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Visual Analytics on Multidimensional Big Data

CGIS
Computer Graphics and Interactive Systems

TECHNICAL UNIVERSITY OF CLUJ-NAPOCA

Dorian Gorgan
Computer Science Department
Technical University of Cluj-Napoca
http://users.utcluj.ro/~gorgan
dorian.gorgan@cs.utcluj.ro

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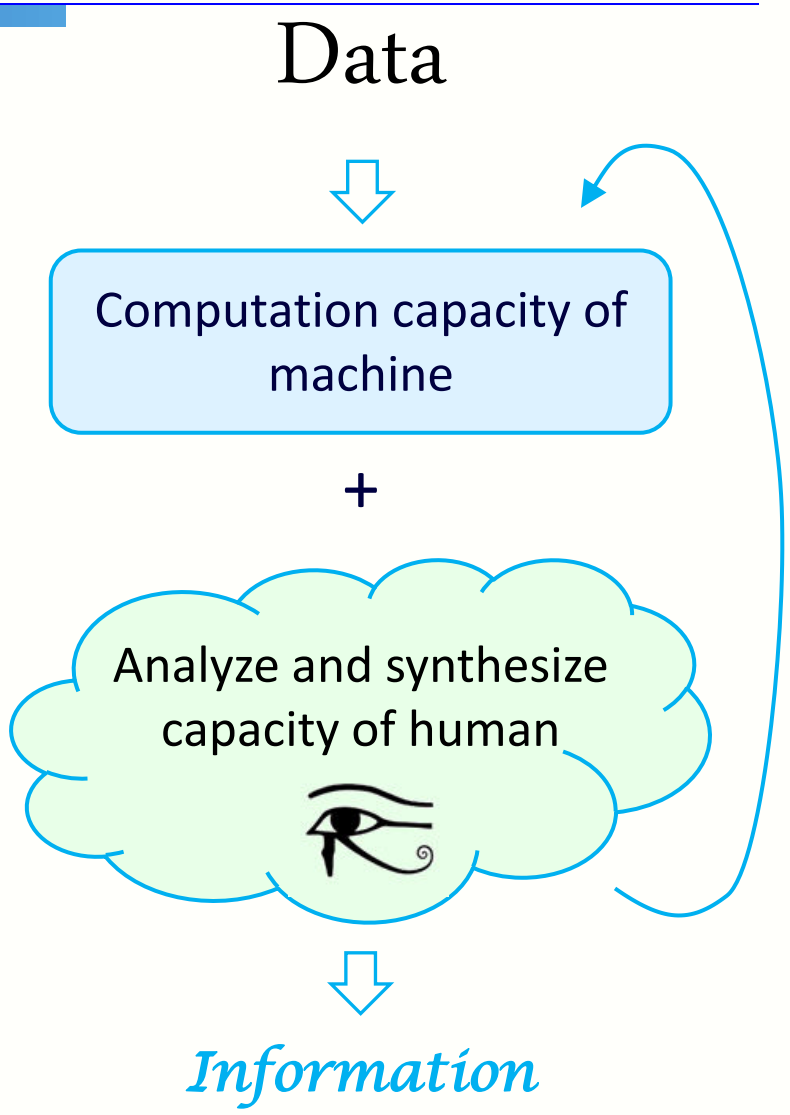
- Big Data
- Data to Information
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- Multidimensional Space
- Computer Game Strategies
- Hydrological SWAT model calibration
- Sociophysics Models
- Publications

Big Data

- Huge data globally available
  - 2012, 2.8×10^{21} Bytes (2.8 ZB) at global level, 10 x 2007
  - 2020, 40 ZB (~14 x 2012)
- 3% marked/annotated, 0.5% analyzed
- Big Data – volume, variety, velocity, variability, veridity
- Earth Observation Data (EO Data)
- High costs of data management
- Increase data value by using instead of just storing
- Data -> knowledge -> information
- High Performance Computation resources + Analytics

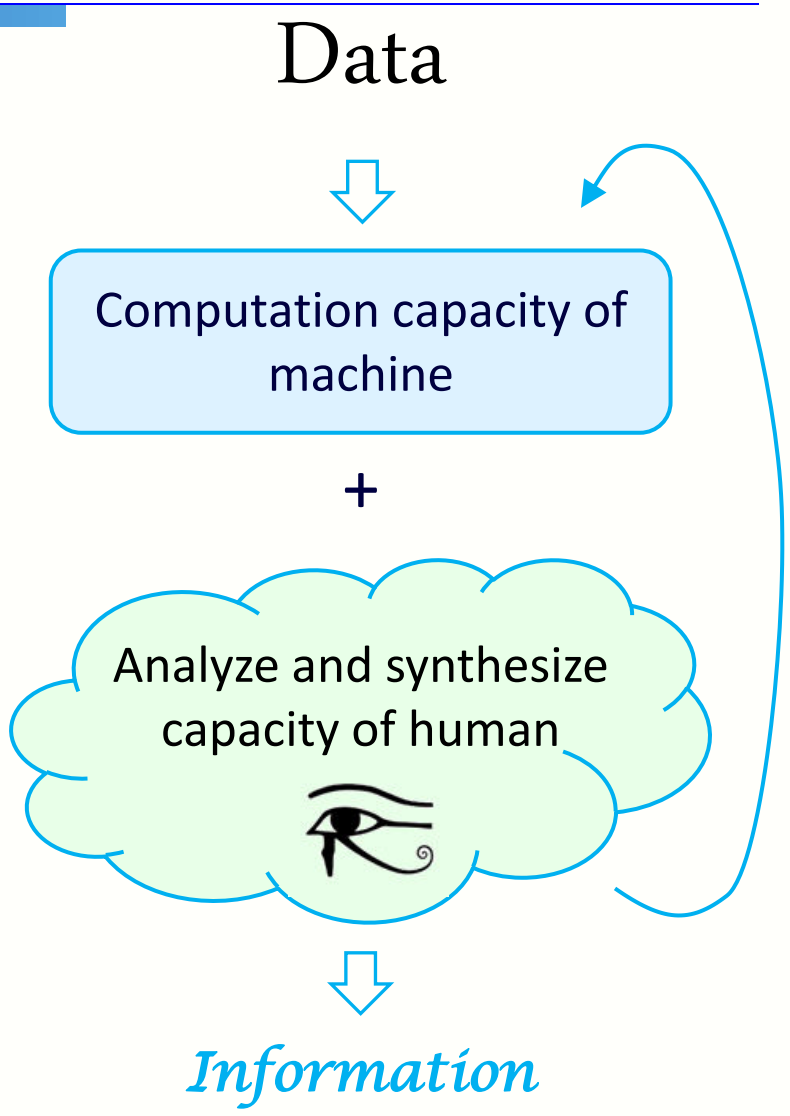
Data to Information

- Just storing data is a trivial, useless and ineffective solution
- How to reduce the data to only those that are useful?
- How to know what is useful?
- What algorithms are able to highlight information?
- How to process and understand raw data?



Data to Information

- Visual channel is the main interface to the human brain
- Visual presentation rather than numerical information
- Dynamically rather than statically



Visual Analytics

- Definition:
  - Visual analytics is the analytical reasoning by user interactive visualization and navigation within value spaces

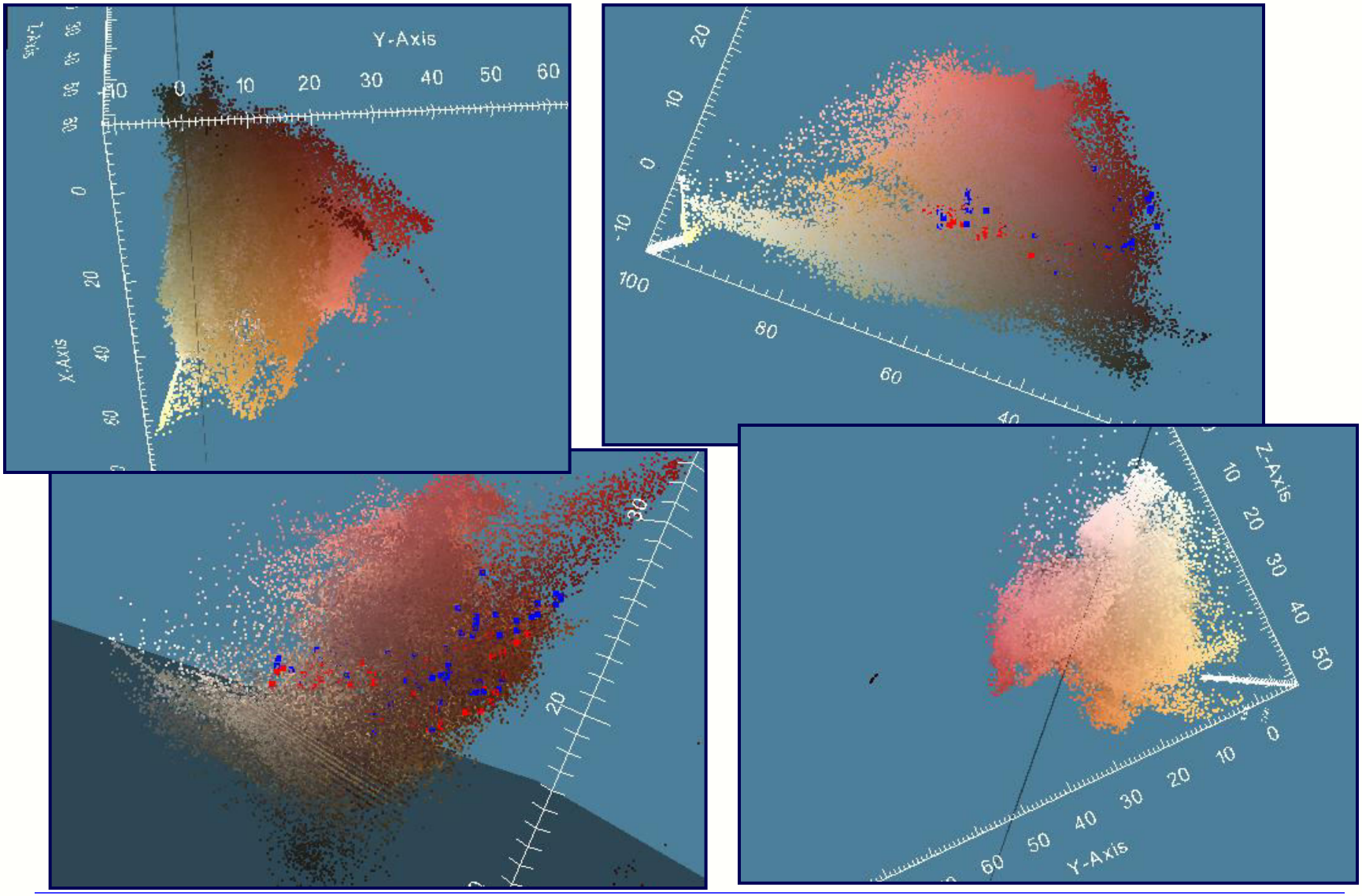
Multidimensional Space

- Model $\mathfrak{M}(\mathfrak{P}, \mathfrak{F}, \mathfrak{S}, \mathfrak{C})$
  - $\mathfrak{P}$ - Basic parameters
    - Coordinate system $(p_1, p_2, \ldots, p_n)$
  - $\mathfrak{F}$ – Functions
    - $f_1(p_1, p_2, \ldots, p_n)$, $g = f_1 \circ f_2$, …
  - $\mathfrak{S}$ – set of model instances (states)
  - $\mathfrak{C}$- set of conditions for transition within S
- Model visualization
  1. Mapping of the model $\mathfrak{M}$ onto k-dimensional space

