Cultural Algorithms Tutorial System (CAT)

Version 1.1

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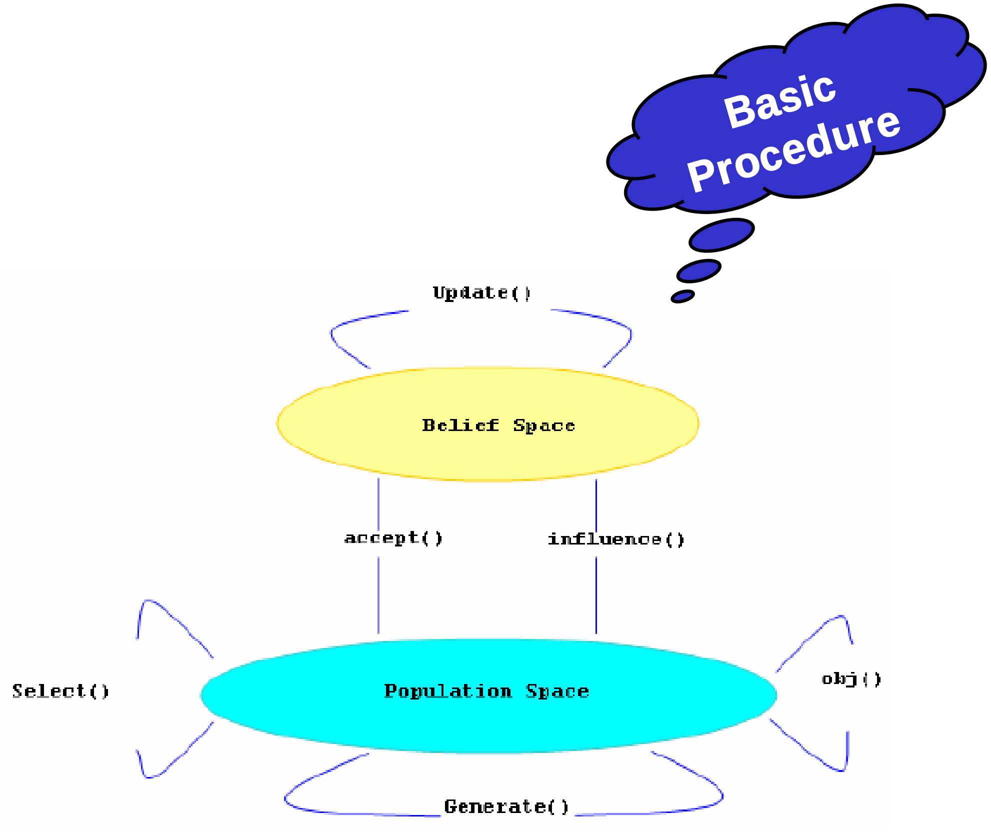
Introduction to Cultural Algorithms

- **Cultural Algorithms are computational models of Cultural Evolution.**
- **Major components.**

Begin
  t = 0;
  Initialize Population POP(t);
  Initialize Belief Space BLF(t);
  repeat
    Evaluate Population POP(t);
    Adjust(BLF(t), Accept(POP(t)));
    Adjust(BLF(t));
    Variation(POP(t) from POP(t- 1));
  until termination condition achieved
End



Knowledge Sources

- **Basic Knowledge Categories:**
  - **Situational Knowledge**
  - **Normative Knowledge**
  - **Topographic Knowledge**
  - **Domain Knowledge**
  - **History knowledge**
- **Classification is complete for a given domain.**

Situational Knowledge

- Comprise a set of exemplars, {en} from population.
- Exemplar added from population if better than current best.
- Situational knowledge reinitialized if environment changes.

Domain Knowledge

- Use change in fitness values to generate diversity and mutation values.
- Comprises set of domain ranges for all parameters.
- Updated from population if best individual outperforms current best.
- Not reinitialized when environment changes.

