Classifier Systems

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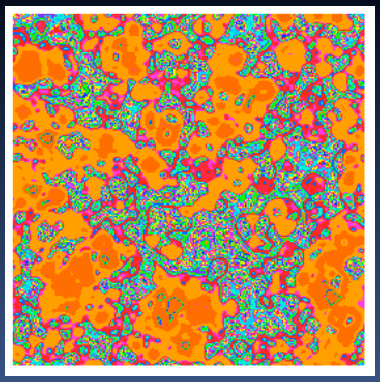
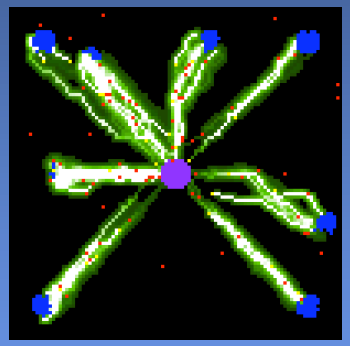
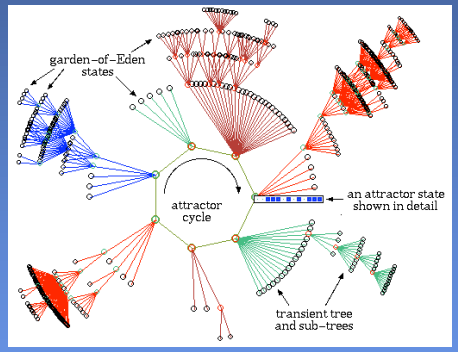
Cellular Automata



Swarm Systems



Random Boolean Networks



Classifier Systems

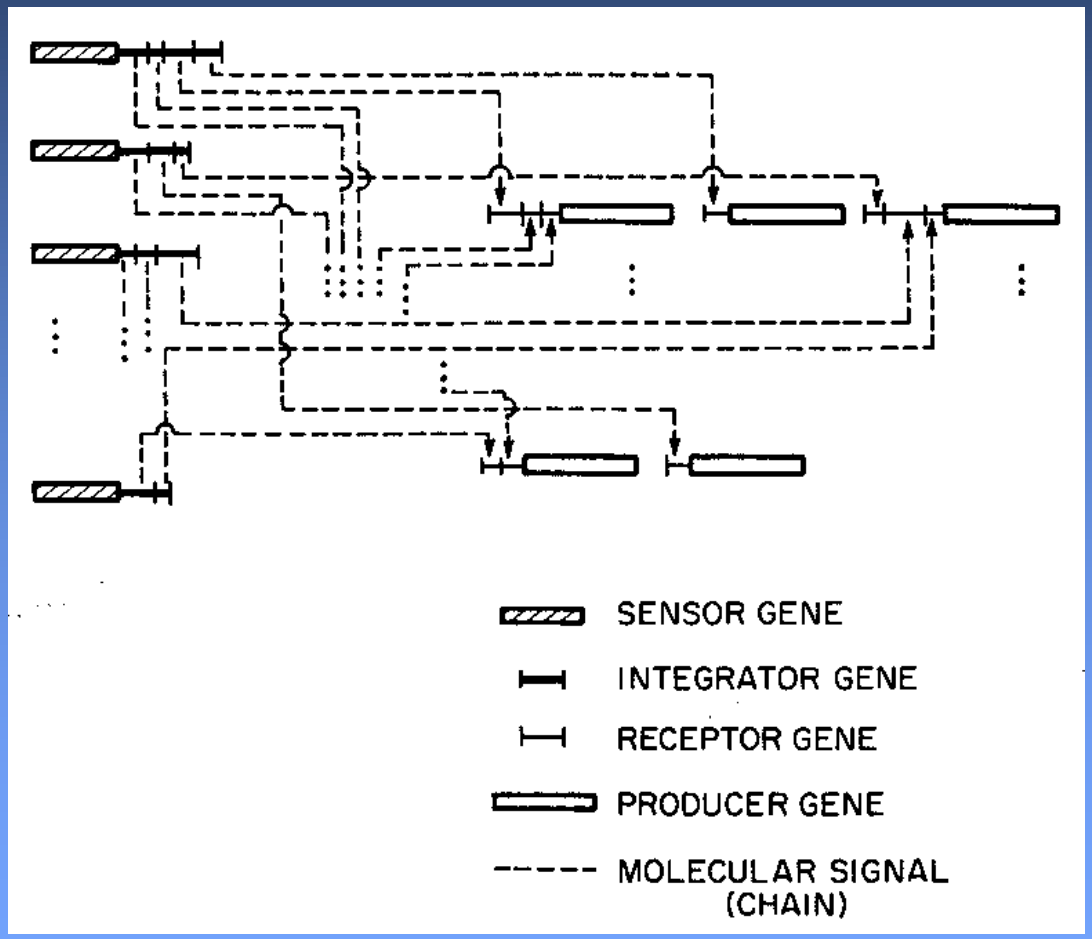
Classifier Systems

J. Holland (1975)

Learning syntactically simple string rules (classifiers) to guide performance in an arbitrary environment

Objective: A Formal Framework for an Operon-Operator Gene Regulation Model

(Britten-Davidson)