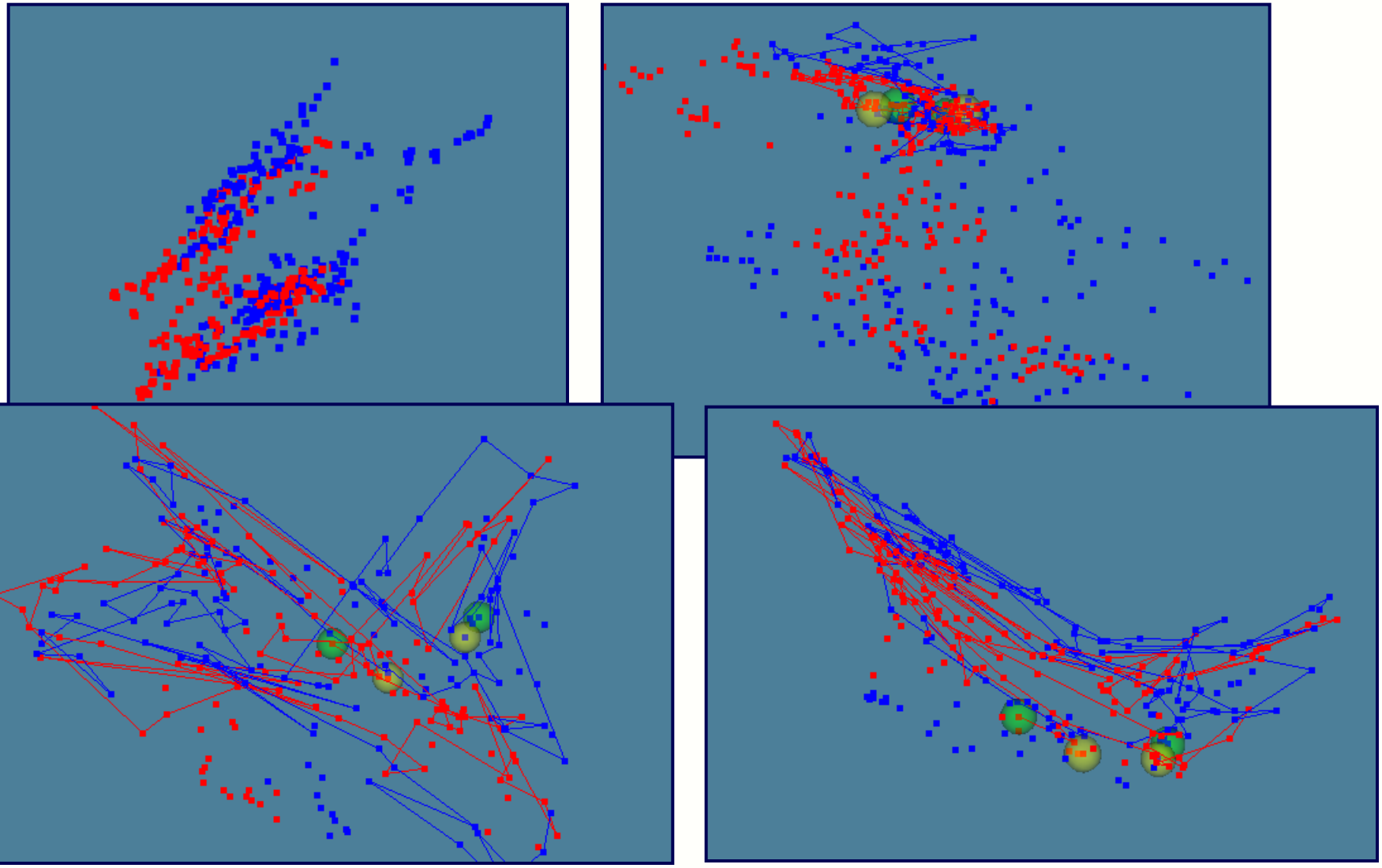
     e.g. k=4, axes: age, weight, happiness, satisfaction
  2. Mapping of the k-dimensional space onto the screen

     e.g. k=4, axes: x(age), y(weight), z(happiness), color(satisfaction)

L*a*b Color Value Space



Navigation in L*a*b Color Value Space



Computer Game Strategies

- Casual Games:
  - little mental involvement
  - high motor skills
  - purpose: entertainment
- Strategy Games:
  - make decisions
  - develop strategy
  - purpose: mental challenge

Problem and Motivation

- Lack of specialized software for analysis of strategies in games
  - Multi-criteria optimization
  - No aid to the player in understanding the game
  - Professional players have to rack up hours of gameplay in order to be successful
- Lack of software tools to help game designers build engaging videogames
  - Research shows importance of game balancing and the ties between user engagement and game difficulty

Solution

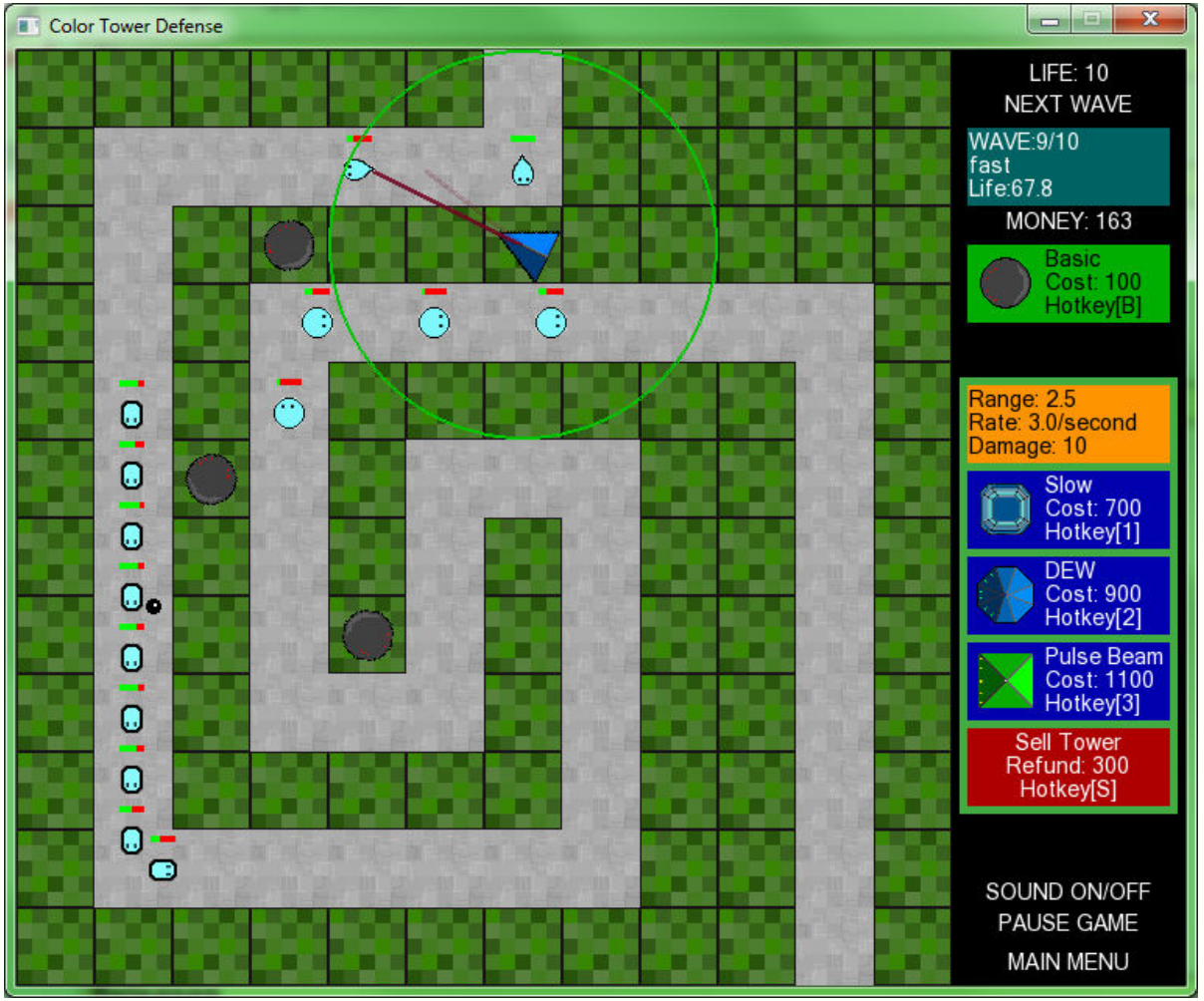
- Computers have great processing power
- Humans have great analytical power and high familiarity with the subject
  - Develop software tools that take advantage of both

How?

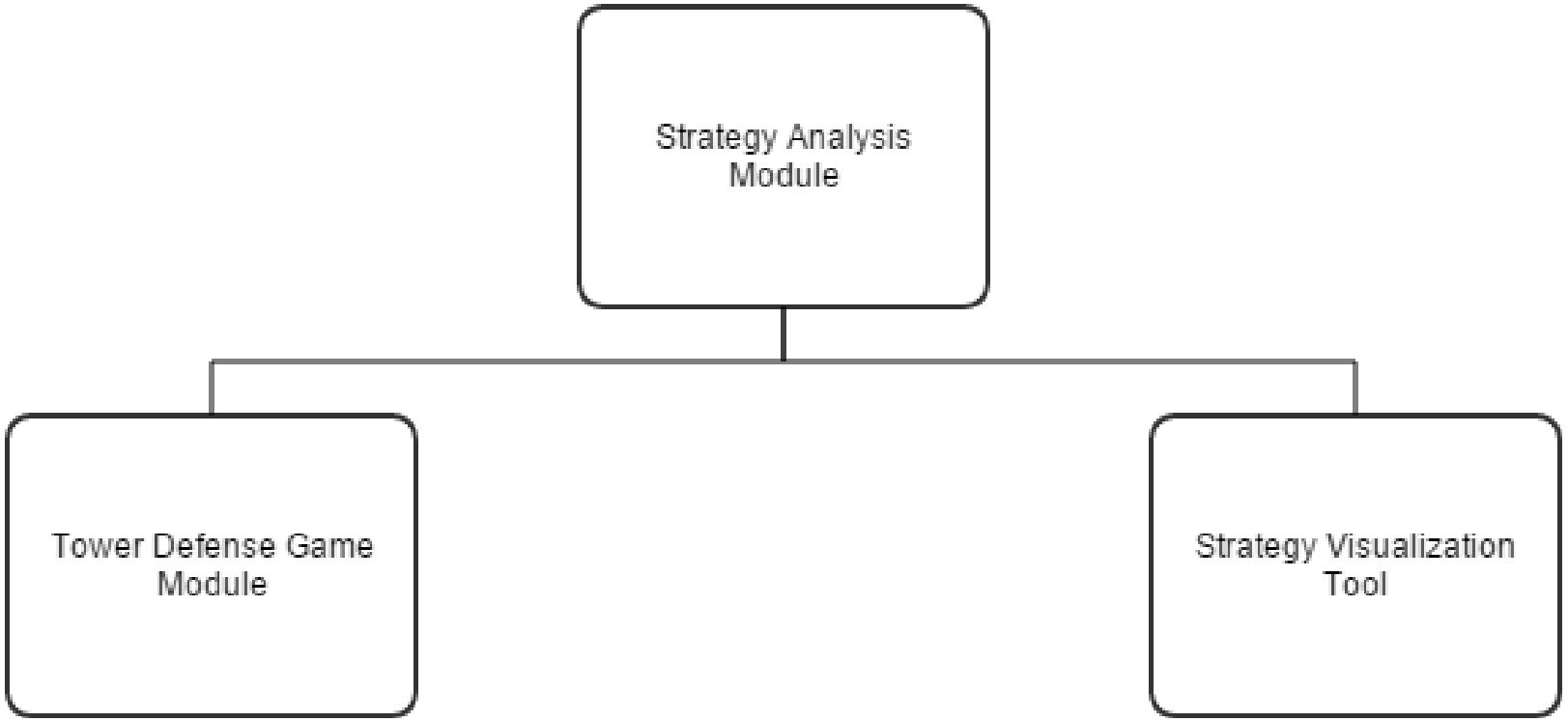
- Games can be modeled as n-dimensional systems
- Computers can analyze a restrained domain of the system
- Humans can analyze through visual representations the results and guide the computer for further searches

Case Study: Tower Defense Game

- Tower Defense:
  - Build turrets
  - Stop computer units
- Strategy:
  - Resource management