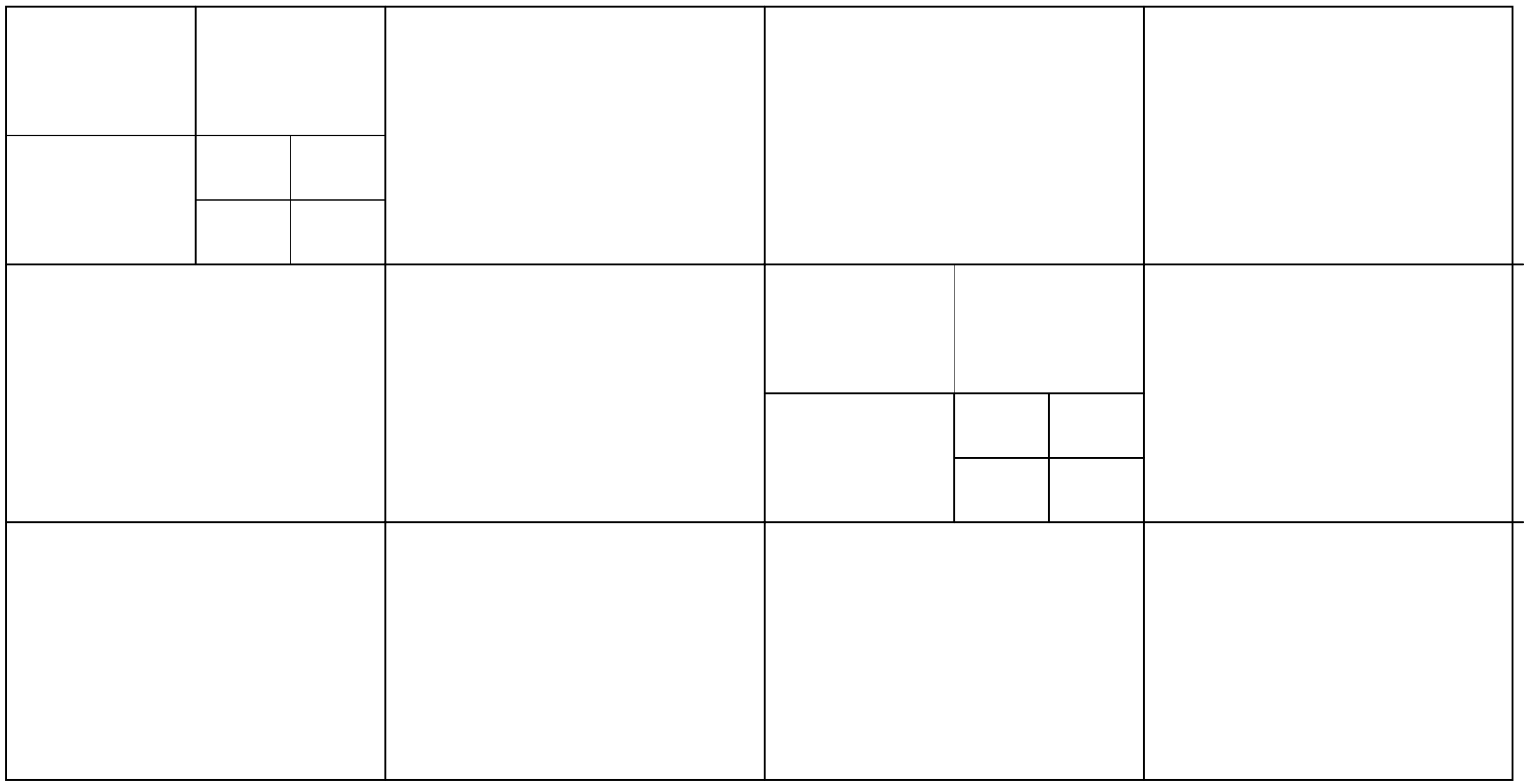
Normative Knowledge

- Set of intervals for each parameter.
- Represents best estimate of values that produce a good solution.
- Interval characterized by upper and lower bounds and the best performance at those limits.
- Update bound when better performance is found.

- Memory of social and environmental changes.
- Comprises list of most recent changes in optimum solution, plus average shift direction and distance.
- Shift direction is summation over all parameters, adjusted for number of events in memory.

- Representation of spatial location of best solutions.
- Variable resolution
  - Focus on most productive areas
  - Increased resolution in productive areas
- Hybrid structure
  - Array of cells
  - Linked list of subdivided cells

Topographical Knowledge Cont…



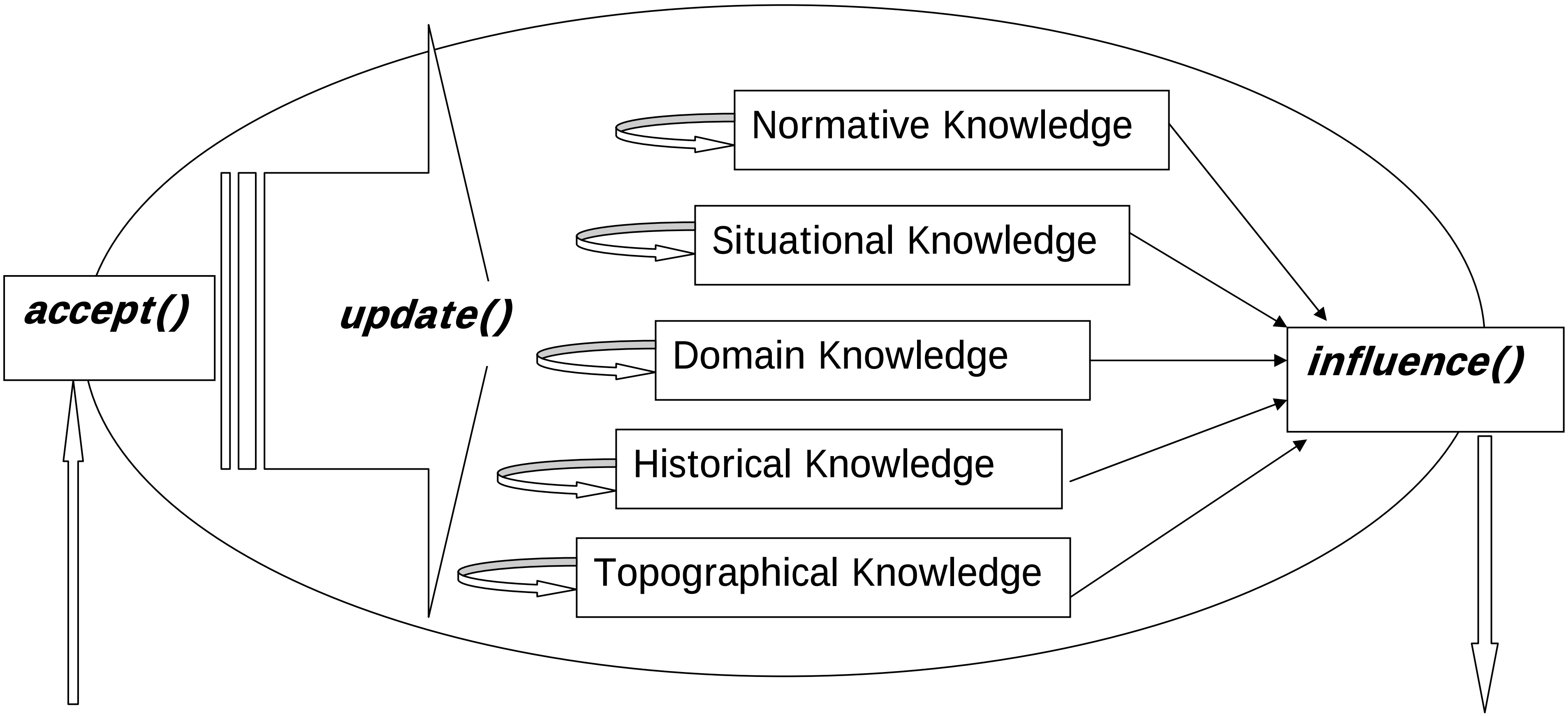
Acceptance Function

- Regulates the movement of knowledge from the Population Space -> Belief Space.
- A subset of the population is chosen to impact the Belief Space. In an optimization problem it is generally a percentage of the top performers.