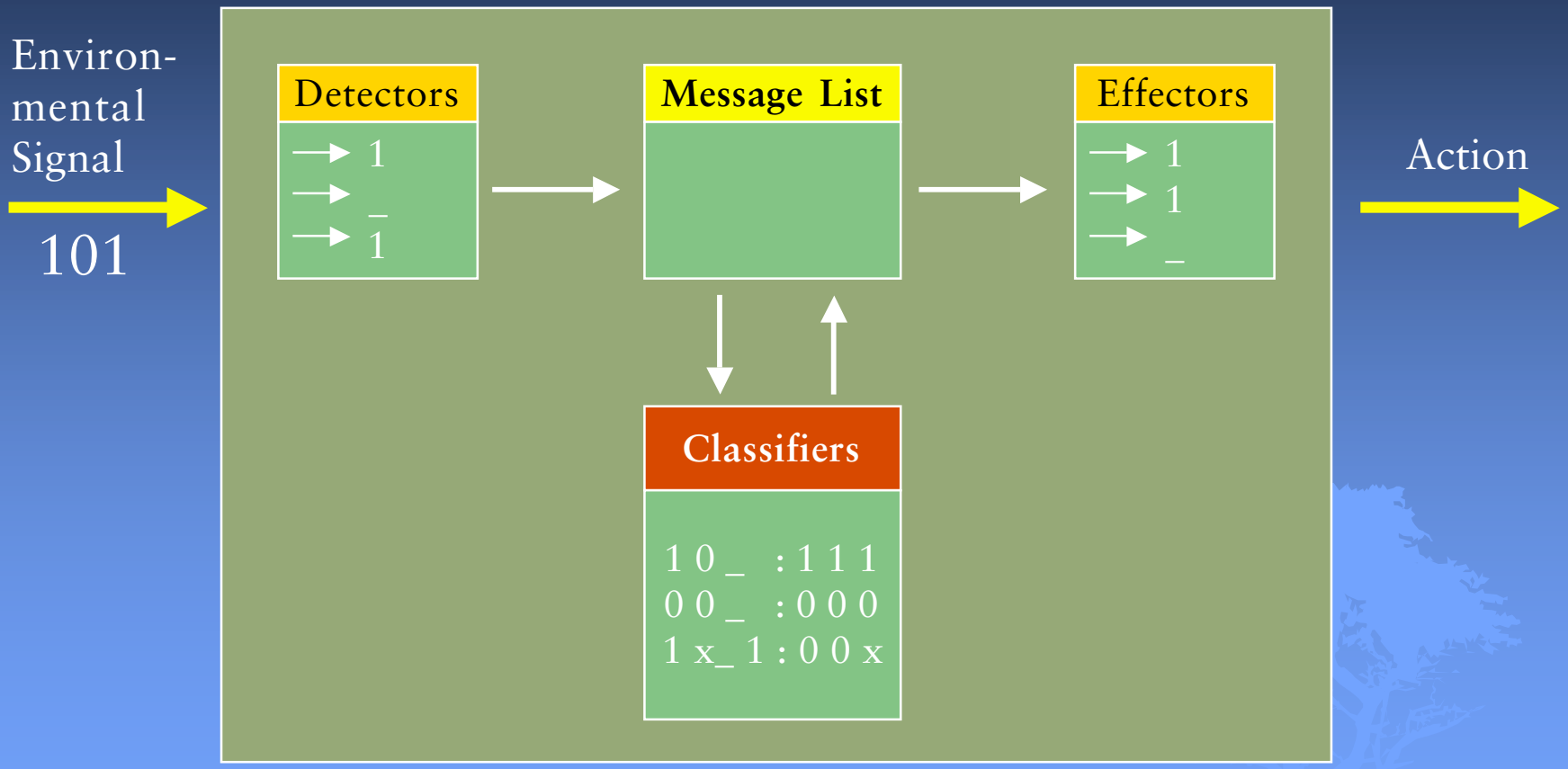


First a Simple Example ...

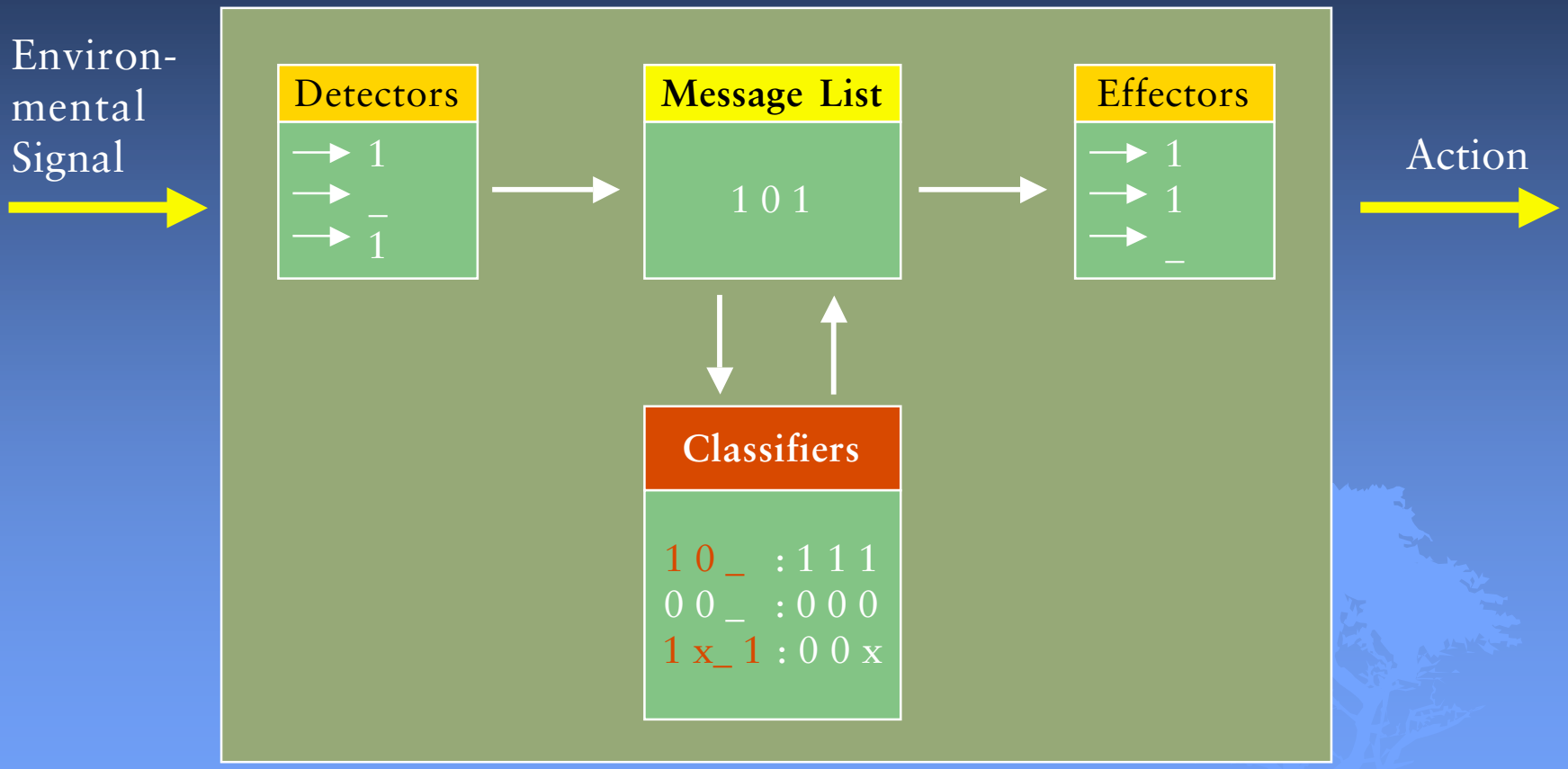
- A classifier system to emulate a frog. The frog reacts to objects it sees.