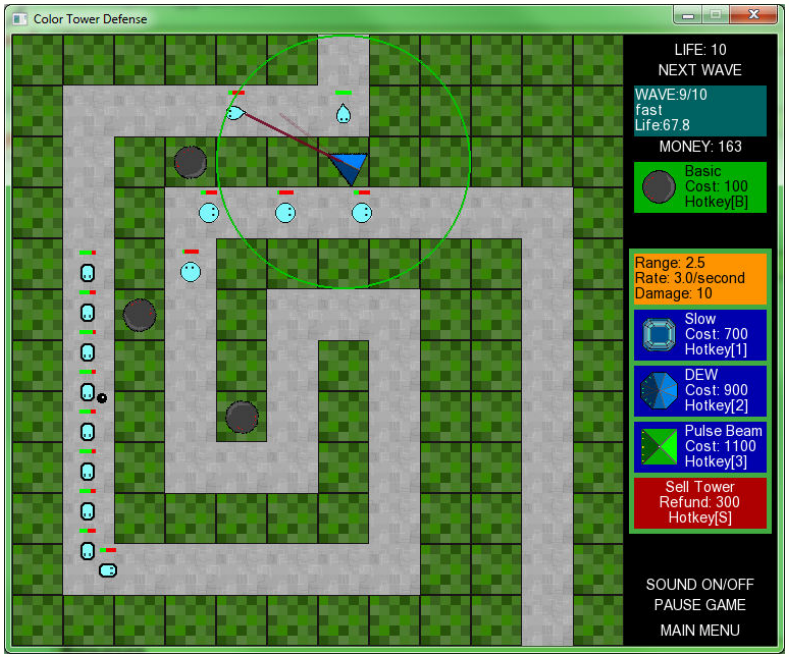


Formal Architecture



Game Breakdown

- Waves of enemies
- Only know information about current wave
- Need to find out all waves before generating strategy



- Basic computation:
  - Local Optimum – quickly find out waves info
  - Global Strategy – combine locals for an overall better solution

Strategy Analysis

Fixed:

Game_World {

Map,

Path

}

Computer_Unit {

Health,

Speed,

Damage

}

Variable:

Turret {

Position,

Range,

Damage,

Speed

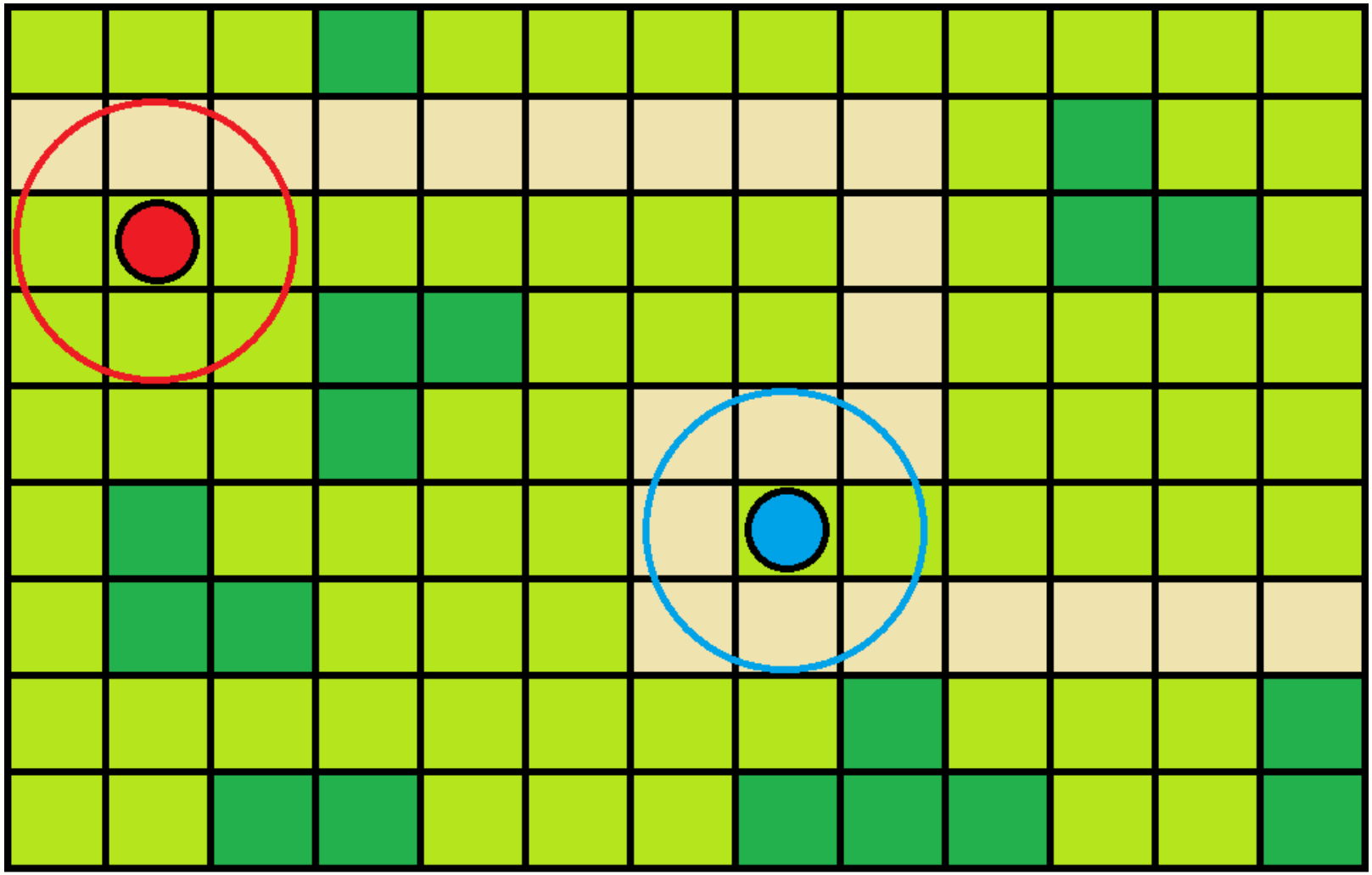
}

Strategy Evaluation

- Metrics:
  - Player health at the end of the game
  - Resources left unspent
  - Difference between total enemy health and total damage given

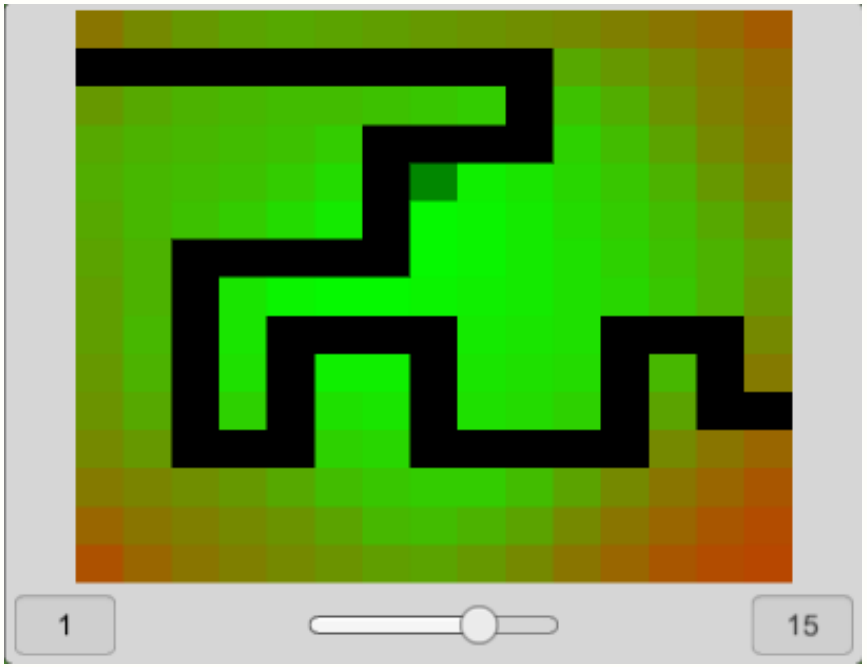
$$Efficiency = 100 \times Player_{health} + 10 \times Budget_{left} + (Total_{damage} - Total_{health})$$