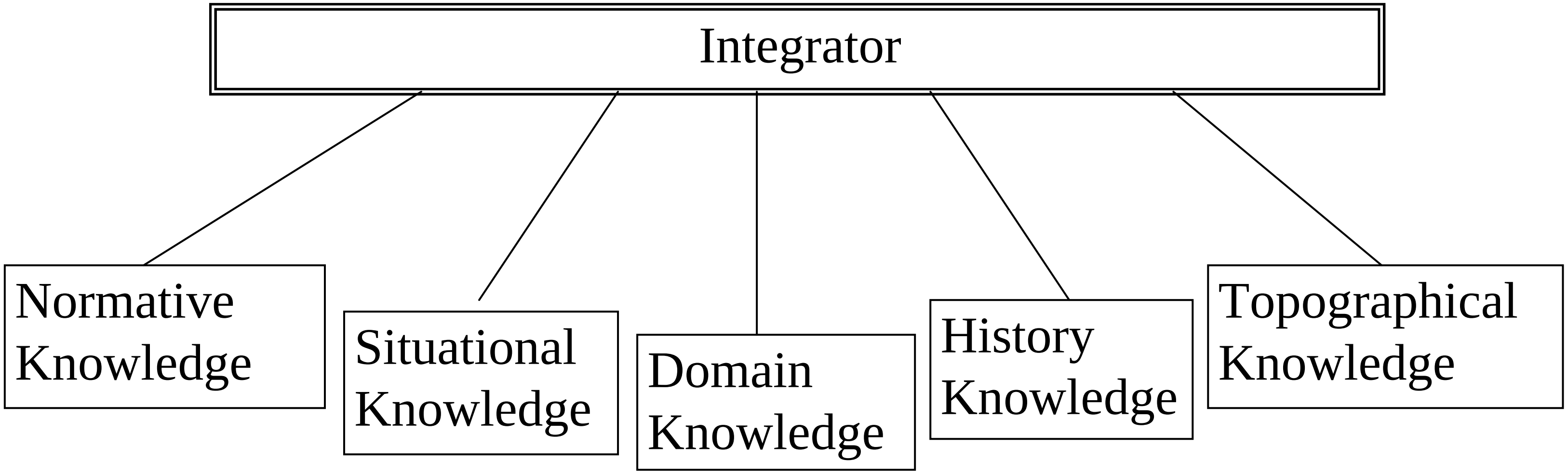
Influence Function

- Belief Space guides the changes made to individuals in the Population Space.
- Early Cultural Algorithms had only one knowledge source which was always applied to individuals.
- When additional sources were used in the Belief Space they were just randomly applied.
- Here we want to investigate the use of a systematic approach to the application of these multiple knowledge sources in the solution of optimization problems.

Integrating the Knowledge Sources in the Influence Function



Hierarchical Integration of the Knowledge Sources



An Approach Based on a Biological Analogy

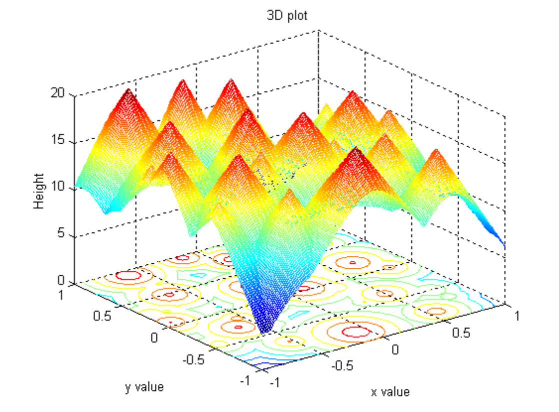
- View each knowledge source as a predator that exploits a patch of the performance function landscape.

- The KS directs individuals in the population to take parameter values that allows them to occupy a location in its current patch. The performance function achieved by the individual accrues to the knowledge source as its energy intake.

- The landscape is given by:

$$f(<x_1,\ldots,x_k>) = \max_{j=1,n}\left(H_j - R_j * \sqrt{\sum_{i=1}^{k}(x_i - C_{j,i})^2}\right)$$

- Why this generator?
  - it can generate test functions over a wide range of surface complexity and problem dynamics. This enables us to evaluate our model in a more flexible and systematic way.



