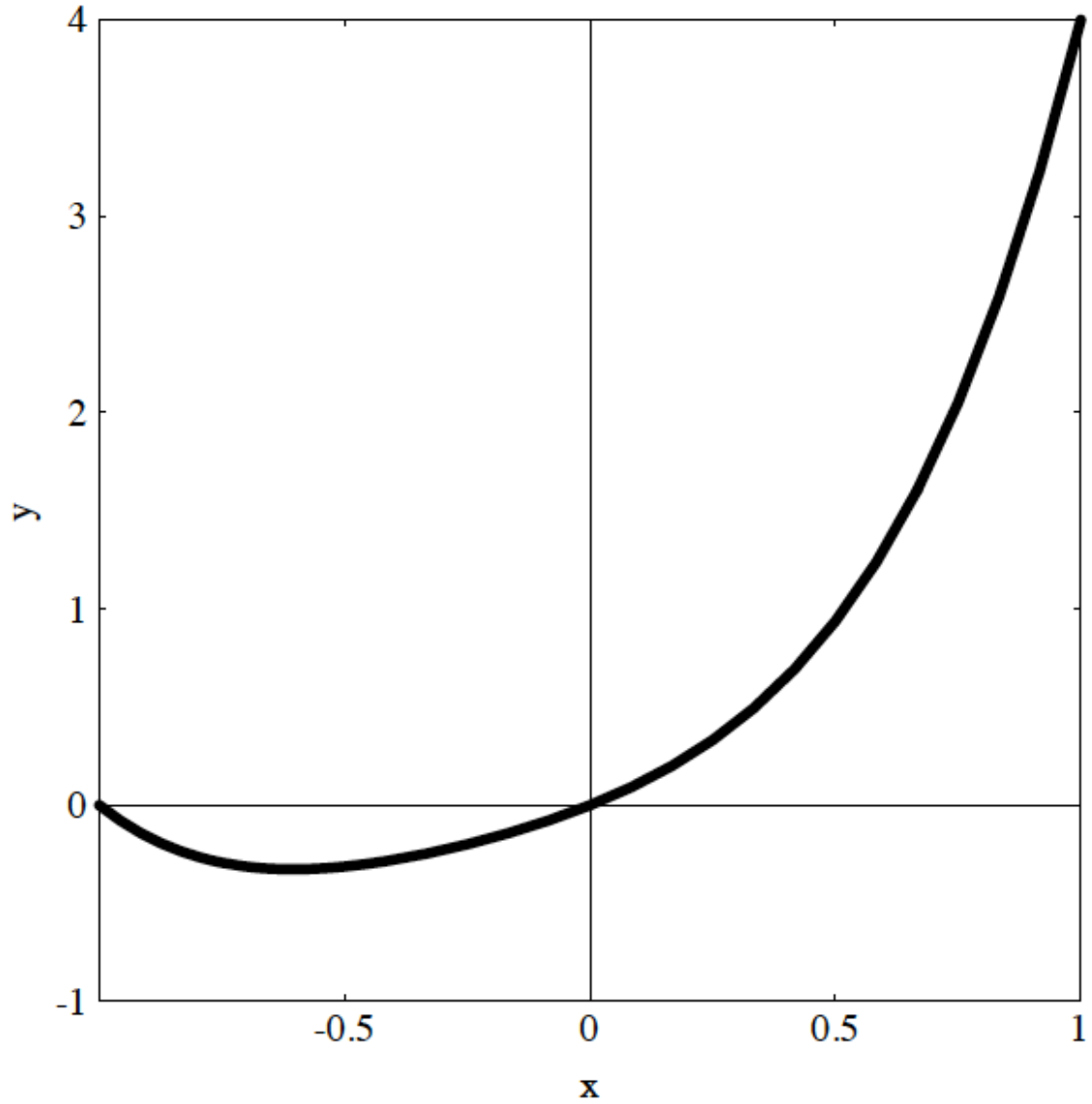

Figure 1: The target function for the symbolic regression problem: $y = x^4 + x^3 + x^2 + x$.