Parameters and Strategy Values

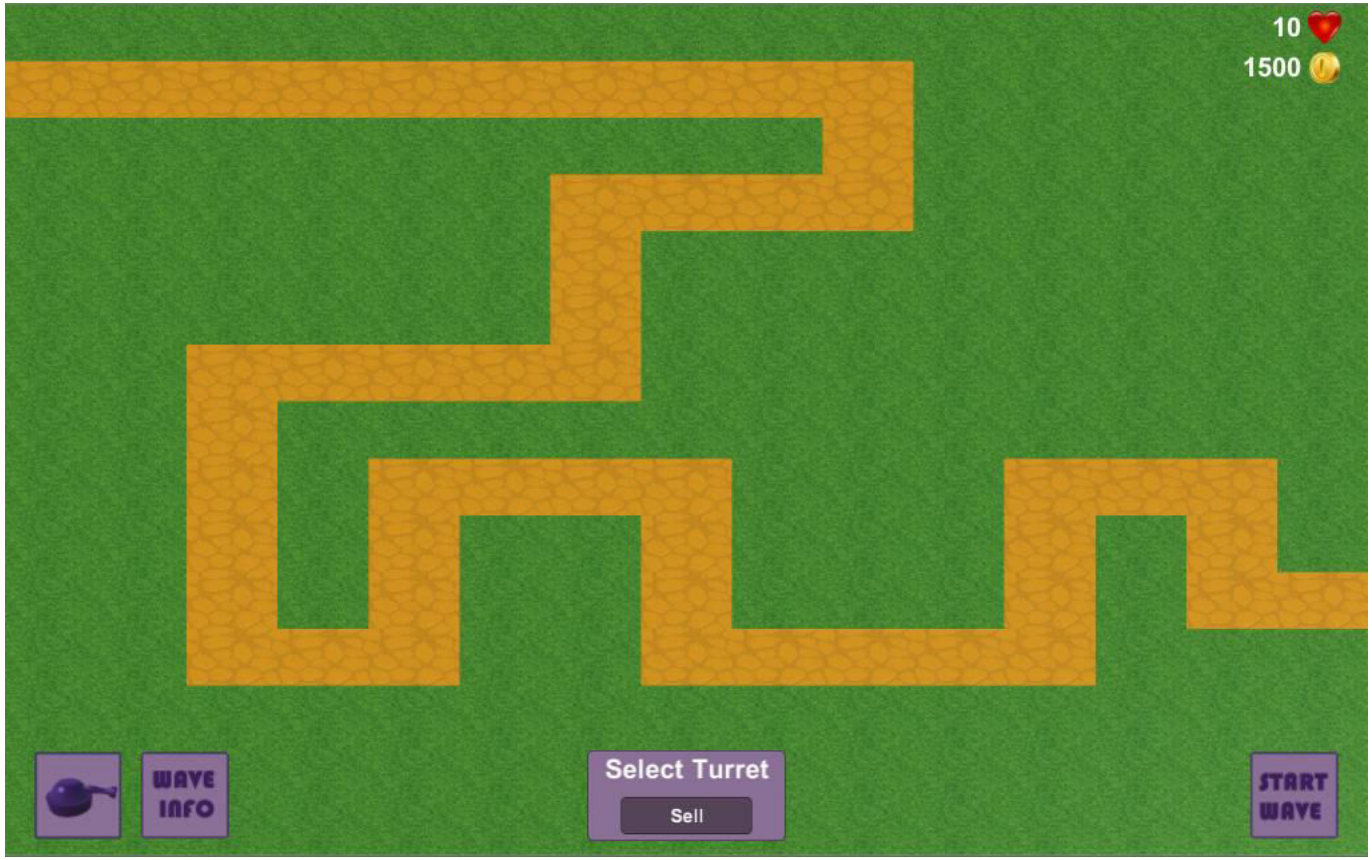


Visualization Technique

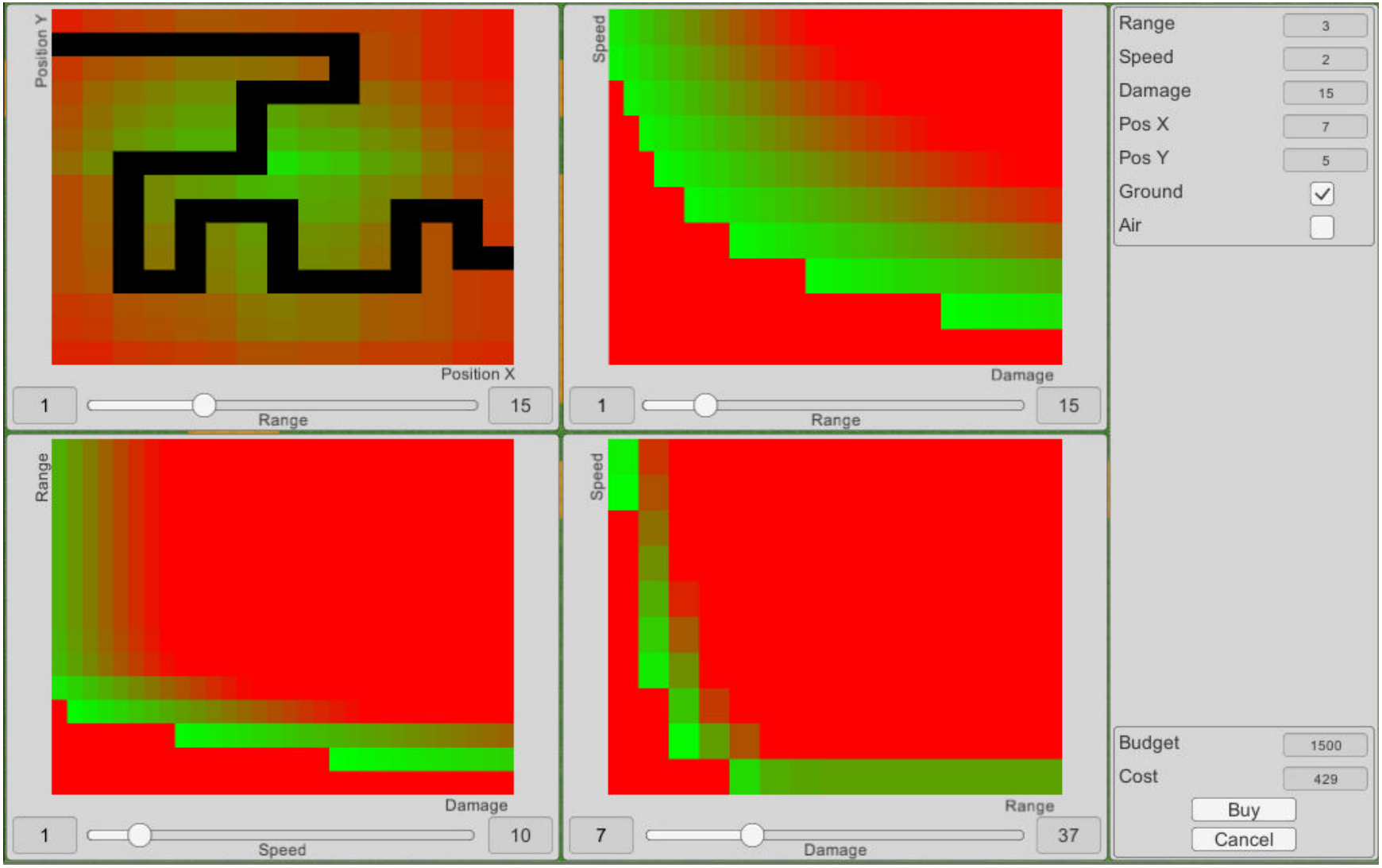
- Represent n-dimensional system as multiple 2D projections
- Coloring scheme:
  - represent strategy analysis
  - through colors
- Projection:
  - 2 axes with sample values
  - 1 slider with varying parameter



