

# Modeling With FABLES

The Functional Agent-Based Language for Simulations

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# Overview

- Context
  - The Multi-Agent Modeling Suite
- FABLES
  - Motivation
  - General Walk-Through
  - Demo
- Outlook



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## ***Participatory Extension (PET)\****

- *WWW Interface*
- *Simulation Recoding & Playback*
- *Participatory / Experimental Modeling*
  - *Multiple Users / Participants*

## **Model Exploration Module (MEME)**

- **Incremental Results Maintenance**
  - **Versioning**
  - **Result Filtering, Variable Selection, Aggregation & Transformation**
- **Statistics & Scripting**
  - **Charting Wizard**
- *Advanced Experiment Design\**
  - *Distributed Experiment Execution\**

## **Charting Package**

- 15+ chart types
- Dynamic / Static charts
- Interactive charts
- Data filtering
- Exports

### **Simulation Core**

*Multi-Agent  
Core (MAC)\**

Repast

- **Directly Editable Java Source**

## **Functional Agent-Based Language for Simulations (FABLES)**

- **Agents, Formulas and Schedules**
- **Charting and Visualization Wizard (No programming necessary!)**
  - **Integrated Modeling Environment**
- **Generates Java Source (cf. Simulation Core)**
  - *Optimized Java Code Generation\**

# Motivation

- Support for modelers, not professional programmers.
  - Save as much on programming as possible.
  - Appropriate language concepts/paradigms for each large part/component of the model.



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# Advanced Programmers are also Supported

- FABLES compiles to Repast
  - And generates Java source
  - Enables further development by advanced users .
  
- FABLES provides
  - Java-to-FABLES and
  - FABLES-to-Java interfaces.
  - Thus, advanced methods can be written in Java.



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# Language Constructs and Paradigms in Support of the Modeler

- Separation of
  - the Model and the Observer
- Structure:
  - Constants, Variables, Objects/Agents
- Behavior:
  - A functional language
- Dynamics:
  - Discrete time, event-driven scheduler.



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# Separation of the Model and the Observer I.

- The FABLES code describes the *model*.
  - It's a 'black box' on its own (albeit, we do have *print statements*).



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# Separation of the Model and the Observer II.

- Interactive *wizard* to add the visualizations
  - Advanced charting options (15++ graphs and displays)
  - Support for basic statistics operations.
  - Without programming.
- Advanced users may use small scripts as well.



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# Separation of the Model and the Observer II.

- Interactive *wizard* to define mass-experiments (i.e., ‘batch running’).
  - Parameter-combinations to explore.
  - Stopping conditions.
  - Variables to record.
  - Support for basic statistics operations.
  - Without programming.
- Advanced users may use small scripts as well.



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# Demo



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Navi...

- Schelling
  - Charts
    - Schelling.xi
  - Documents
  - Import
  - RePast
  - Schelling.fab

```

36 /** Schelling's model of spatial segregation. */
37 model Schelling {
38
39     /** The size of the world (symmetric). */
40     worldSize = 30; // PARAMETER
41
42     /** The level of threshold, when an agent will move away. */
43     threshold = 0.6; // PARAMETER
44
45     /** The number of agents in the world. */
46     agentNum = 895; // PARAMETER
47
48     /** Color 1. */
49     red = 1;
50
51     /** Color 2. */
52     blue = 2;
53
54     /** The world. */
55     world = [0..worldSize-1, 0..worldSize-1] ;
56
57     /** The set of available colors. */
58     colors = {red, blue};
59
60     /** Occupied territories. */
61     occupied = { a.pos : a is Resident };
62
63     /** Empty territories. */
64     empty = setMinus( world, occupied ) ;
65
66     /** Just to normalize x depending on the world's size. */
67     norm(xn) = xn mod worldSize ;
68
69     /** Give back the adjacent squares. */

```

O...

- startUp
- worldSize
- threshold
- agentNum
- red
- blue
- world
- colors
- occupied
- empty
- norm
- neighbourous
- d
- Resident
  - pos
  - color
  - t
  - getX
  - getY
  - neighbors
  - oppNeighbo
  - ratio
  - closestEmpty
- Step

Problems Console

**Schelling - Repast**

Simulation Actions    Advanced Actions    Help

Tick Count: 22.0    Run: 1

---

Model parameters

agentNum: 2300

treshold: 0.6

worldSize: 50

---

Repast parameters

CellDepth: 5

CellHeight: 5

CellWidth: 5

PauseAt: -1

RandomSeed: 1183977452734

---

Grid2D for model Schelling

**Grid2D for model Schelling**  
Schelling's model of spatial segregation

5 10 15 20 25 30 35 40 45 50

---

Console



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# Details



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# Definition of Model Structure

- Constants (  $x = 10;$  )
  - May be declared as *parameters*.
- Variables (  $\text{var } y; y := 2+4;$  )
  - Values can be modified.
- Functions (  $f(x) = 2*x + 1; )$ 
  - Describing relations, formulas or rules.
- Agents/Objects (  $\text{class } A \{ \dots \}$  )

# Definition of Behavior I.

- Functional (declarative) approach.
  - Describe what is true / what is it. Not how!
- Motivation
  - Model descriptions in publications.  
No room to publish algorithms, so most models are described by formulas and quantors.
- Functions describe *always true* relationships.
  - $\text{negate}(x) = \neg x$  ;



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# Definition of Behavior II.

- No real loops
  - But powerful collection handling / generation.  
[ println(i) : i is [1..5] ] ;
  - Syntactic sugar:  
for each i in [1..5] do { println(i) };
- Also recursion.
- **BUT!** Special constructs
  - Variables and assignment operations
  - To describe state information.