- Cones world problem.
- **P2: Where the function is find the minimum of:**
  - f(x) =-12*x-7y+y*y.
  - **Domain Constraints:** 0<=x<=2, 0<=y<=3
  - **Problem Constraints:** y<=-2(x*x*x*x*x)+2

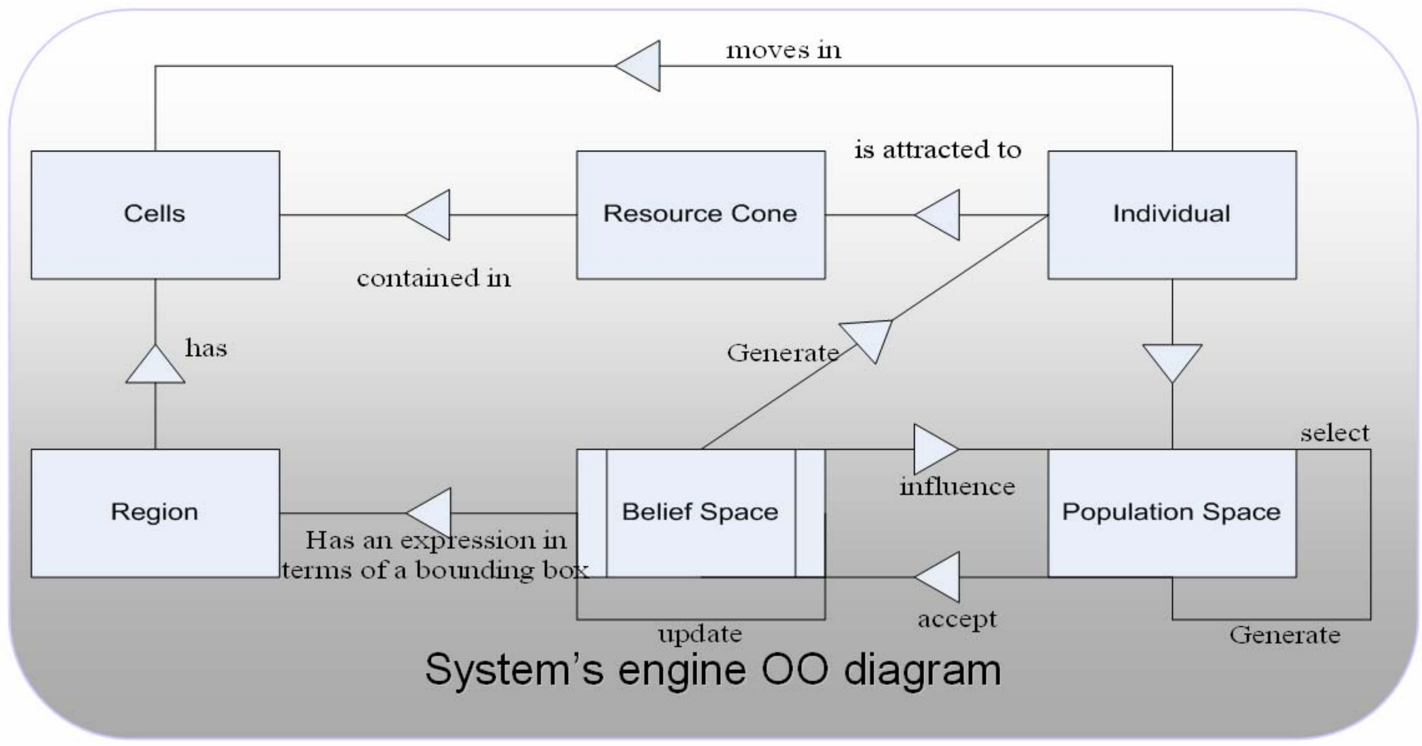
- **P3: The "Design of a pressure vessel“**

  - f(X)=0.6224*x1*x3*x4+1.7781*x2*pow(x3, 2)+3.1661*pow(x1, 2)*x4+19.84*pow(x1, 2)*x3
  - **Domain Constraints:** 1<=x1<=99 (integer), 1<=x2<=99 (integer), 10.0<=x3<=200.0, 10.0<=x4<=200.0.
  - **Problem Constraints:**
    - g1(X) =-x1+0.0193*x3<=0
    - g2(X) =-x2+0.00954*x3<=0
    - g3(X) =-PI*pow(x3, 2)*x4-4/3*PI*pow(x3, 3)+1296000<=0
    - g4(X) =x4-240<=0.

- **P4:** **Welded Beam Design. Find the minimum of the function:**
  - f(X)=1.10471*pow(x1, 2)*x2+0.04811*x3*x4*(14.0+x2)
  - **Domain Constraints:** 0.1<=x1<=2.0, 0.1<=x2<=10.0, 0.1<=x3<=10.0, 0.1<=x4<=2.0

- **P5:** **The "Minimization of the weight of a tension/compression spring“.**
  - **Find the minimum of:** f(X)=(N+2)*D*pow(d,2)
  - **Domain Constraints:** 0.05<=d<=2.0, 0.25<=D(CAP)<=1.3, 2.0<=N<=15.0