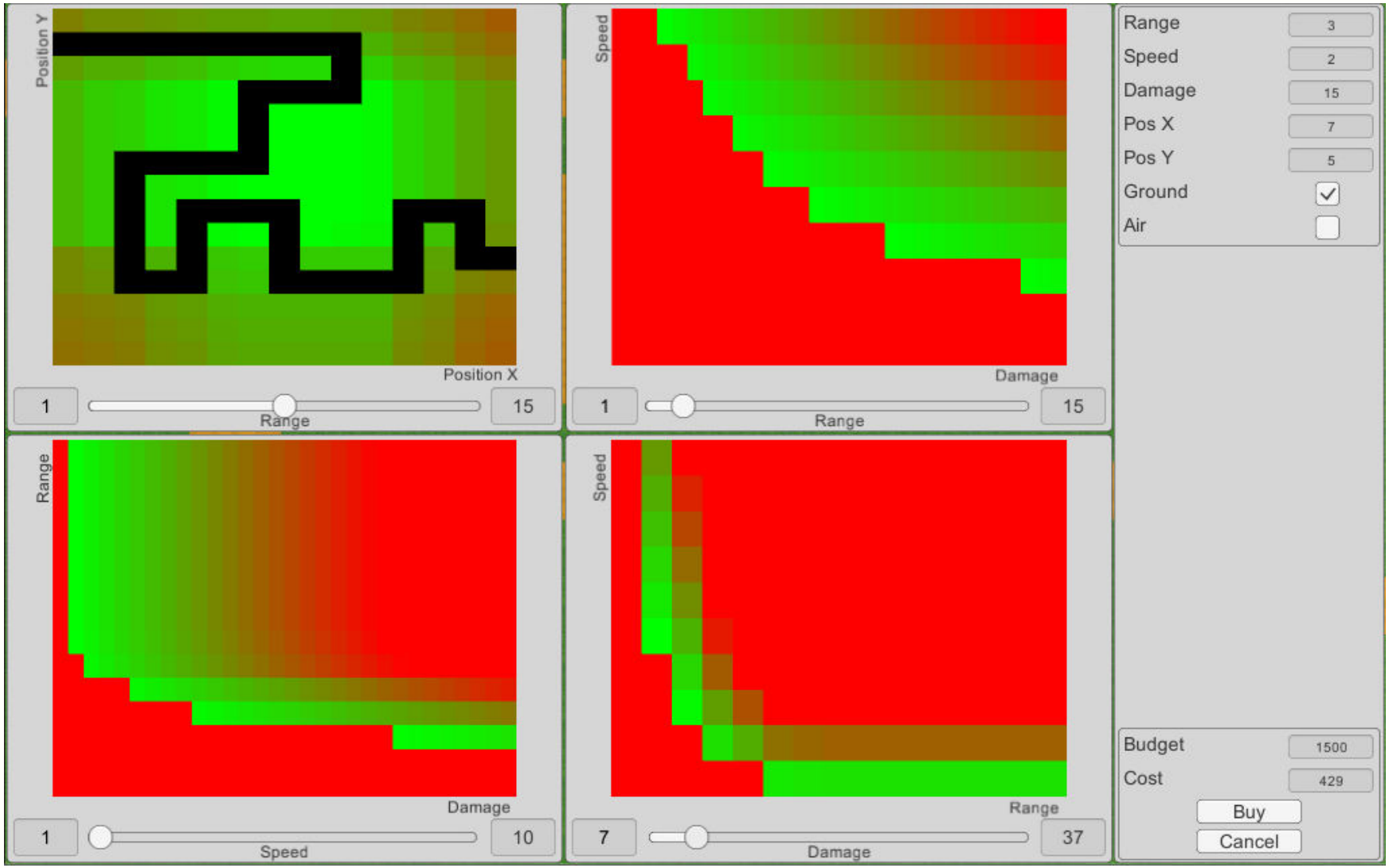
Game World



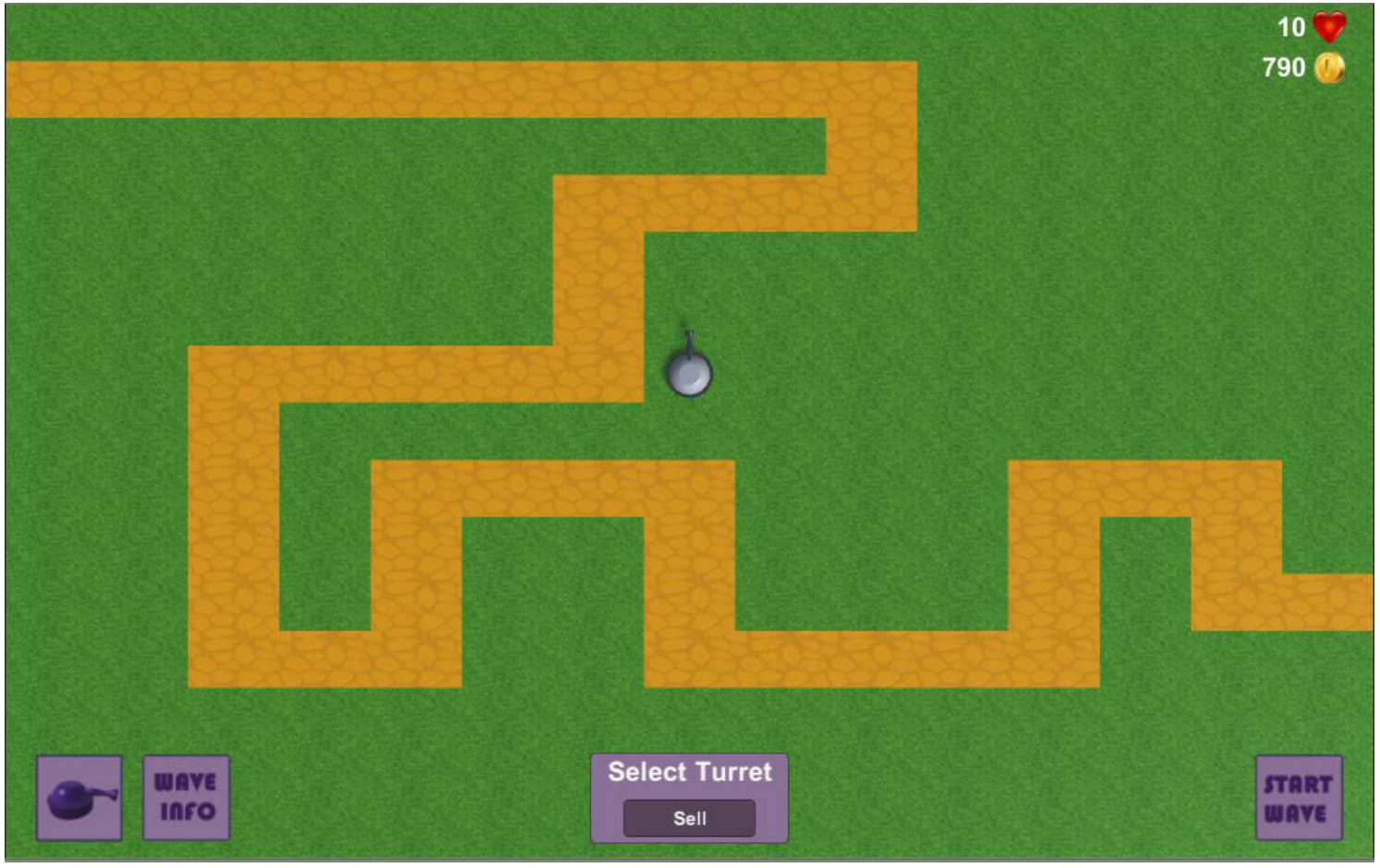
Navigation within Value Space



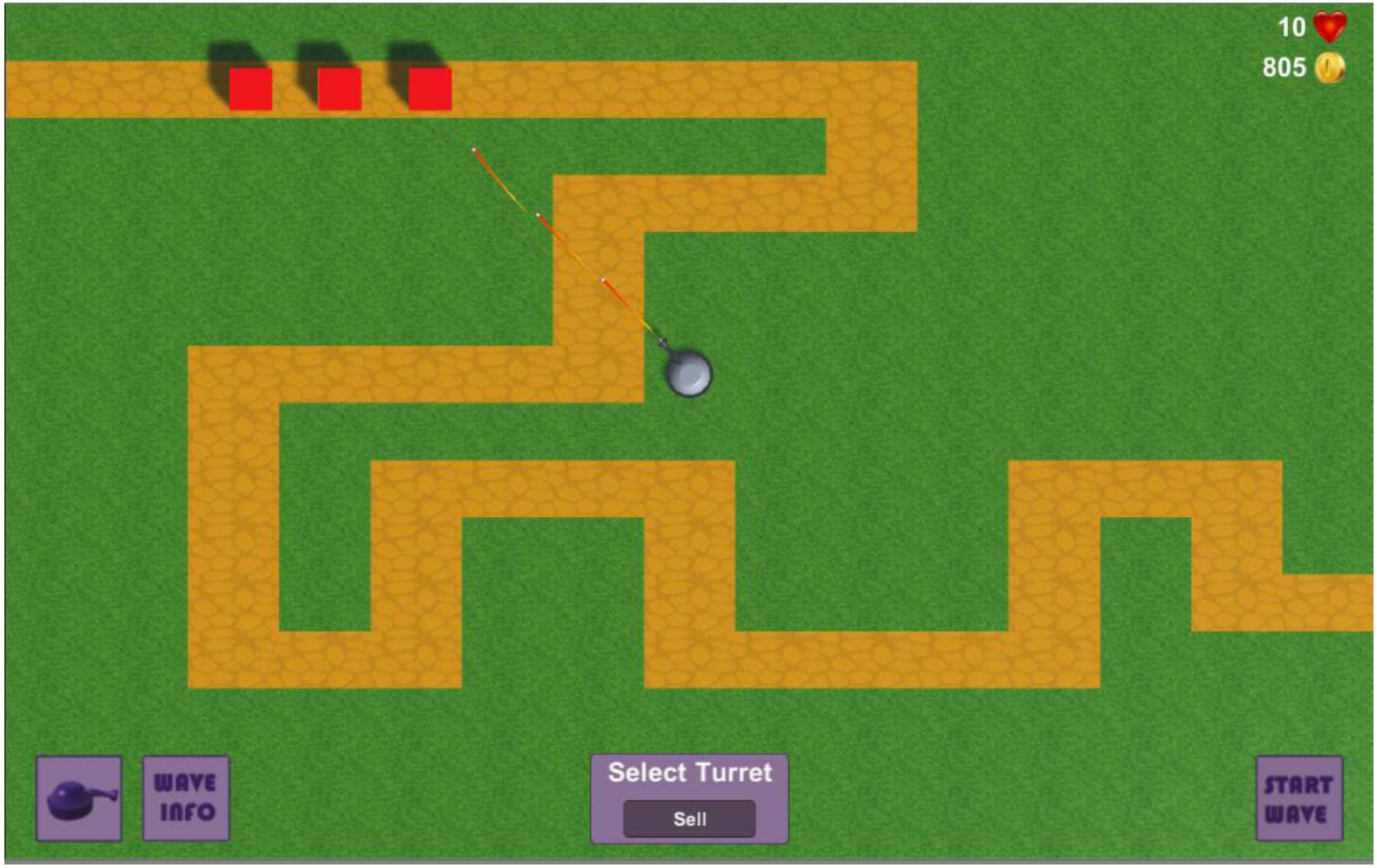
Navigation within Value Space



Game Strategy Tool



Strategy Validation



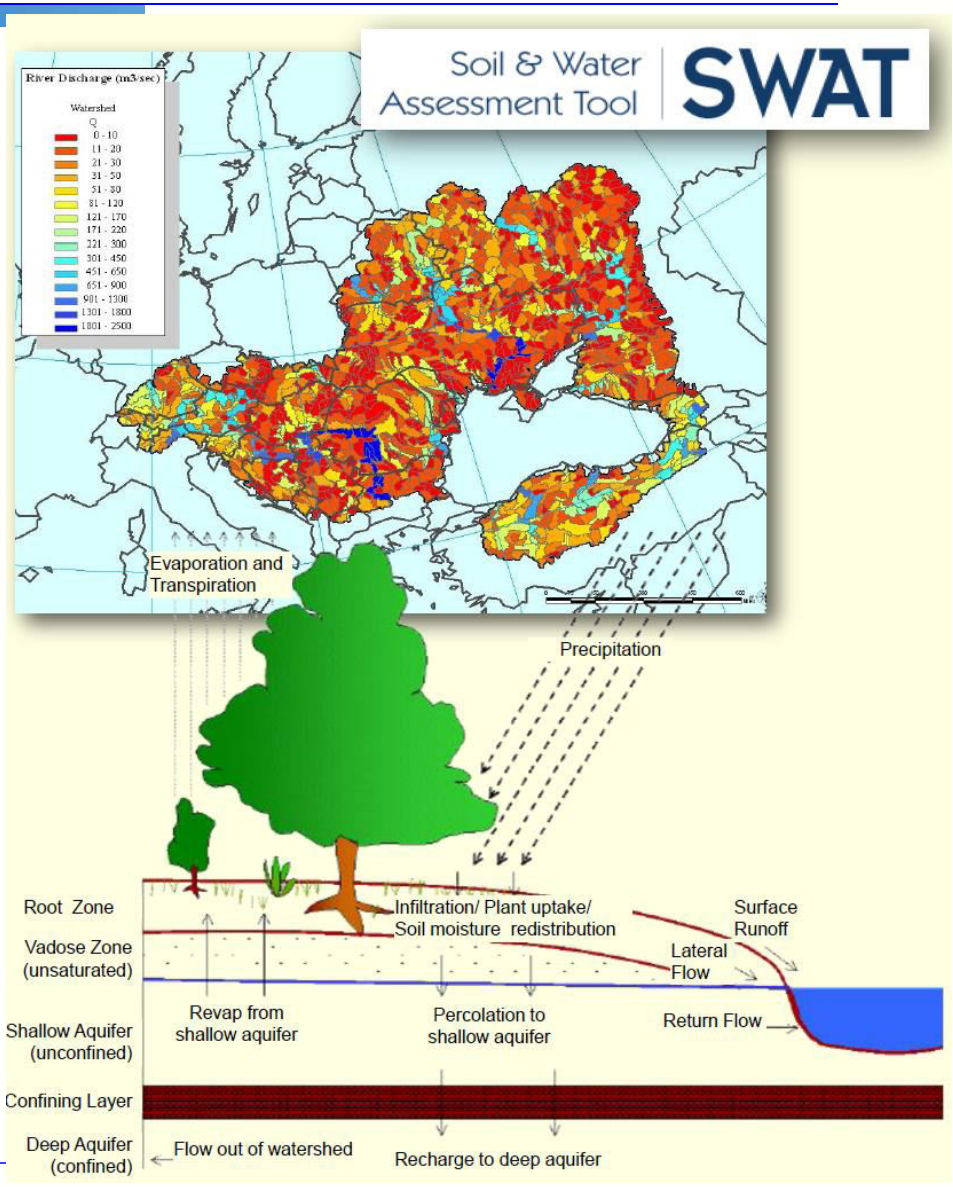
EnviroGRIDS Project

- **enviroGRIDS** - Gridifying the Black Sea catchment to support its sustainable development (http://www.envirogrids.net)
- Founded by the European Commission FP7, 2009-2013, 30 partners, 7.9 mil EUR.
- Coordinator: University of Geneva, Switzerland
- Objectives:
  - Develop a SDI (Spatial Data Infrastructure) targeting the Black Sea catchment region

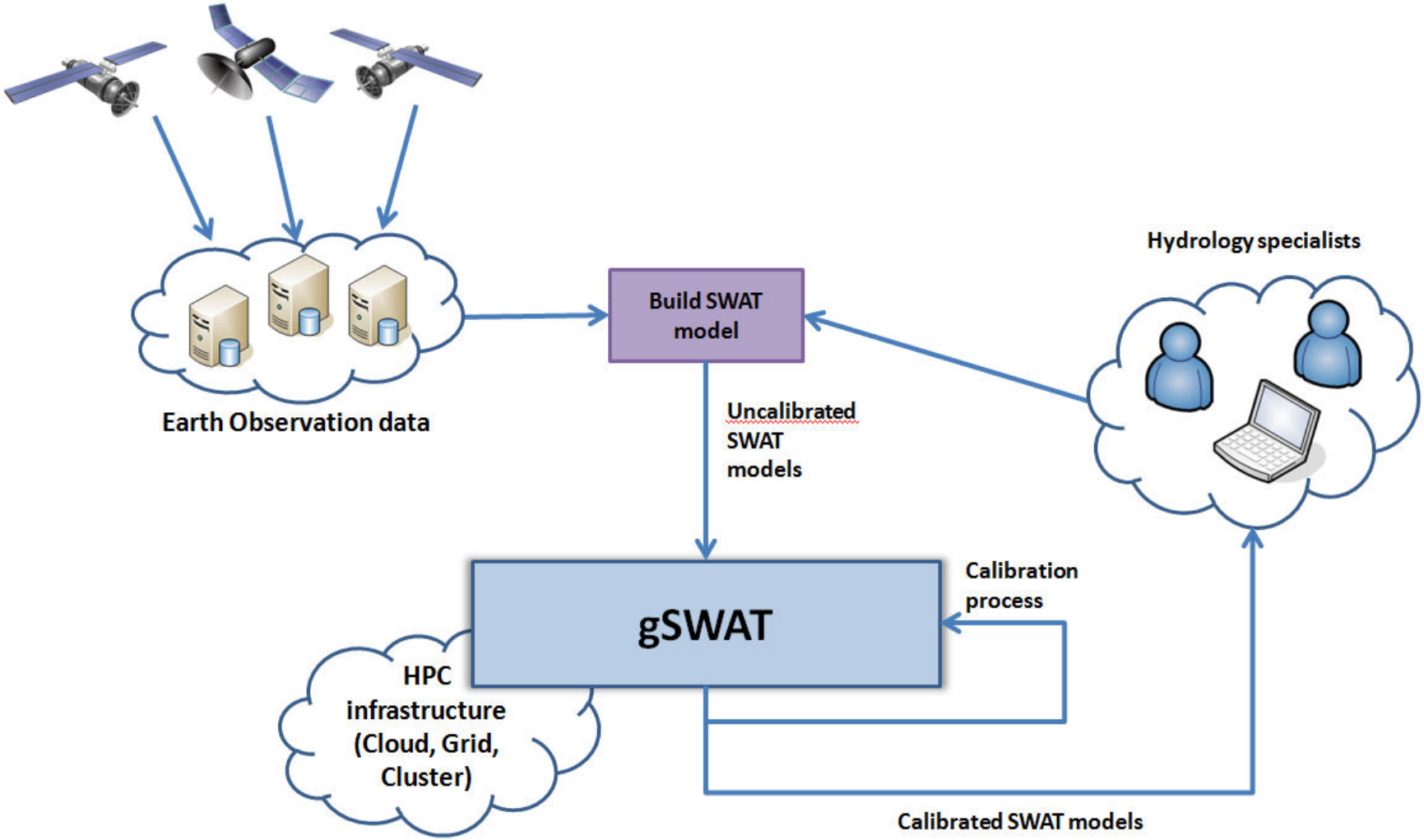
    E.g. hydrological models, satellite images, and maps
  - Perform distributed spatially-explicit simulations of environmental changes

SWAT Model Overview

- SWAT (Soil Water Assessment Tool)
  - hydrological model
  - operates on a daily time step
  - used for predicting the water resources, sediment, and chemical yields in a specific watershed
- *Input data*: weather, soil properties, topography, vegetation, and land management practices of the watershed
- SWAT estimates the impact of land management practices on water quantity and quality in complex watersheds