# Definition of Dynamics I.

- FABLES is a discrete time, discrete event simulator.
- Time-dynamics is the *imperative part* of ABM models.
- The construct to describe state-transitions is the scheduler.



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# Definition of Dynamics II.

Time	Event
1	Fables statement;
3	Fables statement;
10	Fables statement;
12	Fables statement;
15	Fables statement;
44	Fables statement;



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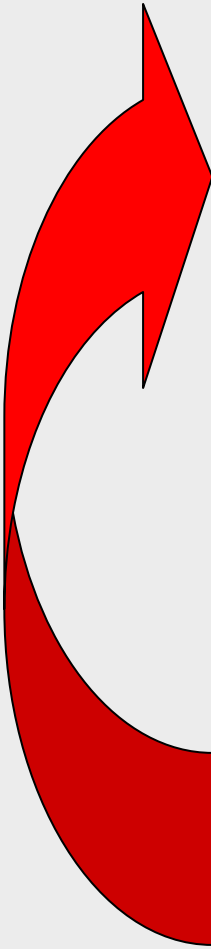
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# Definition of Dynamics III.

Time

Event



1	Fables statement;
3	Fables statement;
10	Fables statement;
12	Fables statement;
15	Fables statement;
44	Fables statement;

Cyclic schedule (optional)



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# Definition of Dynamics IV.

Time	Event
1	Fables statement;
3	Fables statement;
10	Fables statement;
12	Fables statement;
15	Fables statement;
44	Fables statement;

Remove!

Dynamic schedule:

Add!

11

Fables statement;



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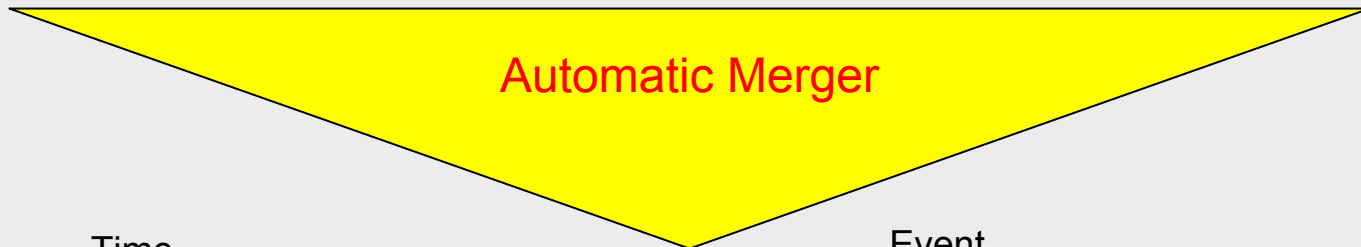


# Definition of Dynamics V.

Time	Event
1	Fables statement;
3	Fables statement;
10	Fables statement;
12	Fables statement;
15	Fables statement;
44	Fables statement;

Time	Event
2	Fables statement;
4	Fables statement;
10	Fables statement;
11	Fables statement;
14	Fables statement;
50	Fables statement;

Time	Event
1	Fables statement;
5	Fables statement;
8	Fables statement;
9	Fables statement;
12	Fables statement;
14	Fables statement;



Time	Event
1	Fables statement; Fables statement;
2	Fables statement;



# Definition of Dynamics VI.

- The model and all agents may have *any number* of schedules.
  - The model's schedules start at time 0.
  - The agents' schedules start at the time of their creation.
    - Times within it are relative to the time of creation.



# Schedule Example

```
class Agent {  
    schedule {  
        5 : println ("Time is now : " ++ time);  
    }  
}  
  
schedule Main {  
    10 : new Agent;  
}
```

→ **Time is now : 15**



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# More details...



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# Collections (sets, lists, etc.)

- Enumerating the elements:
  - $\text{nums} = \{1,2,3,4,5\}; \rightarrow \{1,2,3,4,5\}$
- Creating a subset by a logical condition:
  - $\text{odds} = \{x \text{ is nums when } x \bmod 2 == 0\}; \rightarrow \{2,4\}$
- Making a transformation:
  - $\text{squares} = [x*x : x \text{ is nums}]; \rightarrow [1,4,9,16,25]$
- Combining the two previous:
  - $\text{odd\_squares} = [x*x : x \text{ is nums when } x \bmod 2 == 0]; \rightarrow [4,16]$
- Defining multi dimensional integer intervals:
  - $[2..4, 1..3] \rightarrow [[2,1],[2,2],[2,3],[3,1],[3,2],[3,3],[4,1],[4,2],[4,3]]$



# Default Collections for Agents

- Class names denote the set of its agents.

```
class Agent {  
    var id;  
}
```

```
odd_agents = { a.id mod 2 == 0 : a is Agent };
```



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# Technical Notes



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# Typing

- Fables is a strongly typed language
  - All identifiers (variables, functions, etc.) must have their types identified at compilation time.
- Yet, no type-declaration is required
  - All type information is deduced automatically from the type of constants and usage.



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# Data Structures and Optimization

- FABLES has an advanced optimizer that generates efficient data structures
  - from functional (declarative) description of behavior.
- Currently this is focused around collection handling and generation operations.

\*Subject to further development.

\*\*Generated Java source is available for further optimizations.



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# Additional Features

- Standard Library
  - Pseudo Random Generators
  - Etc.
- IME: Syntax highlighting, outline, etc.
- Document generation



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# Outlook



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# Summary

- Advanced simulation platform (partially anchored in Repast) for
  - Easy model development,
  - Efficient execution,
  - Careful experiment design, and
  - Accurate result analysis.
  
- **FREE OF CHARGE!**
  - Coming in December...



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# THANK YOU!!

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