Input:					Output:	
Moving	On the Ground	Large	Far	Striped	Flee!	Pursue!
1	_	_	_	_	1	0
1	0	0	0	_	0	1
1	0	0	0	1	0	0

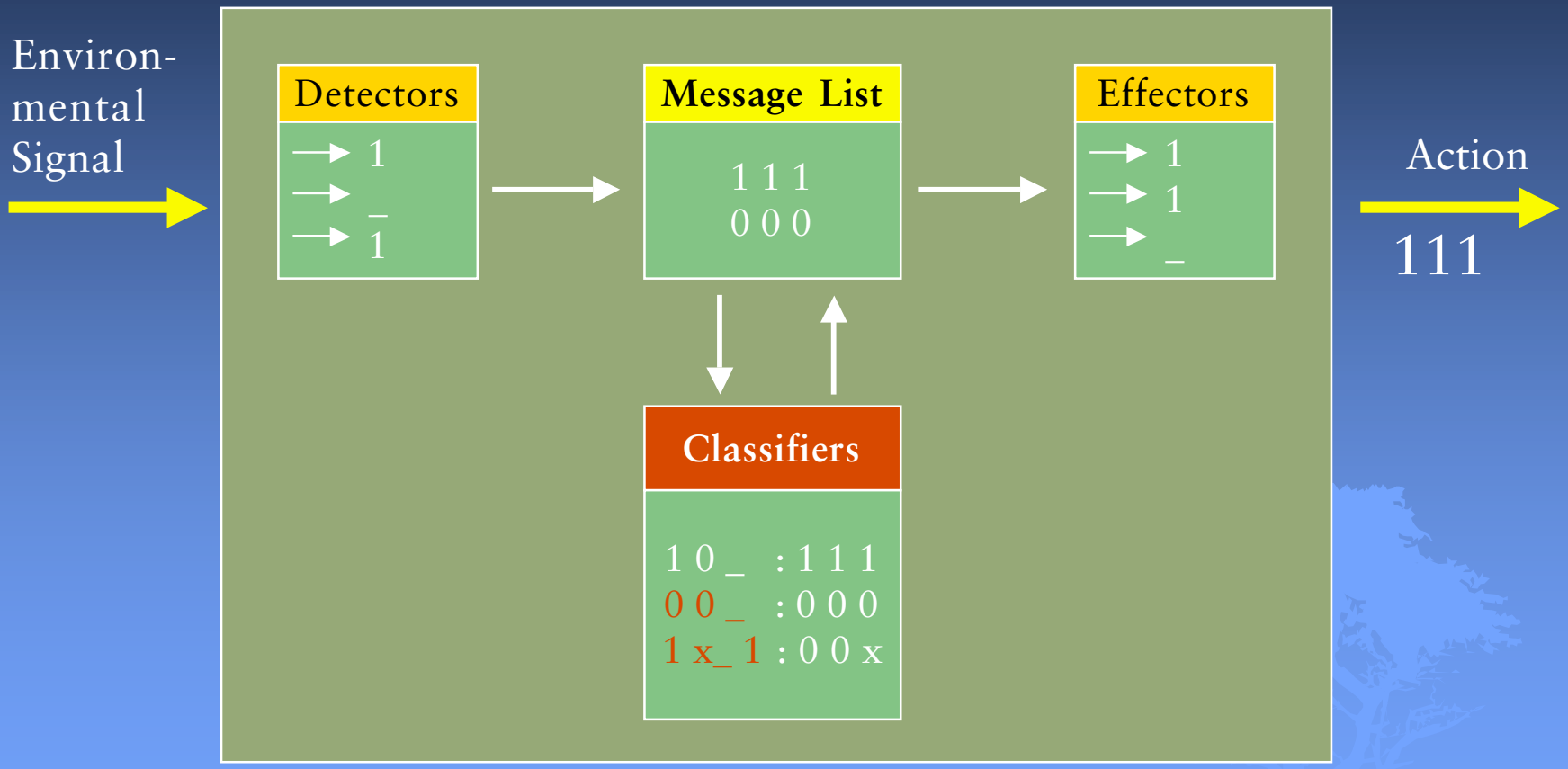
Classifier System in Action



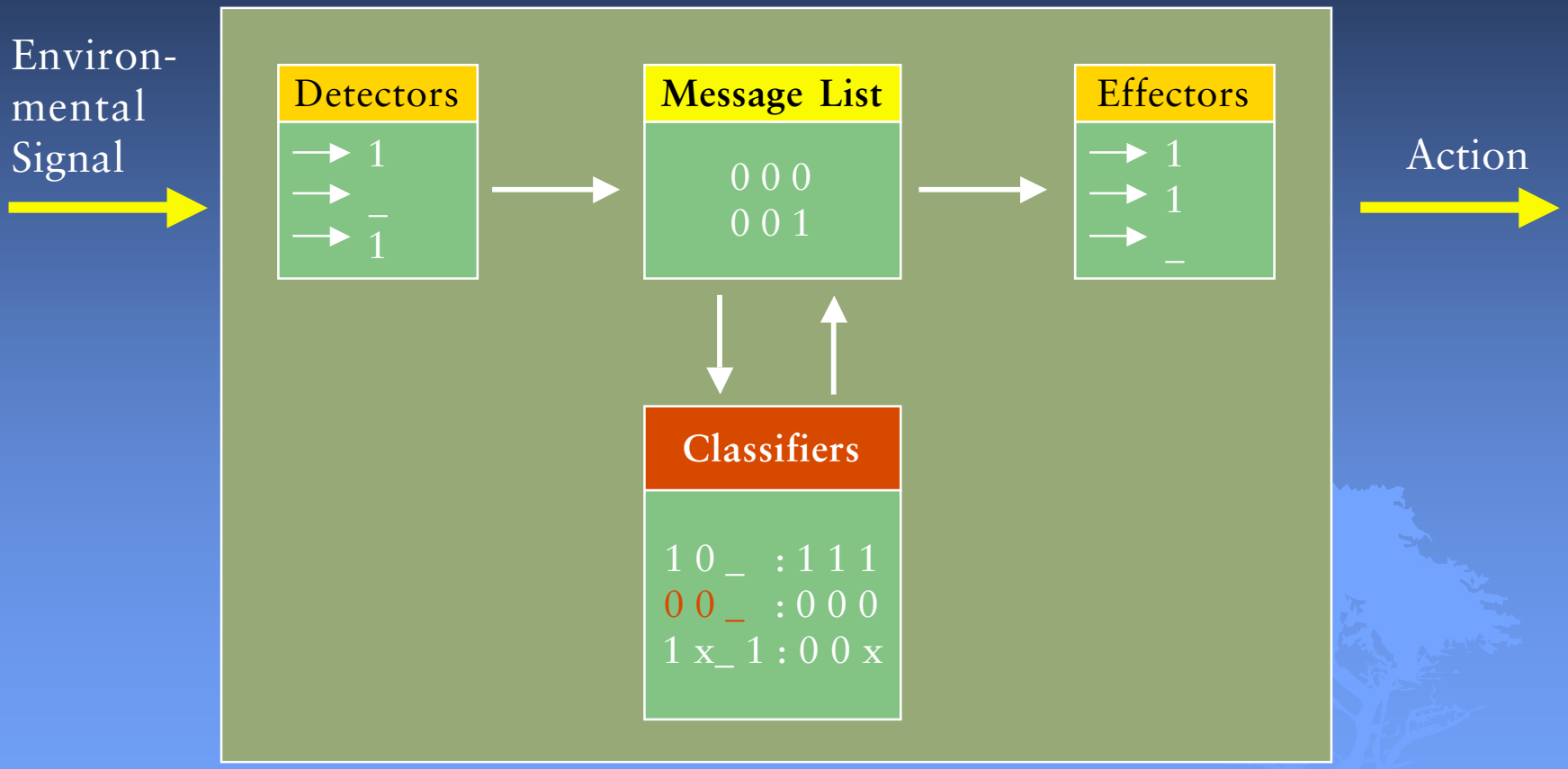
Classifier System in Action



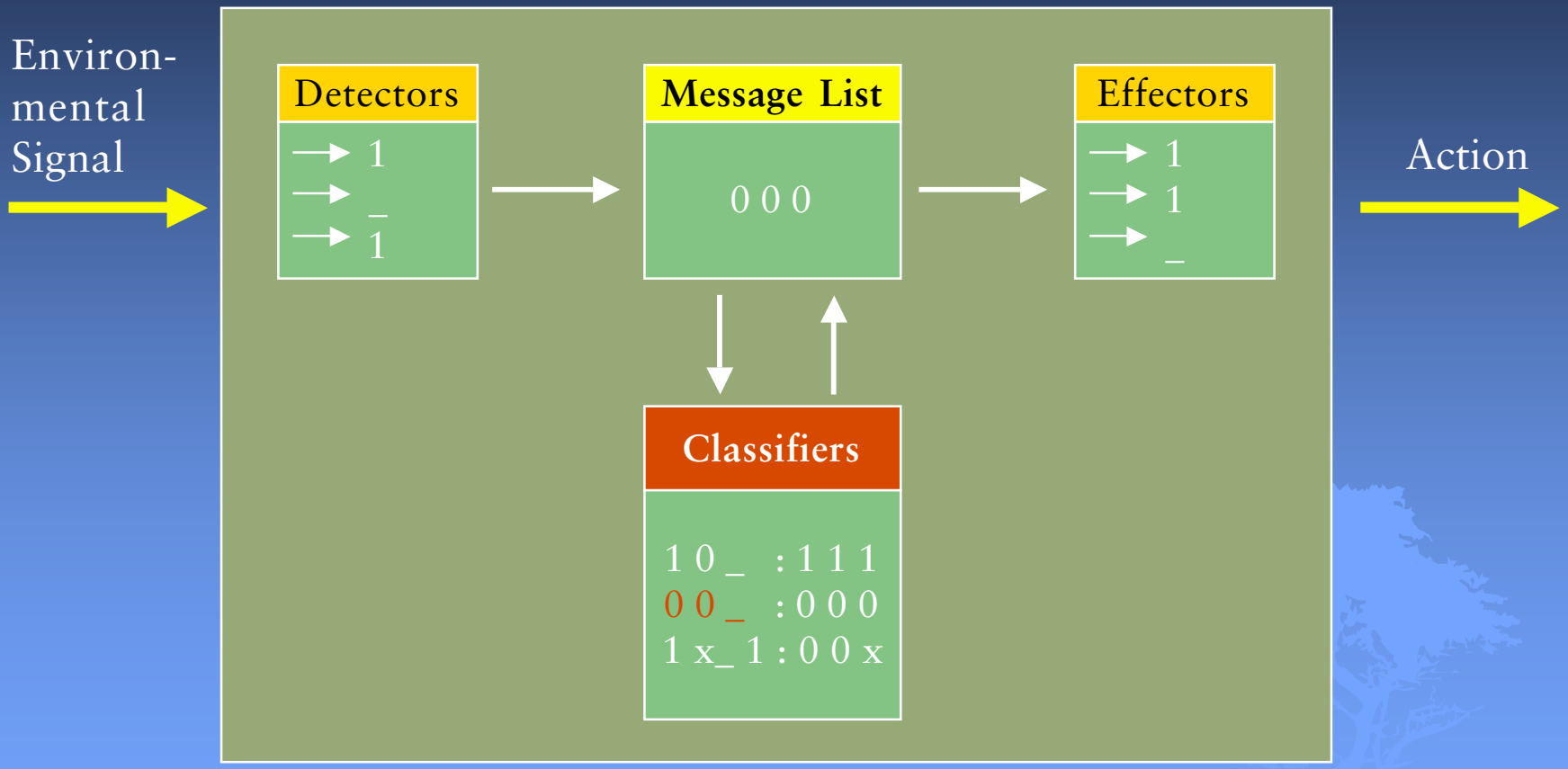