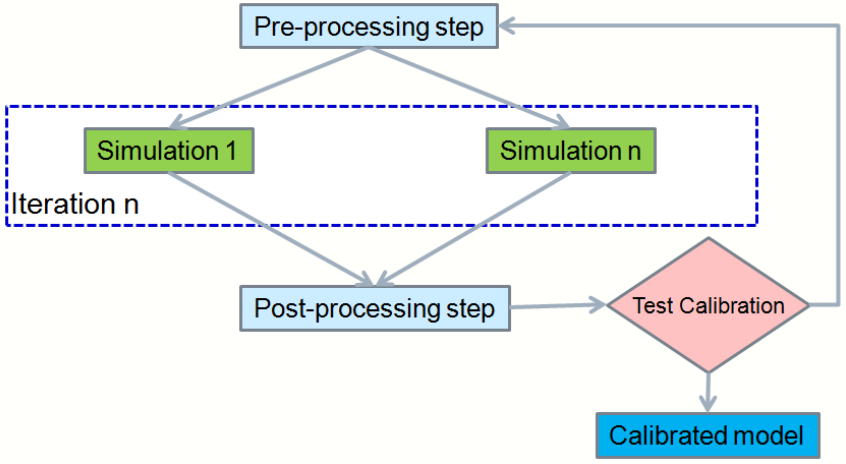


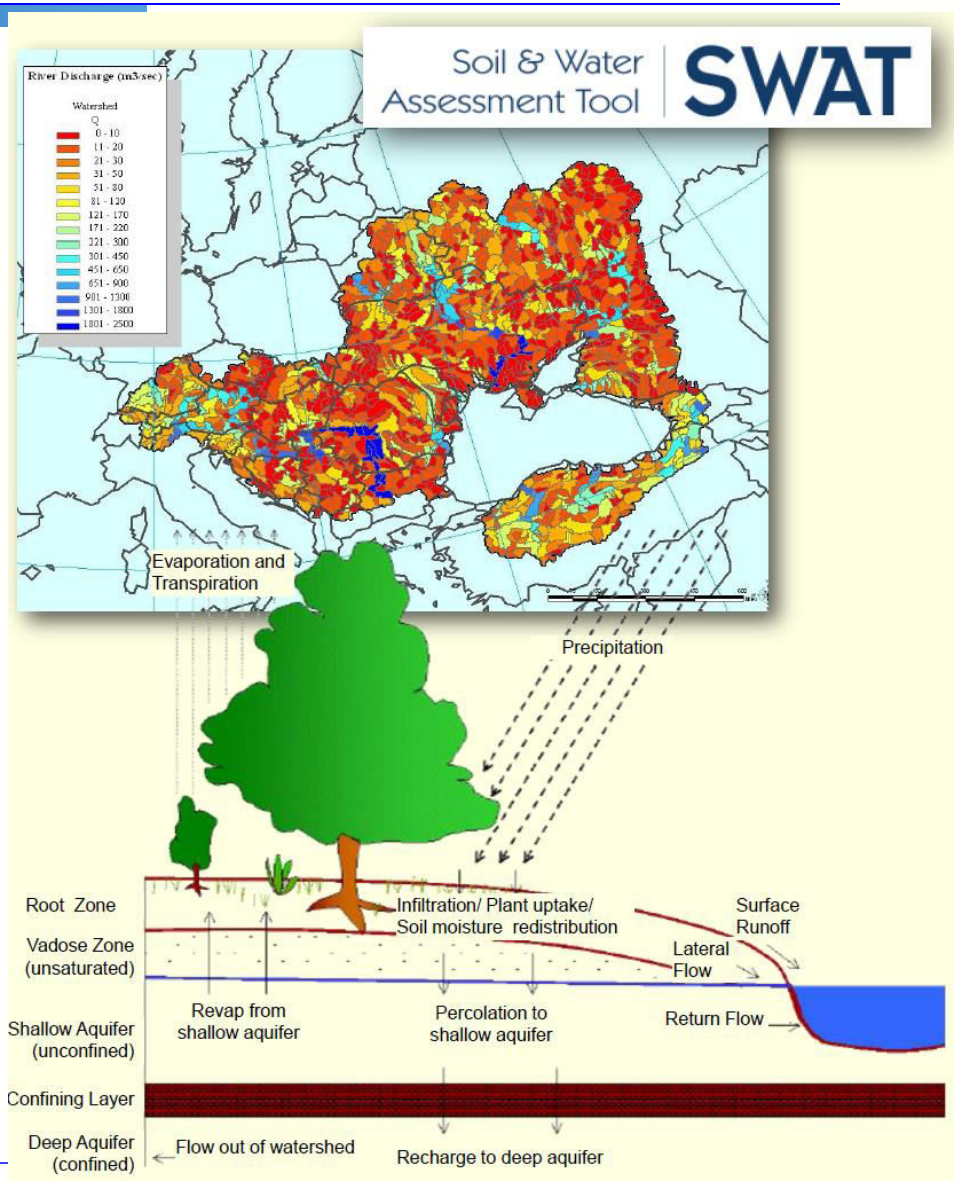
SWAT Hydrological Model Calibration



SWAT Model Calibration

- SWAT model must pass through a careful calibration and uncertainty analysis

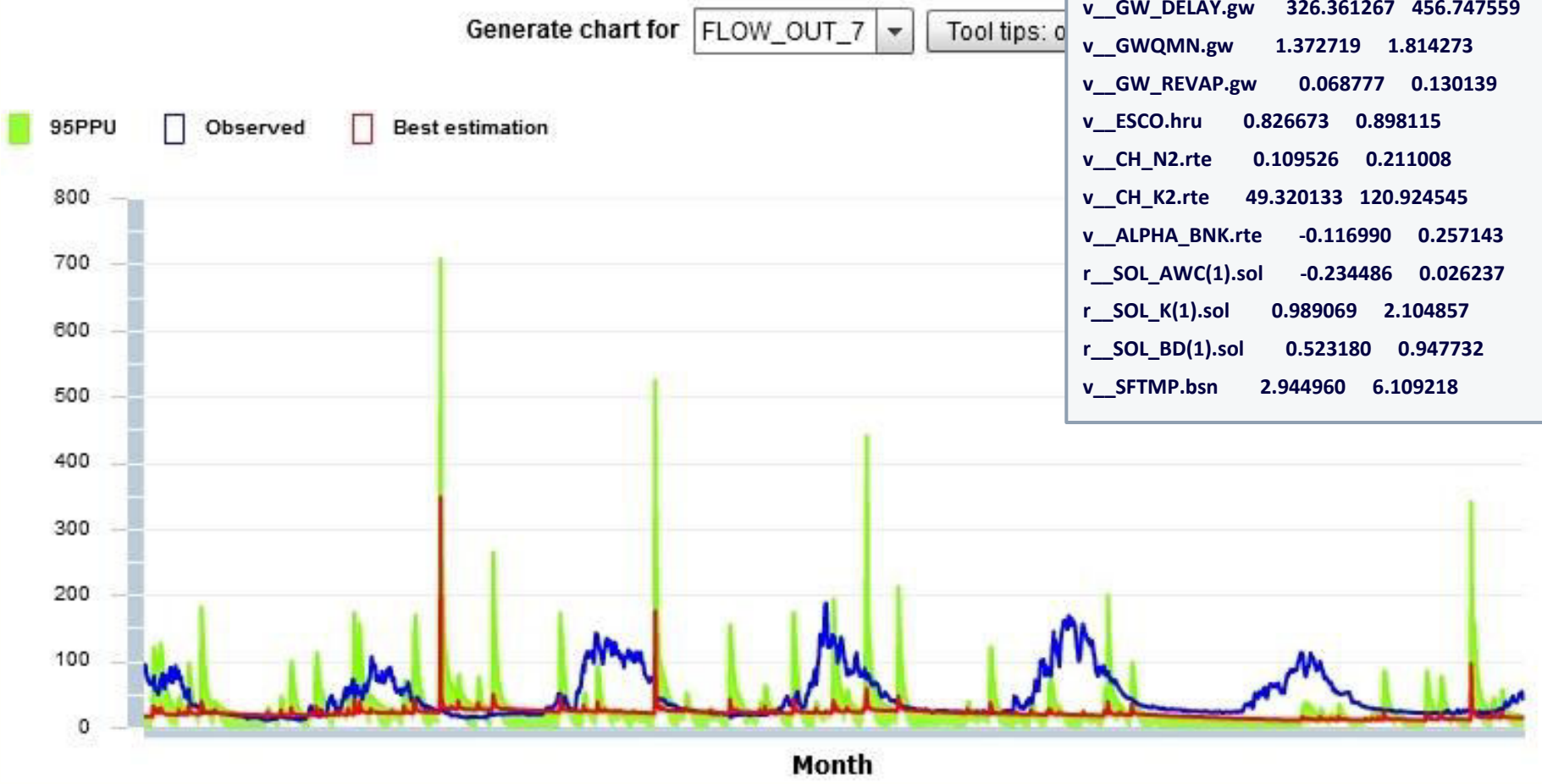




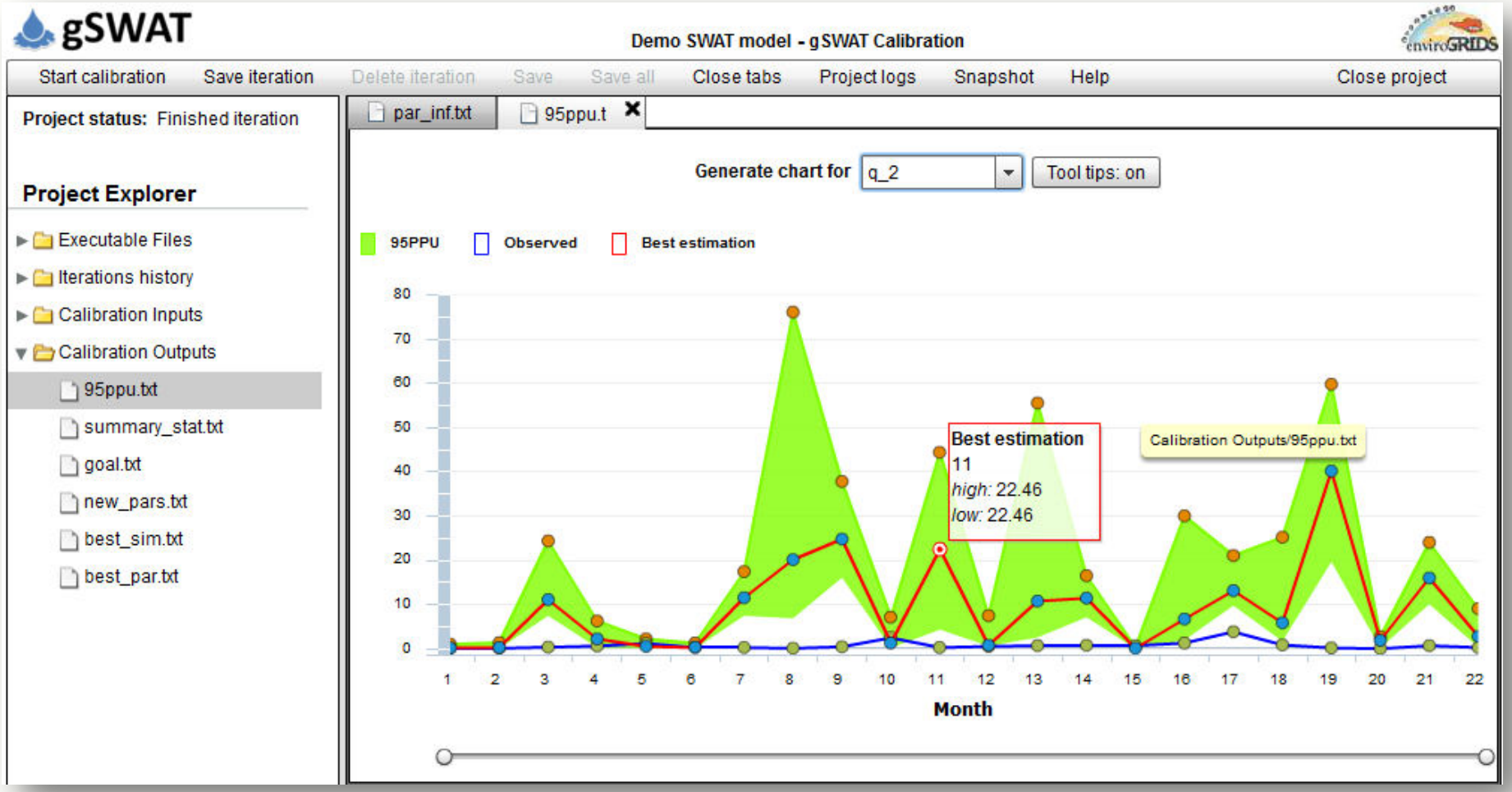
Model Calibration – one iteration

Calibration parameters:

r__CN2.mgt	-0.168640	-0.048970
v__ALPHA_BF.gw	0.326250	0.792908
v__GW_DELAY.gw	326.361267	456.747559
v__GWQMN.gw	1.372719	1.814273
v__GW_REVAP.gw	0.068777	0.130139
v__ESCO.hru	0.826673	0.898115
v__CH_N2.rte	0.109526	0.211008
v__CH_K2.rte	49.320133	120.924545
v__ALPHA_BNK.rte	-0.116990	0.257143
r__SOL_AWC(1).sol	-0.234486	0.026237
r__SOL_K(1).sol	0.989069	2.104857
r__SOL_BD(1).sol	0.523180	0.947732
v__SFTMP.bsn	2.944960	6.109218