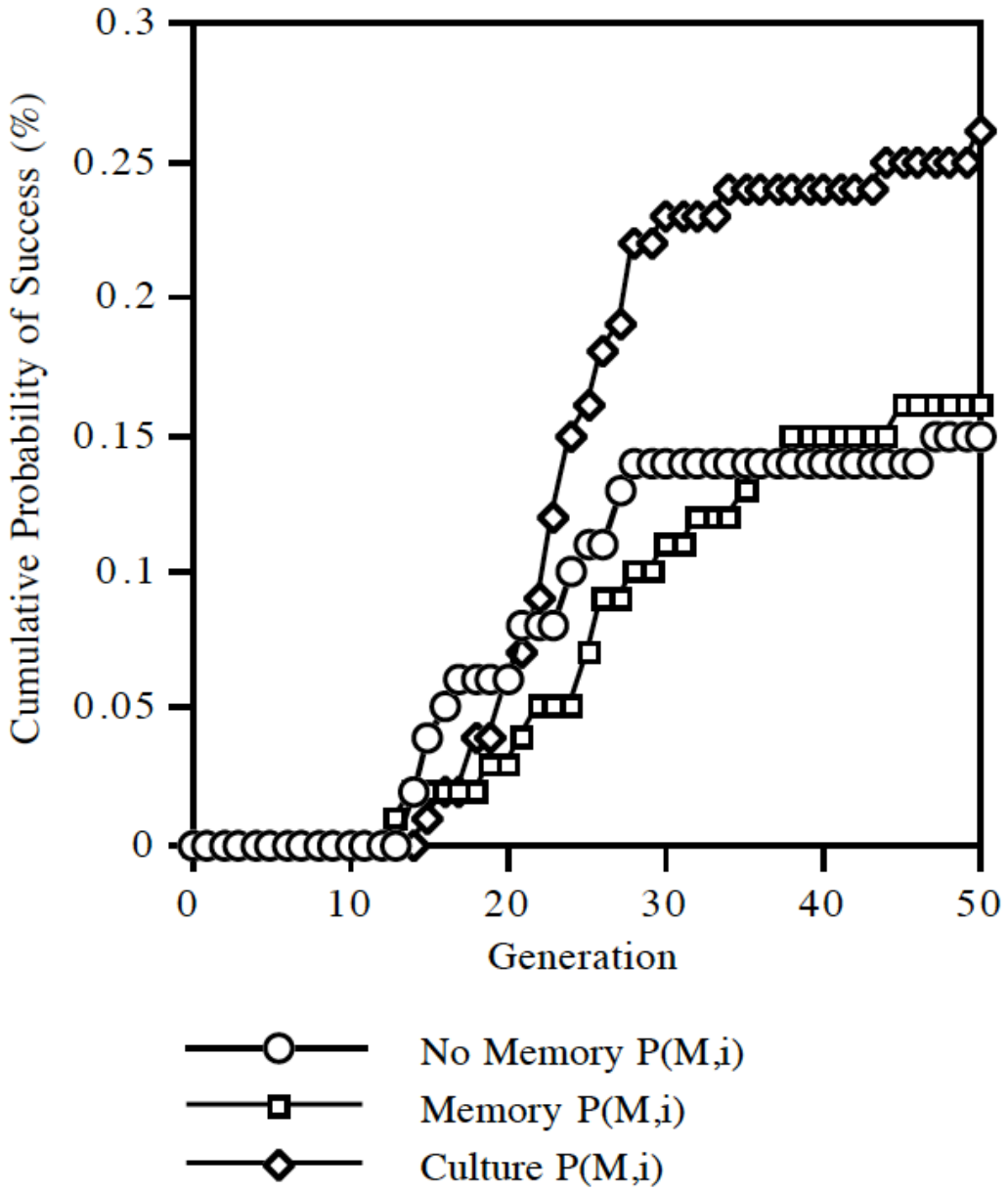

Figure 3: $P(M,i)$ for the symbolic regression problem.