Classifier System in Action



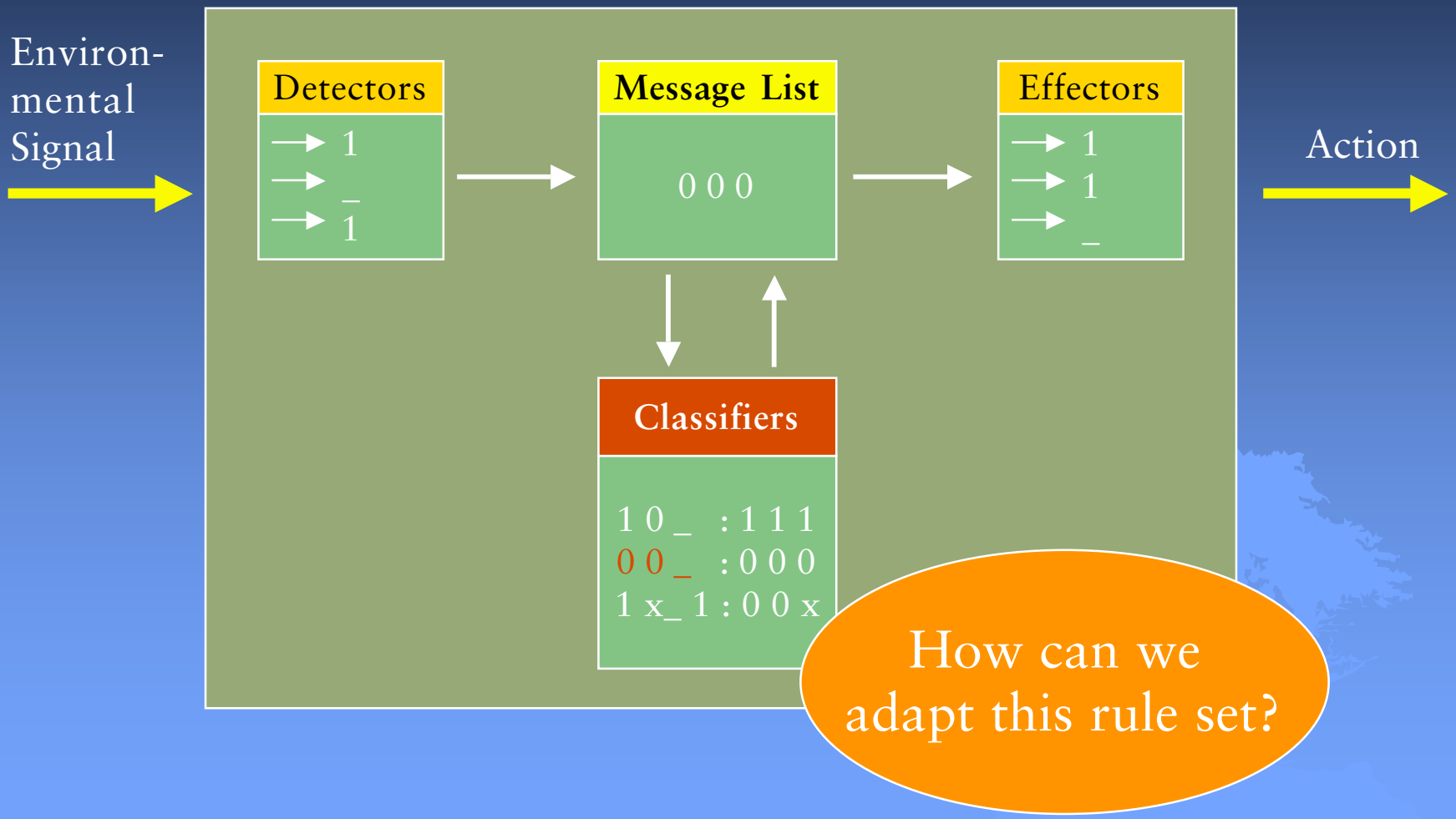
Classifier System in Action



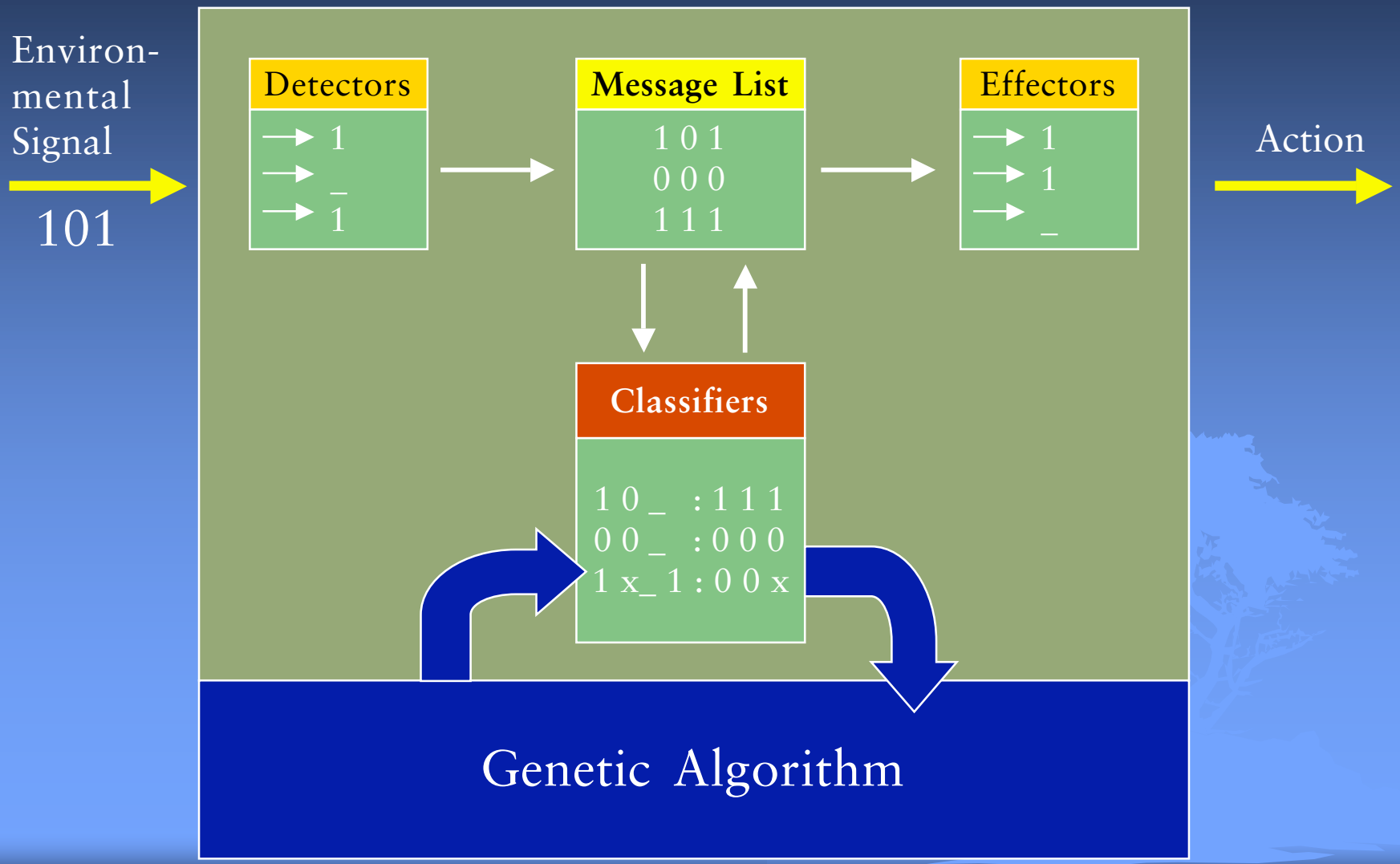
Classifier System in Action



Classifier System in Action



Learning CS Architecture



Genetic Algorithms

J. Holland (1975)