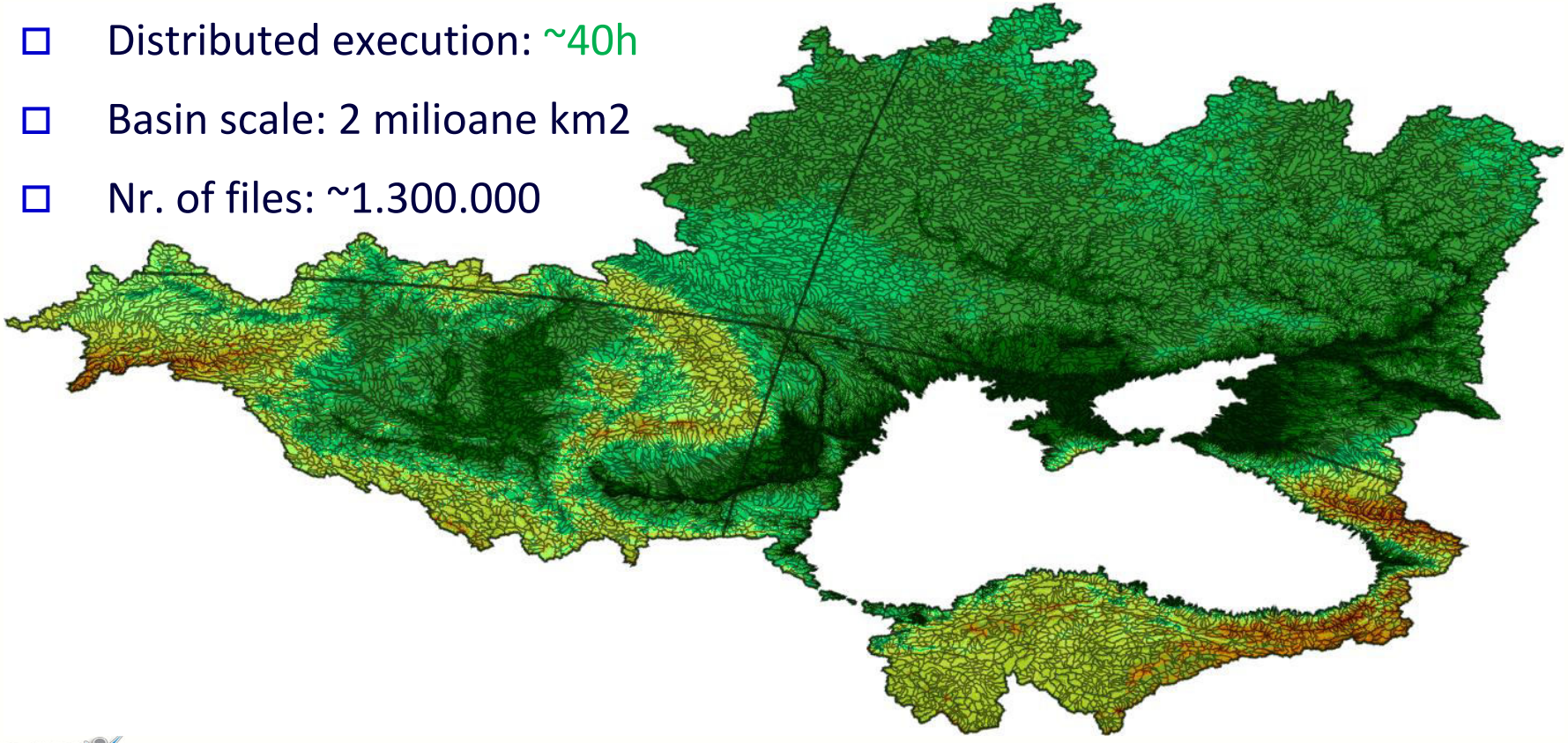


gSWAT – SWAT model calibration



Complex SWAT models

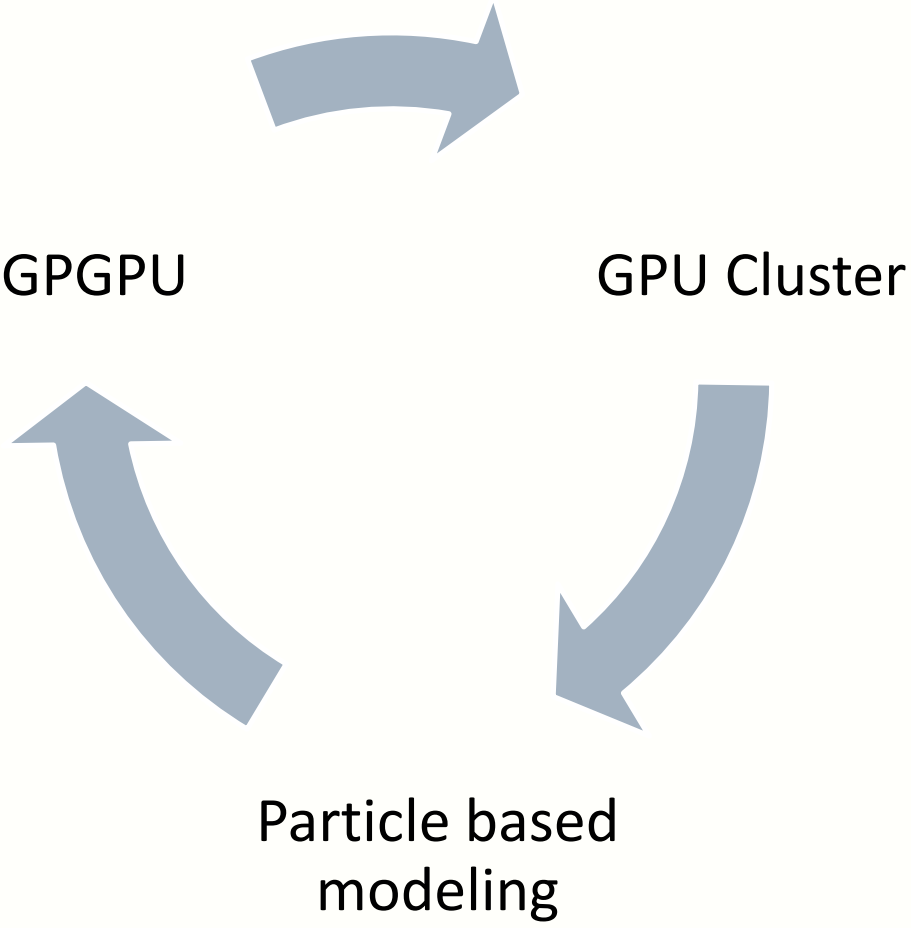
- Black Sea basin
- 200 simulations
- Local sequential execution: 8,059 hours
- Distributed execution: ~40h
- Basin scale: 2 milioane km2
- Nr. of files: ~1.300.000



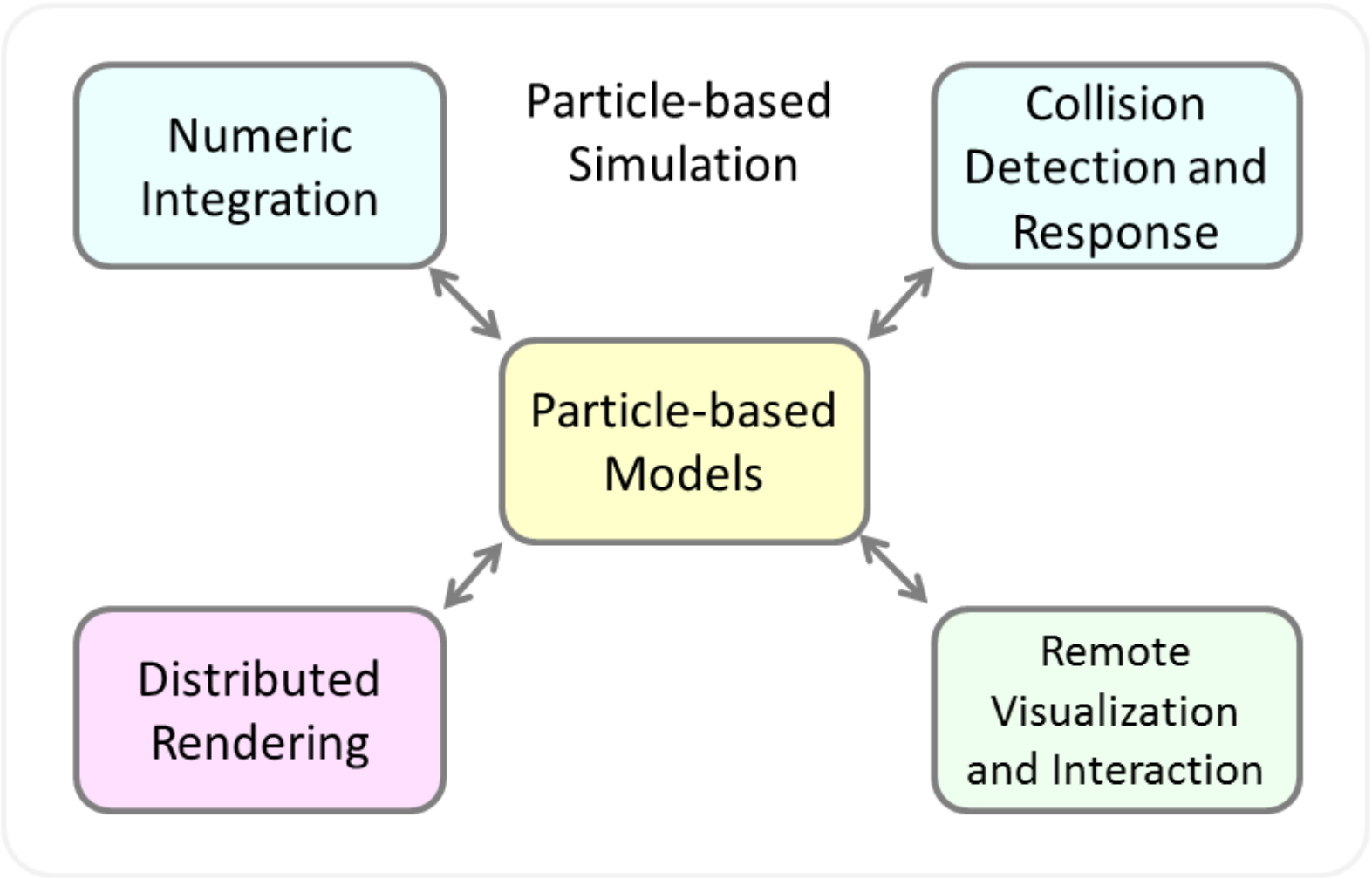
Sociophysics Models

- Social model
- Economic system
- Demographic evolution
- Financial system
- Human relationships
- Resources oriented concurrency
- Business relationships
- . . .

High Performance Computation



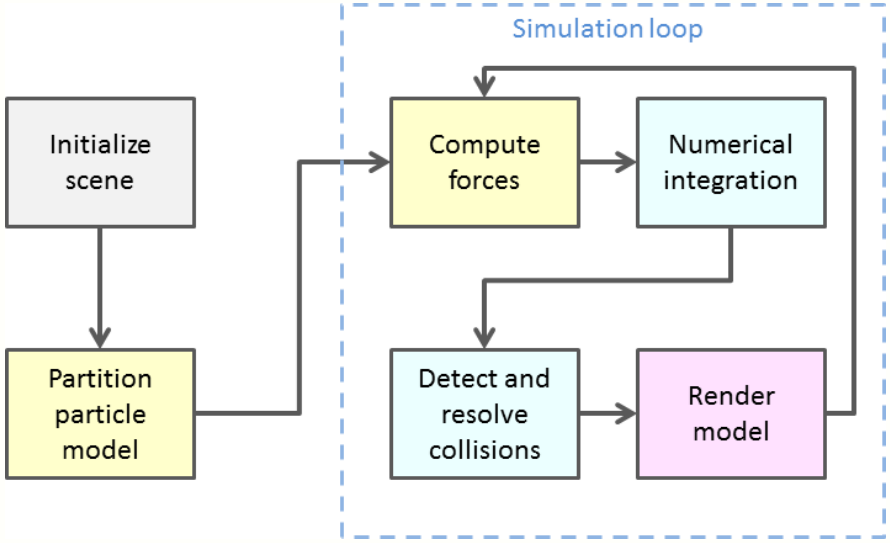
Computation Architecture Overview



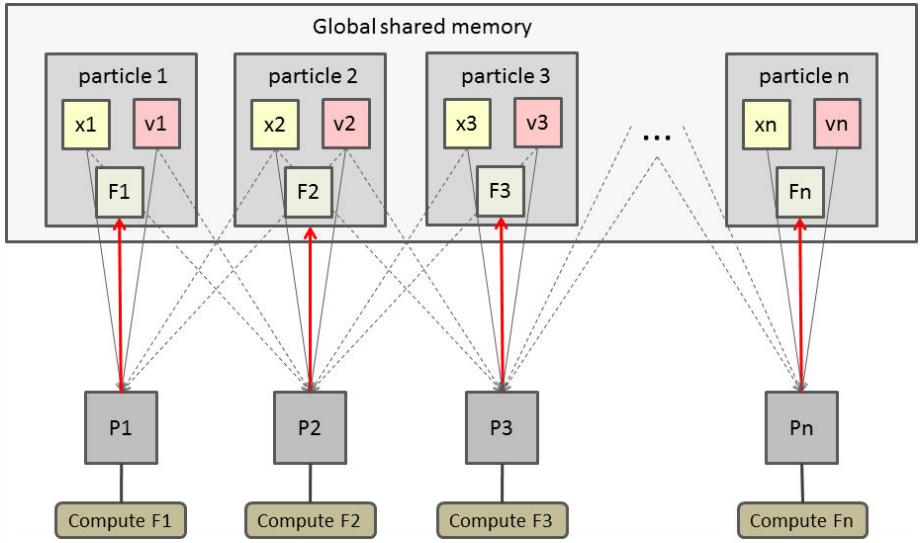
Particle Model Partitioning

- GPU level
  a) Static 2D cyclic partitioning
  b) Communication and synchronization
  c) Simulation algorithm

a)