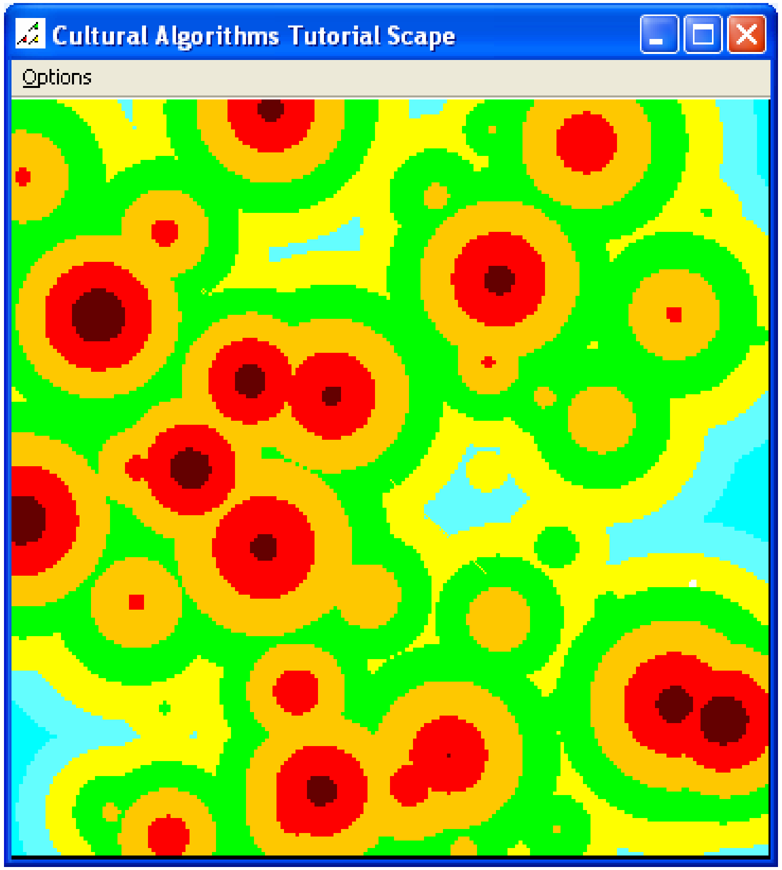
Object Relationship Model for CAT

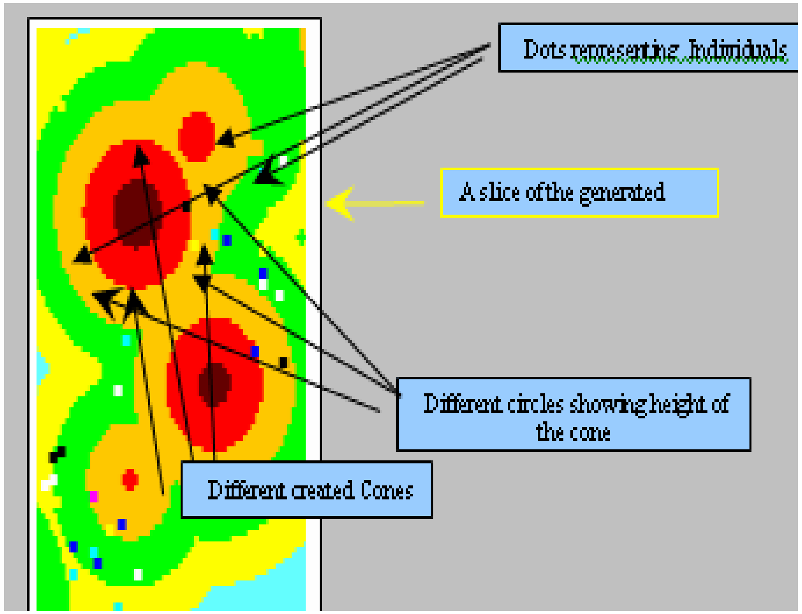


Experimental framework

- A Real-Valued optimization Environment.
- Two dimensional problem landscape.
- The performance function is continuous and its shape is shown by contour lines.
- The patch for a knowledge source is the sub-region of the landscape that it is the most likely to place individuals into.

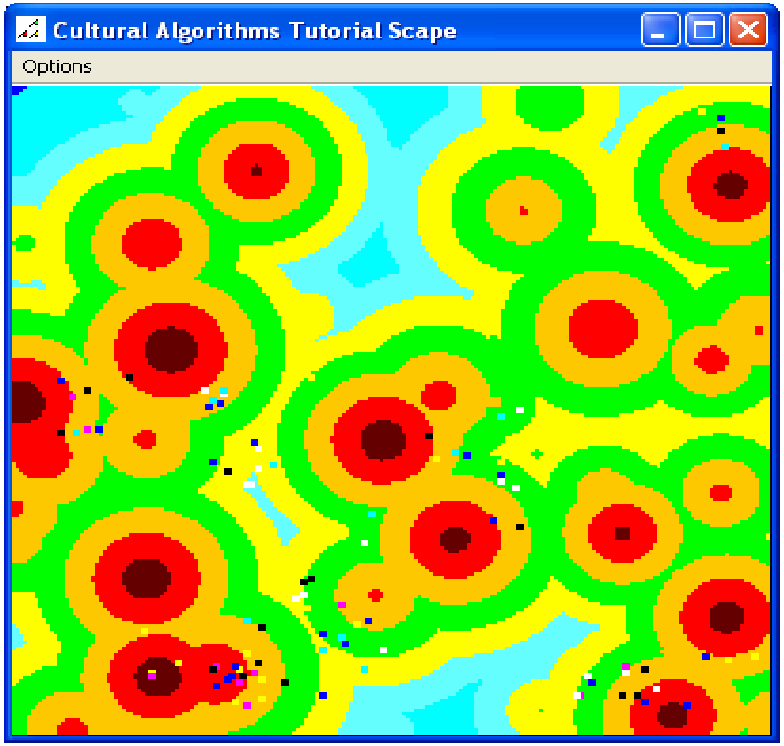
Experimental framework Cont…





- Cones are merged together whenever two cones overlap.
- The height at a point is the height of the cone with the largest value at that point.

- Agents and Landscape Visualization.



- **Individuals are displayed with different colors depending on the knowledge source that they belong to.**

Knowledge Types	Color
Normative	yellow
Situational	black
Domain	gray
History	cyan
Topographical	blue

A Real-Valued optimization Environment

- Two dimensional problem landscape.
- The performance function is continuous and its shape is shown by contour lines.
- The patch for a knowledge source is the sub-region of the landscape that it is the most likely to place individuals into.