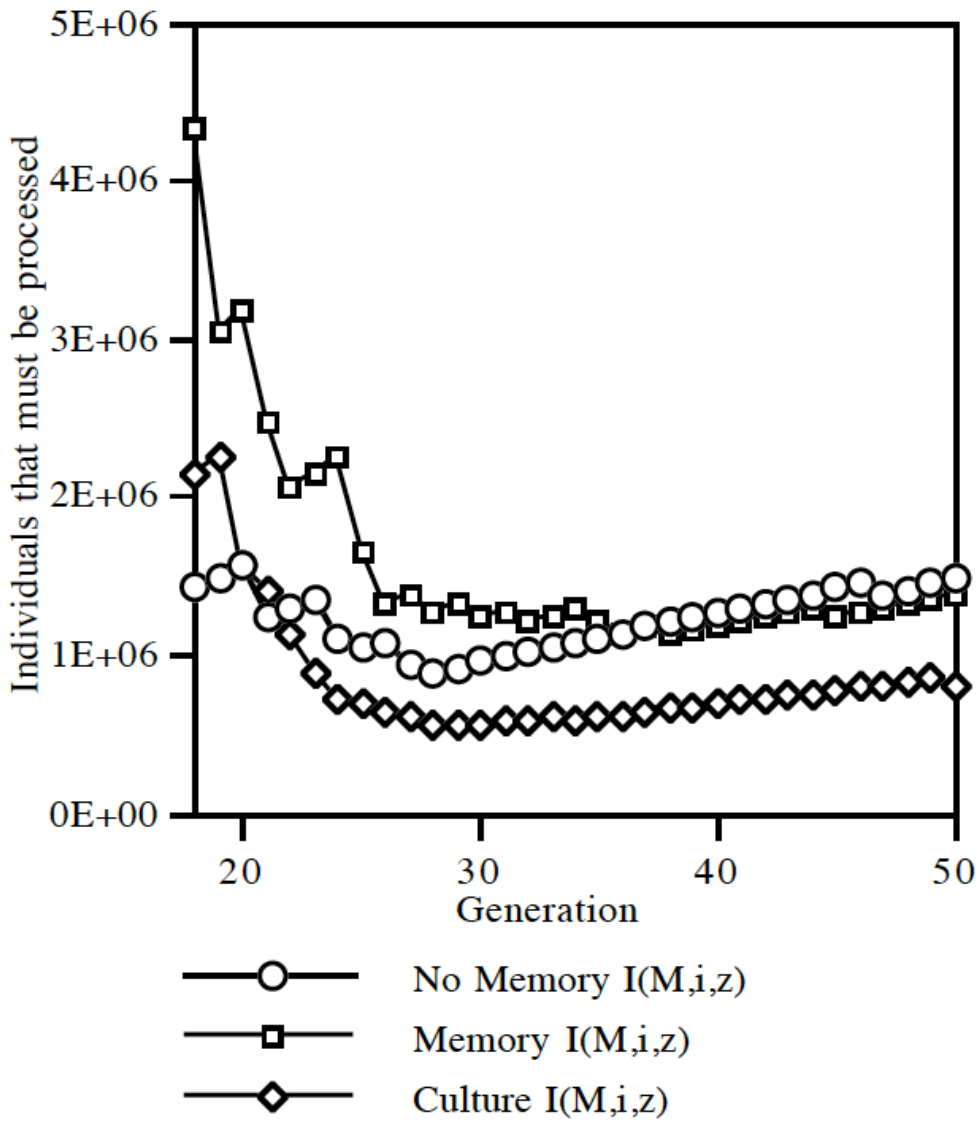

Figure 4: $I(M,i,z)$ for the symbolic regression problem.

Condition	Computational Effort
No memory	899,000
Memory	1,131,000
Culture	551,000

Table 1: Computational efforts for symbolic regression.

Wumpus World

Breeze	O Pit	Breeze		Breeze	O Pit
O Pit	Breeze			Breeze	O Pit
Breeze		Breeze			Breeze
	Breeze	O Pit	Breeze Stench		$ Gold
		Breeze Stench	 Wumpus	Stench	Breeze
 Agent			Stench	Breeze	O Pit

Wumpus World

- As in [Russell and Norvig 1995; Spector 1996]
- Goal: to find a program for controlling the actions of an agent in a relatively complex virtual world.
- Function set: AND, OR, NOT, PROGN2, IFZ, IFLTE, -, + , *, READ, WRITE
- Terminal set: 0, 1, 2, 3, 4, 5, 6, (RAND7), *STENCH*, *BREEZE*, *GLITTER*, *BUMP*, *SOUND*
- Total runs: 1709 (population size 1000, 21 gens/run)