D. Goldberg (1989)

Simulated Genome-based Evolution

Genetic Algorithms

Representation of individuals

Binary vector

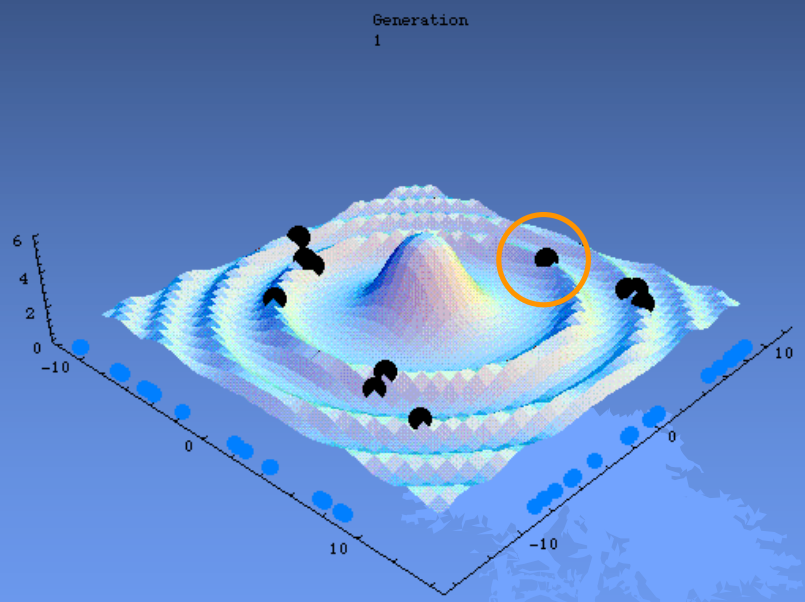
{1,0,1,1,0,1,0,0,1,0,1,1}
{0,1,1,1,1,0,0,1,0,0,0,1}
{0,0,1,1,0,101,1,0,1,0,0}

...
{1,1,0,0,0,1,0,1,0,1,0,0}
...