- **Objectives:**
  - **Introduce Cultural Algorithm as a computational model.**
  - **Optimize Real-valued Functions.**
  - **Intended to be the basis for an AI tool that introduces Cultural Algorithm as a vehicle for using social intelligence concepts in problem solving process.**

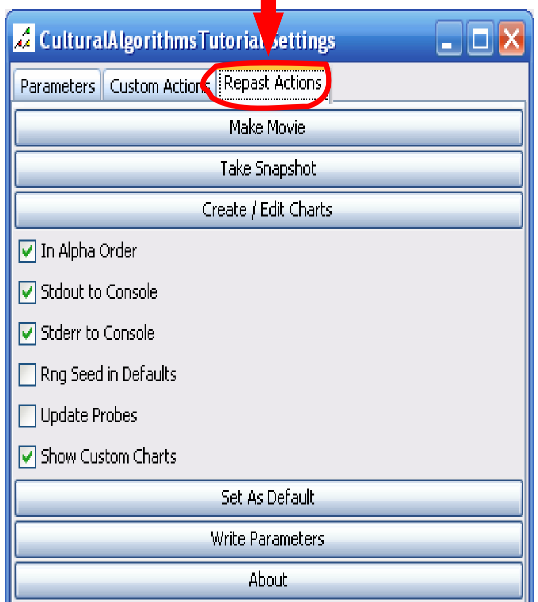
- **CAT is a Java-Based simulator that simulates the Cultural Algorithms on Cones World problem.**
- **CAT was built over the Repast tool.**
- **Installation:**
  - **Double click the icon called *CAT_Tutorial.exe* as in Figure 1.**

- The GUI allows you to start, stop, pause, setup, and exit a simulation through the toolbar.
- The Control Strip:

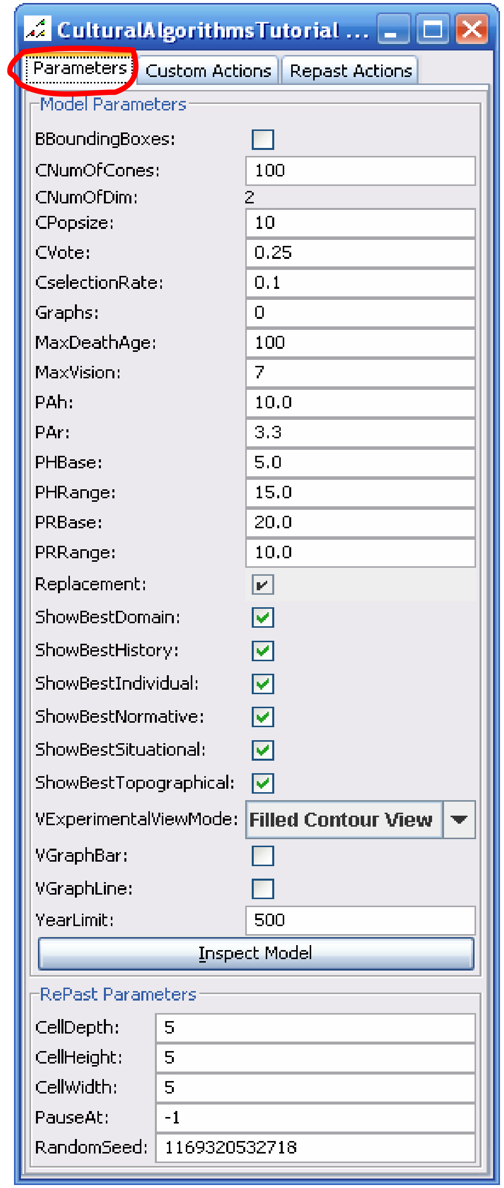
- **How to interact with the Control Strip.**

Button Name	Button symbol	Button's Function
Start Multi-Run		Starts a batch run of a simulation
Start		Starts the simulation when it is paused or has not yet been started, and iterates through our scheduled Cultural Algorithms main loop
Step		Starts the simulation when it is paused or has not yet been started, iterates only through a single iteration.
Initialize		Executes only the initialize code. Starts the simulation but pauses before iterating any scheduled behavior.
Stop		Stops the simulation
Pause		Pauses the simulation.
Setup		Executes the CA setup code to "Setup" the whole system.
Load Model		Pops up a dialog allowing the user to specify a model to load
View Settings		Displays the various model settings panel if it is hidden or destroyed
Exit		Terminates the simulation and exit the whole system.

- The settings window:



Actions Tab



Parameters Tab

Parameters

- Belief space parameters start with "B".
- Cultural Algorithm parameters start with "C".
- Visualization parameters start with "V".
- Parameters specific to the problem start with "P“.
- Otherwise means general parameters for manipulating display or the overall system's run.

- ***Belief Space Parameters:***
  - ***BBoundingBoxes***
- ***Cultural Algorithms parameters:***
  - ***CVote**: the percent of individuals to be accepted in the belief space for updating knowledge source. It takes double values. The default value is chosen to be 0.25.*
  - ***CNumOfCones**: number of cones. Maximum is chosen to be 100.*
  - ***CNumOfDim**: Problem dimension, i.e. number of parameters for the problem to be optimized. This is fixed to 2 for visualization purposes. This value must be the same as the dimensionality of the individual. This value has a maximum of 32 for the CA simulator.*
  - ***CPopSize**: number of individuals to be thrown in the landscape.*
  - ***CSelctionRate**: the portion of individuals to be moved into the new generation. Double values are used.*

- **Cones world specific parameters (problem specific):**
  - ***PAh***: **the value for peak height dynamics.**
  - ***PAr***: **the value for cone slope dynamics.**
  - ***PHBase***: **lower bound for cone height, default is 5.0. Double Precision values are used.**
  - ***PHRange***: **range of cone height starting from PHBase. The default is 15.0. Double Precision values are used.**
  - ***PRBase***: **lower bound for cone radius. The default is 20.0. Double Precision values are used.**
  - ***PRRange***: **range of cone radius starting from PRBase. Default is 10.0. Double Precision values are used.**

- **Visualization parameters:**

  - ***VGraphLine*: Show the sequence of the best individual in each Knowledge Source in addition to the average fitness of all individuals, on a line graph.**
  - ***VGraphBar*: Show the real-time fitness distribution as a bar graph.**
  - ***VShowBestDomain*: Add the sequence of "the best Domain Knowledge individual" at each clock tick to the line graph.**
  - ***VshowBestHistory*: Add the sequence of "the best History Knowledge individual" at each clock tick to the line graph.**
  - ***VshowBestIndividual*: Add the sequence of "the best individual" at each clock tick to the line graph.**