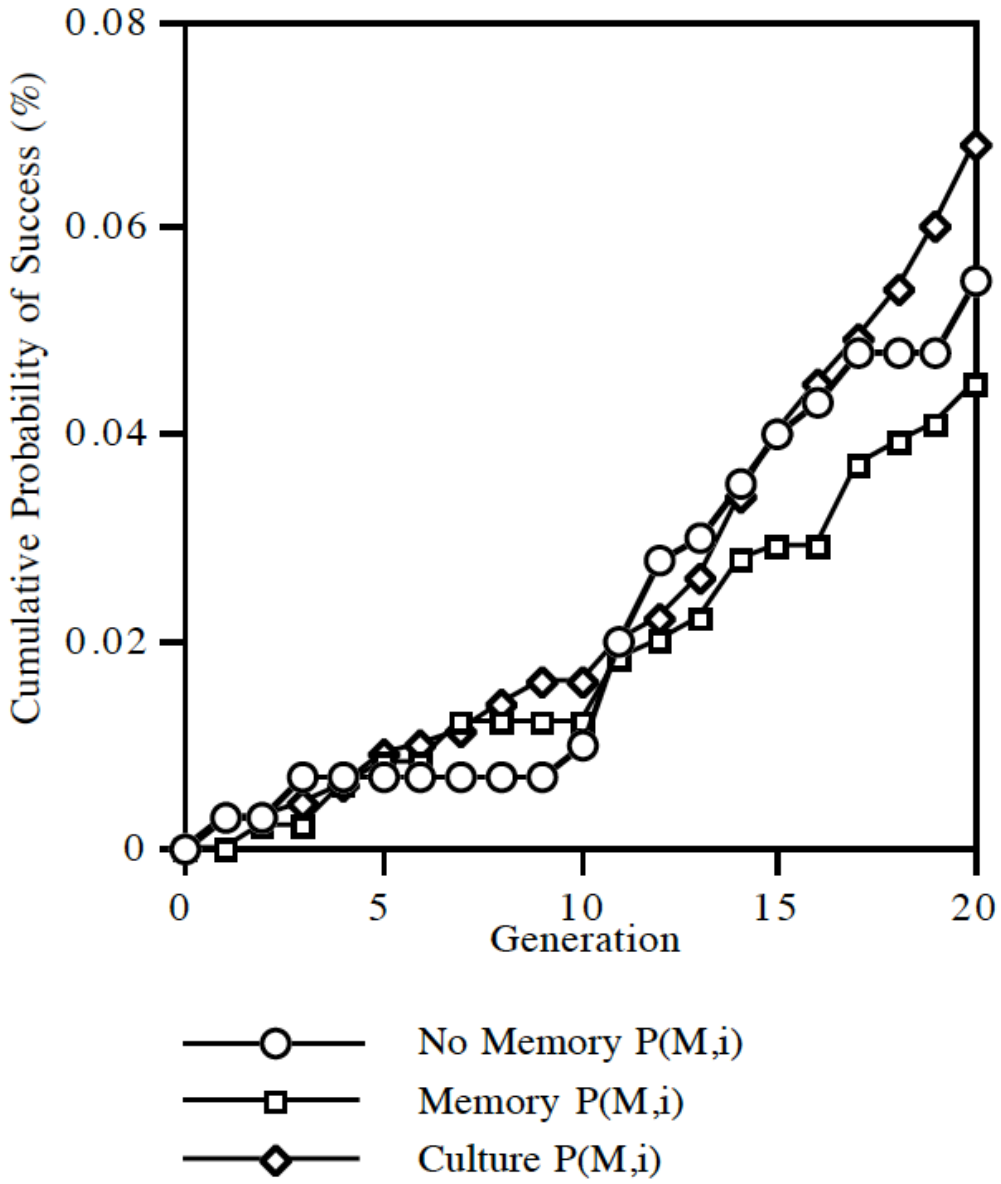

Figure 5: $P(M,i)$ for the Wumpus world problem.