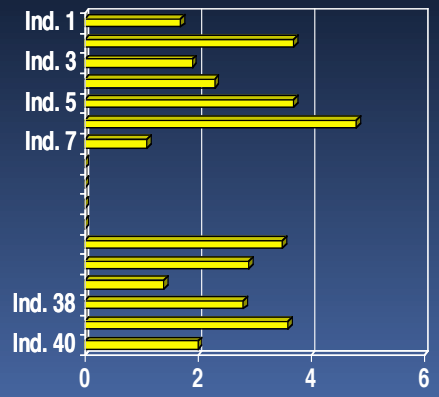
{1,0,1,0,0,1,1,1,0,1,1,1}
{0,0,1,1,0,1,1,1,0,1,0,0}
{1,0,0,1,0,1,1,1,0,0,0,1}

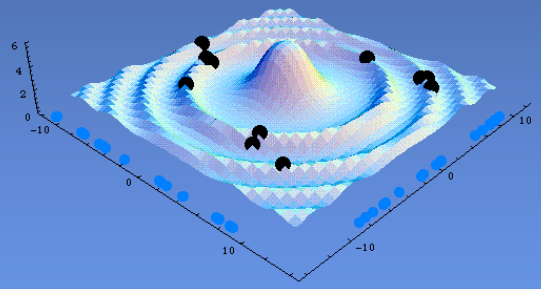
decoding

interpretation



evaluation





{1,0,1,1,0,1,0,0,1,0,1,1}
{0,1,1,1,1,0,0,1,0,0,0,1}
{1,1,0,0,0,1,0,1,0,1,0,0}
...