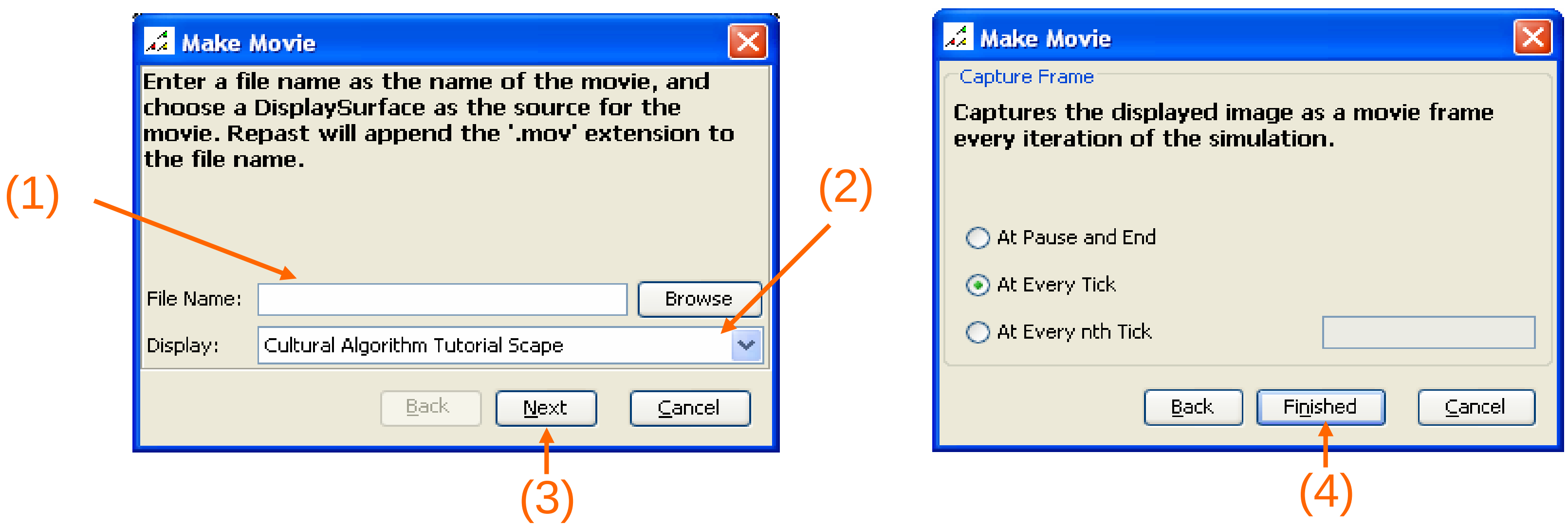
- ***VshowBestNormative*: Add the sequence of "the best Normative Knowledge individual" at each clock tick to the line graph.**
- ***VshowBestSituational*: Add the sequence of "the best Situational individual" at each clock tick to the line graph.**
- ***VshowBestTopographical*: Add the sequence of "the best Topographical individual" at each clock tick to the line graph.**
- ***VExperimentalViewMode*: Two different modes for visualizing the landscape. The first one is the filled contour view (solid circles). The second one is the line contour view, with just colored circles to view the different cones on the landscape.**

- **General parameters:**
  - ***YearLimit*: Number of years to run the CA simulator for.**

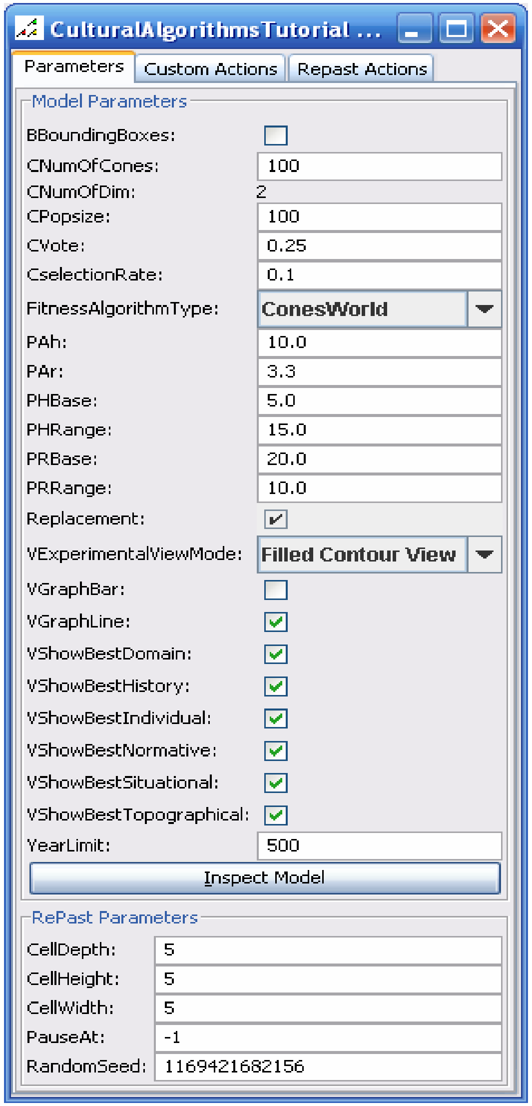
Make a Movie

- Repast Actions Folder : Creating a movie
- From Repast Actions folder (In the settings window), select Make Movie. It shows the following dialog box (left side). Fill in the file name and the directory (1), and choose what kind of movie to display. In this case I choose "CA_Tutorial" simulation (2). Other possible choices are "Histogram" and "Plot" . Click the Next button (3).