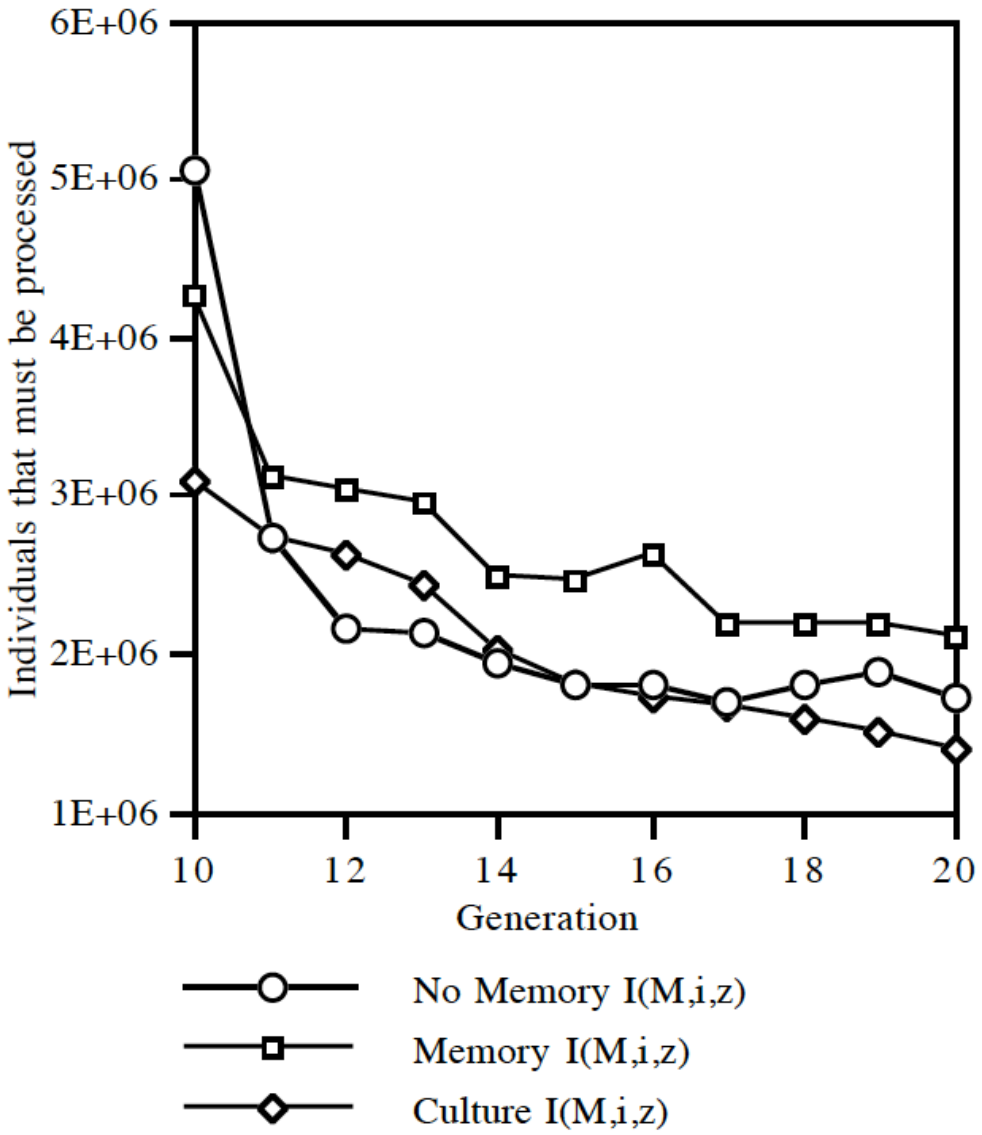

Figure 6: *I*(*M*,*i*,*z*) for the Wumpus world problem.

Condition	Computational Effort
No memory	1,710,000
Memory	2,100,000
Culture	1,386,000

Table 2: Computational efforts for Wumpus world.

Future Work

- Apply culture to additional problems and delineate the cases in which culture helps.
- Combine ordinary indexed memory and culture.
- Minimize the effects of culturally destructive individuals.
- Examine the ways in which culture is actually used by successful individuals.

Conclusions

- Culture can be added to most GP applications very simply:
  1. add an indexed memory shared by all individuals
  2. arrange to return the appropriate memory state with the best-of-run individual.
- In some cases culture decreases the computational effort required to solve a problem.