{1,0,1,0,0,1,1,1,0,1,1,1}
{0,0,1,1,0,1,1,1,0,1,0,0}
{1,0,0,1,0,1,1,1,0,0,0,1}

selection

{0,0,1,1,0,1,1,1,0,1,0,0} {1,1,0,0,0,1,0,1,0,1,0,0}

mutation

{0,1,1,1,0,0,1,1,0,1,1,0} {1,1,1,1,0,1,0,1,0,0,0,0}

crossover

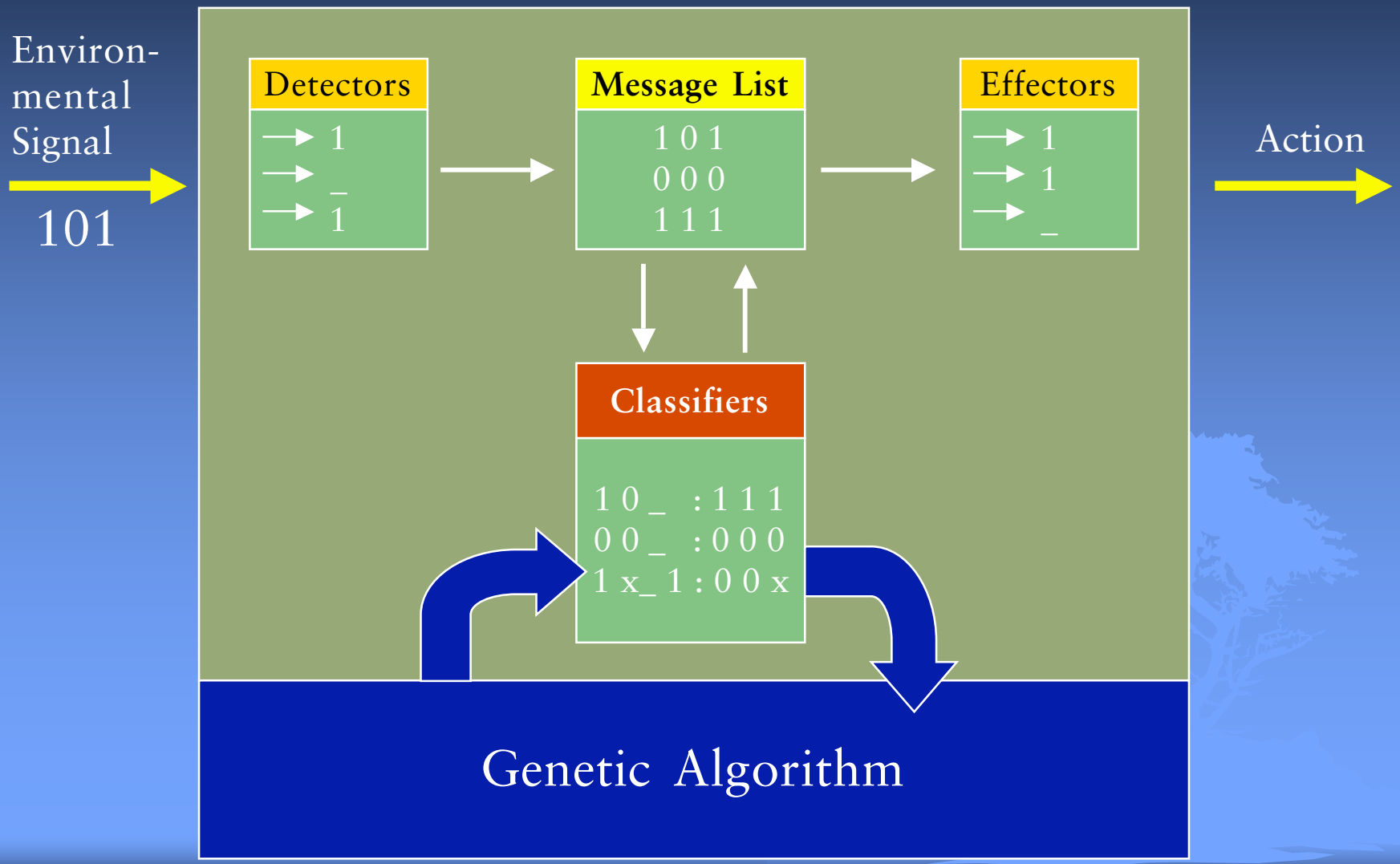
{1,1,1,1,0,0,1,1,0,1,1,0} {0,1,1,1,0,1,0,1,0,0,0,0}

{1,0,1,1,0,1,0,0,1,0,1,1}
{0,1,1,1,1,0,0,1,0,0,0,1}
{1,1,0,0,0,1,0,1,0,1,0,0}
...

{1,0,1,0,0,1,1,1,0,1,1,1}
{0,0,1,1,0,1,1,1,0,1,0,0}
{1,0,0,1,0,1,1,1,0,0,0,1}

interpretation

Learning CS Architecture



How do Classifiers Receive their Fitnesses?

Apportionment of Credit
through
Bucket Brigades

Bucket Brigade Algorithm

Index	Rule	Fitness	Triggering Rule	Bid	Message	
1	0 1 _ _ : 0000	200	0	20	0000	
2	0 0 _ 0 : 1100	200				1
3	1 1 _ _ : 1000	200				
4	_ _ 0 0 : 0001	200				
1	0 1 _ _ : 0000	180				
2	0 0 _ 0 : 1100	200	1	20	1100	2
3	1 1 _ _ : 1000	200				
4	_ _ 0 0 : 0001	200	1	20	0001	

Bucket Brigade Algorithm

Index	Rule	Fitness	Triggering Rule	Bid	Message	
1	0 1 _ _ : 0000	180				
2	0 0 _ 0 : 1100	200	1	20	1100	2
3	1 1 _ _ : 1000	200				
4	_ _ 0 0 : 0001	200	1	20	0001	
1	0 1 _ _ : 0000	220				
2	0 0 _ 0 : 1100	180				
3	1 1 _ _ : 1000	200	2	20	1000	3
4	_ _ 0 0 : 0001	180	2	18	0001	

Bucket Brigade Algorithm

Index	Rule	Fitness	Triggering Rule	Bid	Message
1	0 1 _ _ : 0000	220			
2	0 0 _ 0 : 1100	180			
3	1 1 _ _ : 1000	200	2	20	1000
4	_ _ 0 0 : 0001	180	2	18	0001