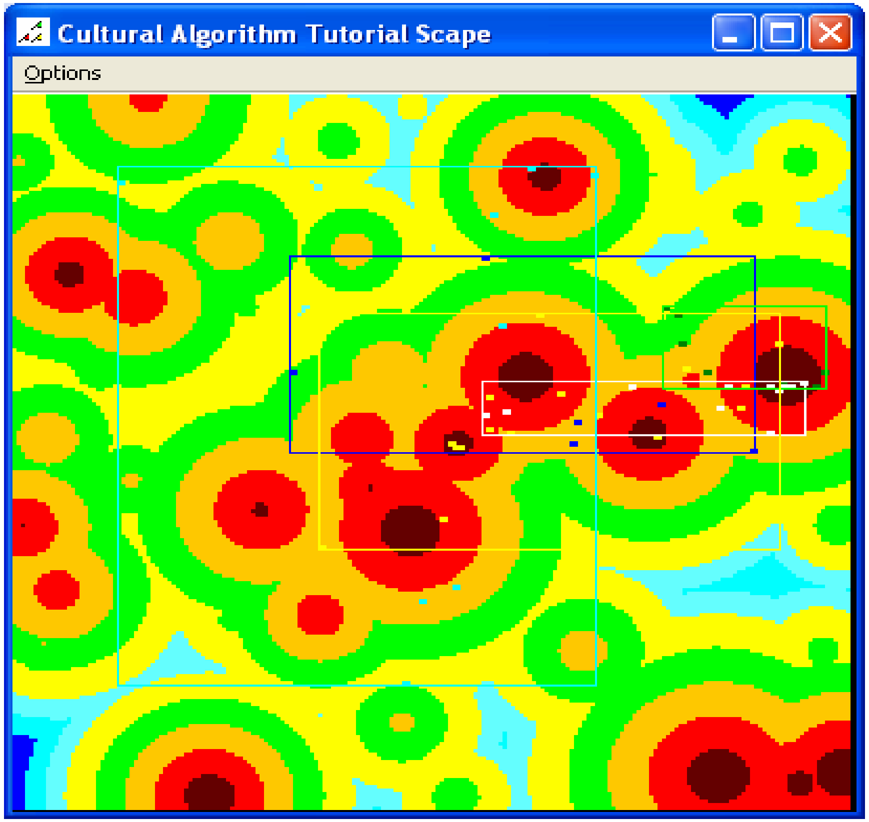
- The next dialog box (right side) will ask when and how the movie is recorded. Click the Finished button (4) after choosing the way movie being recorded .



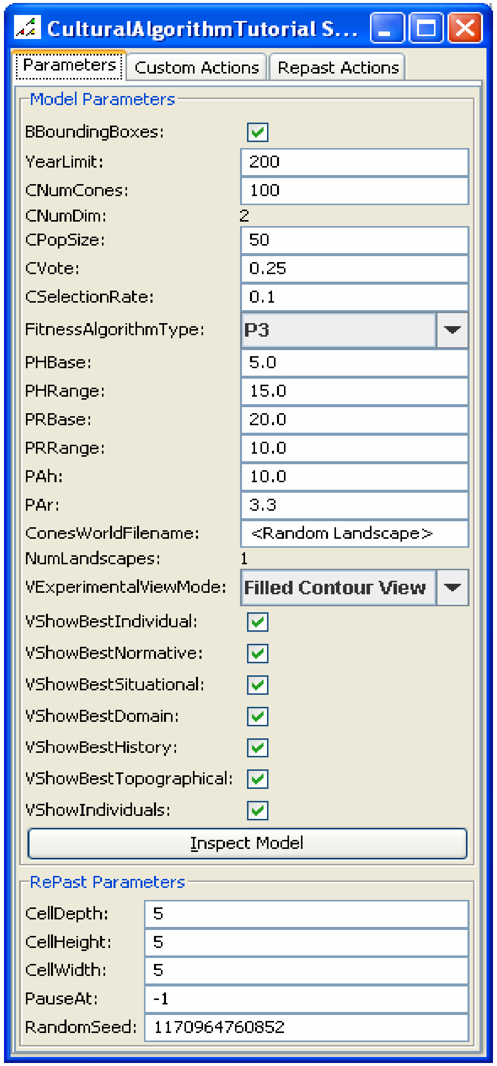
Example Runs



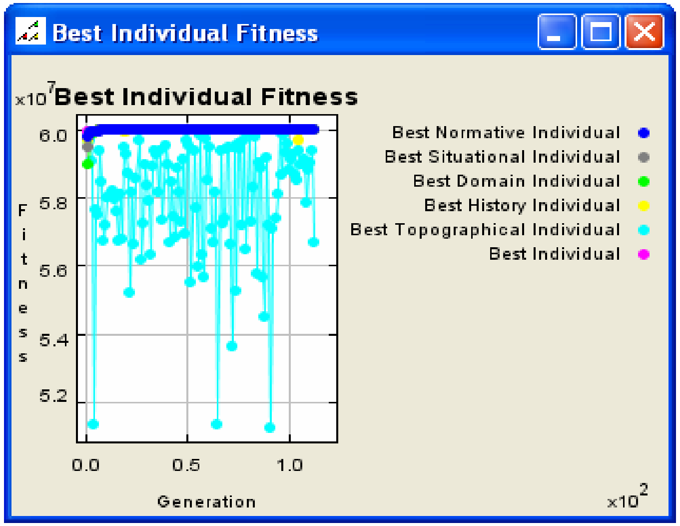
- Testing the Cones World Problem.
- P3 Engineering Problem.



- The *setup()* function returns the model to the initial condition.



- Testing the Cones World Problem.
- **P3 Engineering Problem.**



Questions

- Questions?
- Demo