3

1	0 1 _ _ : 0000	220			
2	0 0 _ 0 : 1100	218			
3	1 1 _ _ : 1000	180			
4	_ _ 0 0 : 0001	162	3	16	0001

4

Bucket Brigade Algorithm

Index	Rule	Fitness	Triggering Rule	Bid	Message
1	0 1 _ _ : 0000	220			
2	0 0 _ 0 : 1100	218			
3	1 1 _ _ : 1000	180			
4	_ _ 0 0 : 0001	162	3	16	0001

4

1	0 1 _ _ : 0000	220			
2	0 0 _ 0 : 1100	218			
3	1 1 _ _ : 1000	196			
4	_ _ 0 0 : 0001	146			

5

Bucket Brigade Algorithm

Index	Rule	Fitness	Triggering Rule	Bid	Message
1	0 1 _ _ : 0000	220			
2	0 0 _ 0 : 1100	218			
3	1 1 _ _ : 1000	180			
4	_ _ 0 0 : 0001	162	3	16	0001

4

1	0 1 _ _ : 0000	220
2	0 0 _ 0 : 1100	218
3	1 1 _ _ : 1000	196
4	_ _ 0 0 : 0001	146

Here are the fitnesses

5

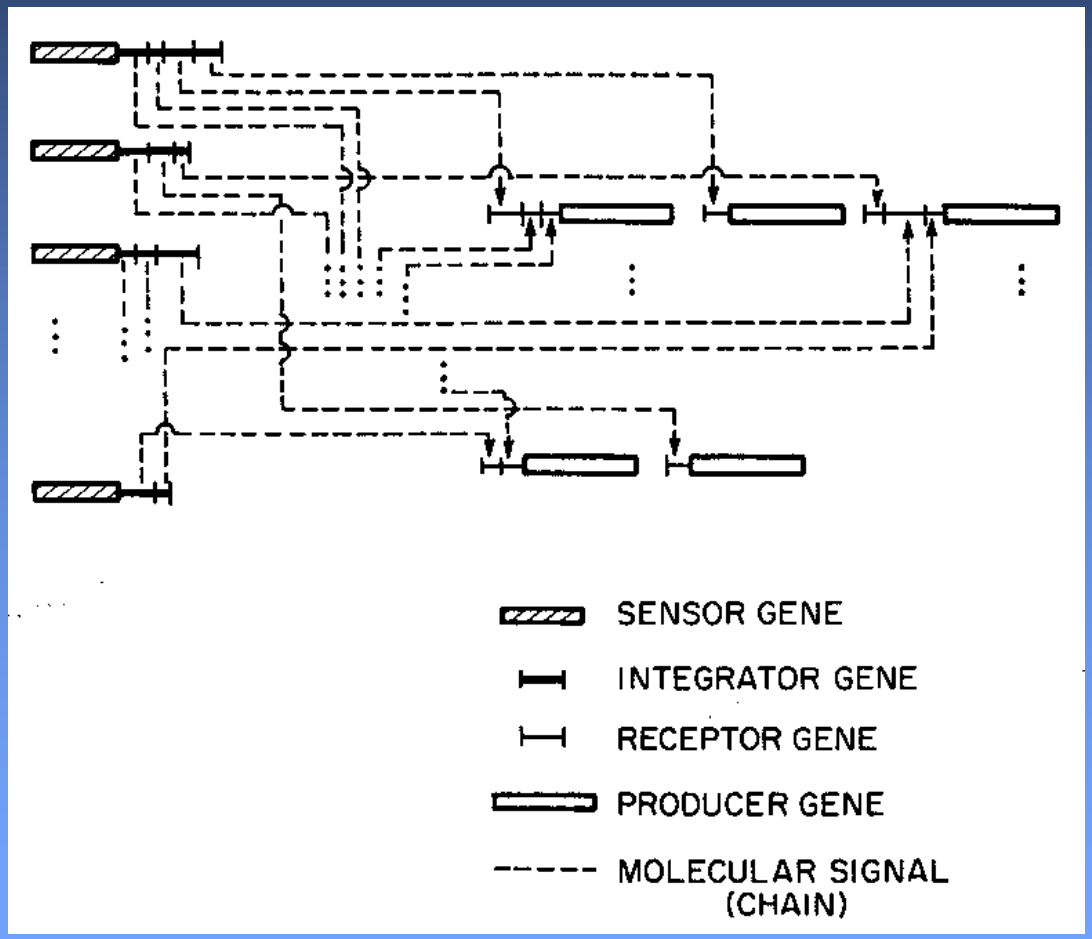
The Broadcast Language

J. Holland (1975)

A Formal Framework for Modeling Evolvable Gene Regulation Networks

Backing up again: A Formal Framework for an Operon-Operator Gene Regulation Model

(Britten-Davidson)



Broadcast Units

- BC[S_1, S_2, S_3, S_4]

  If at time t a signal of type S_1 is present
  and no signal of type S_2 is present,
  then at time t+1
  the signal S_3 is broadcast
  and the signal S_4 is deleted at time t.

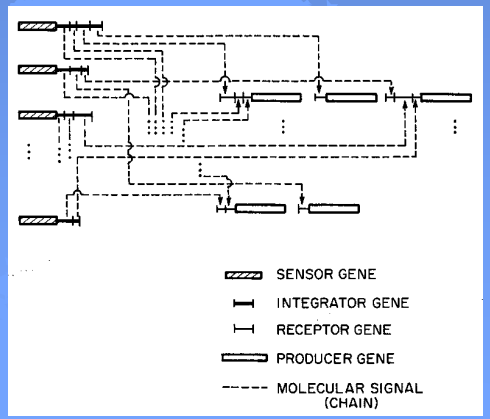
Gene Regulation with BC Units

- Sensor-integrator gene complex $SI_1I_2I_3$:

  BC[S, _, {I_1, I_2, I_3}, _]

- Receptor-producer complex R_1R_2P:

  BC[{R_1, R_2}, _, P, _]



Broadcast Language Example

References

- Holland, J. H. (1992). Adaptation in Natural and Artificial Systems. Cambridge, MA, MIT Press.