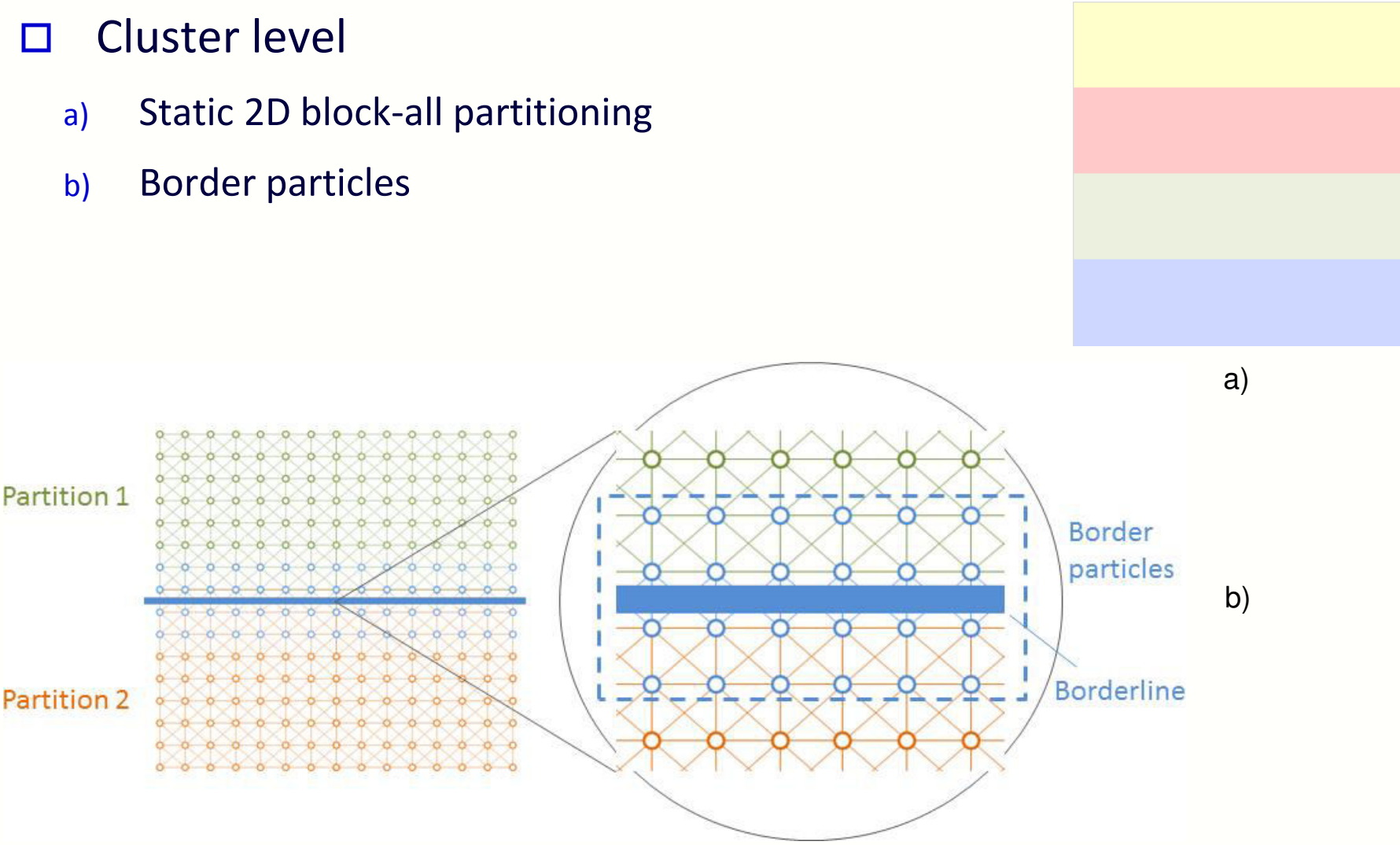
c)



b)

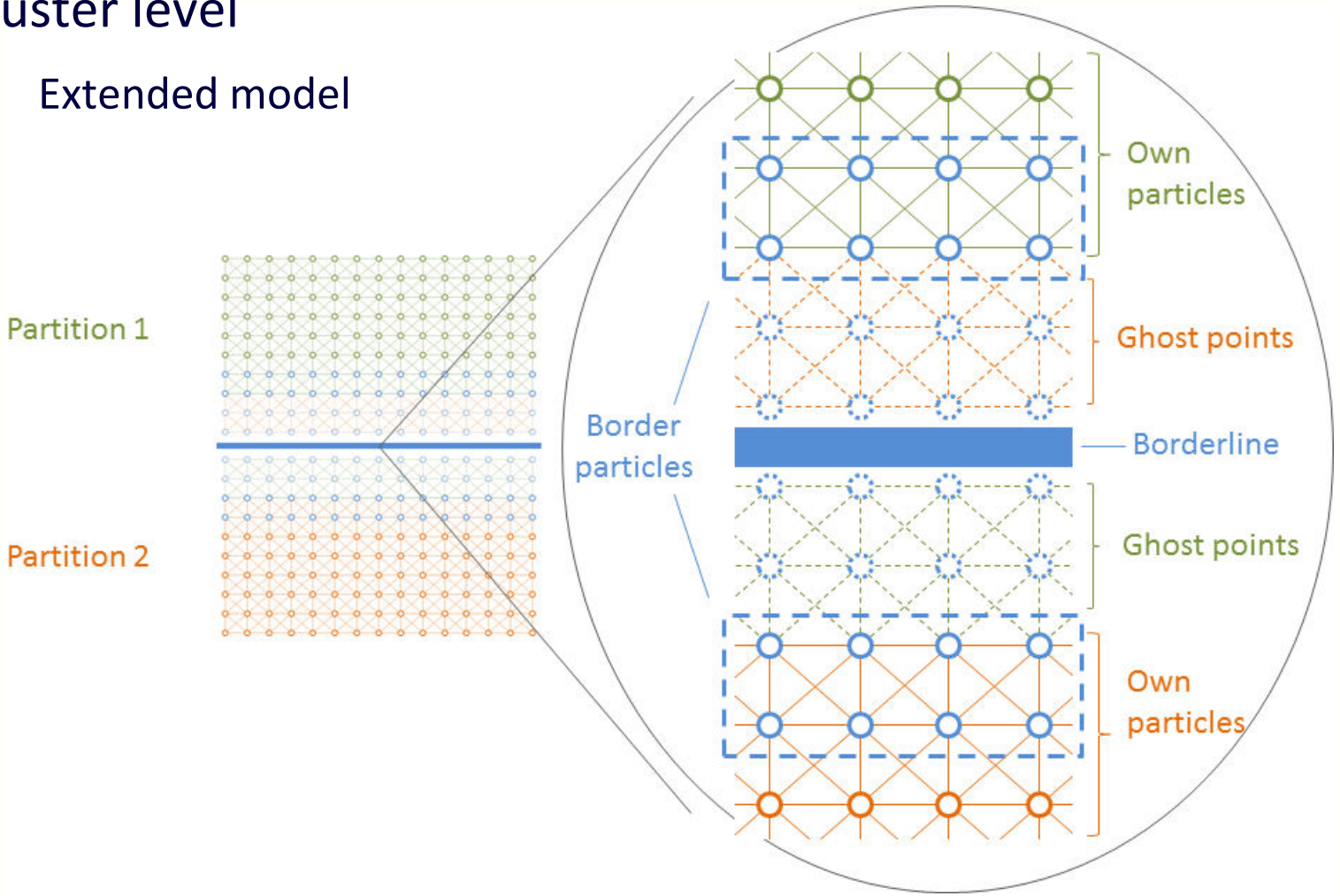
Particle Model Partitioning

- Cluster level
  - a) Static 2D block-all partitioning
  - b) Border particles

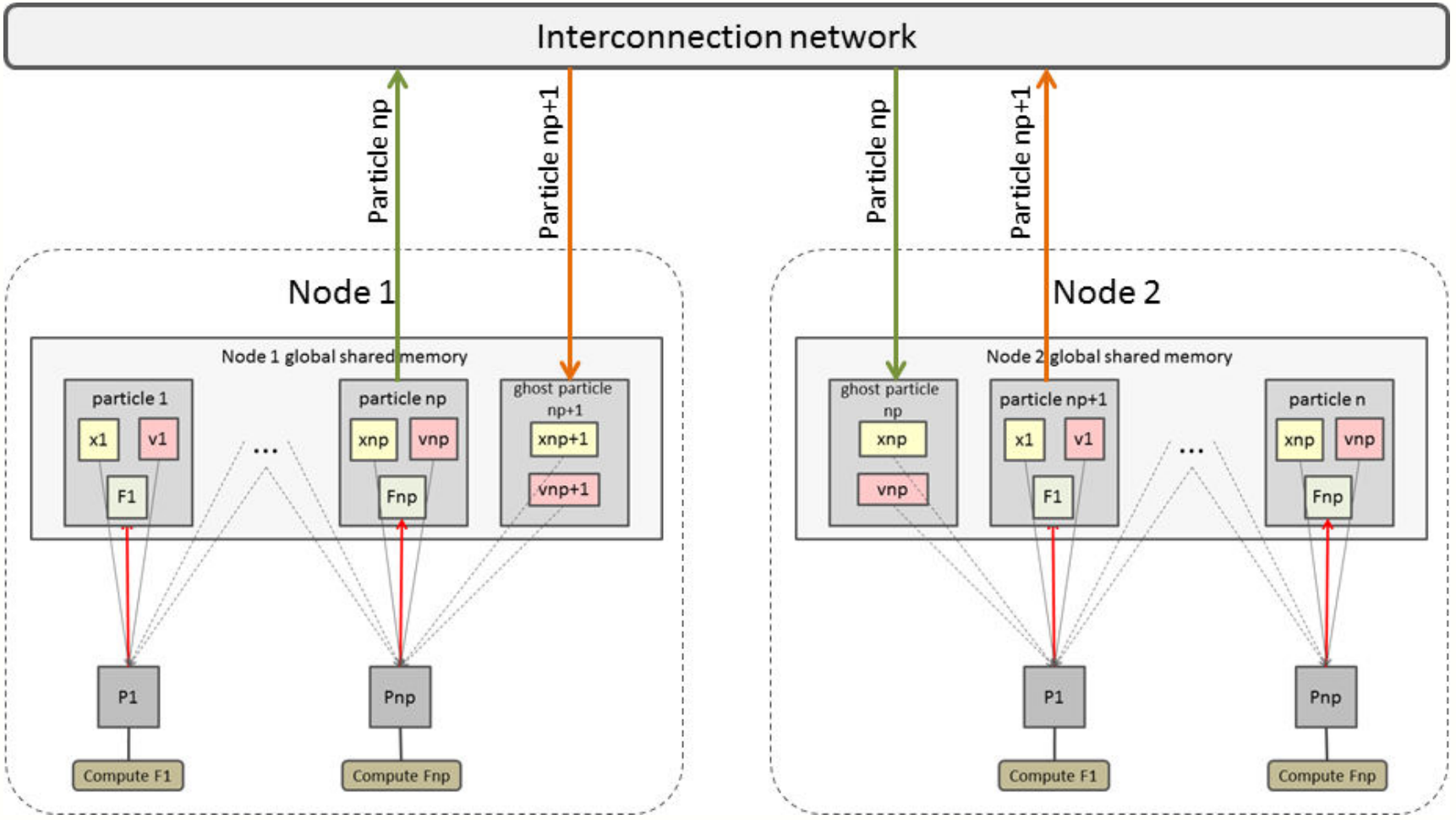


Particle Model Partitioning

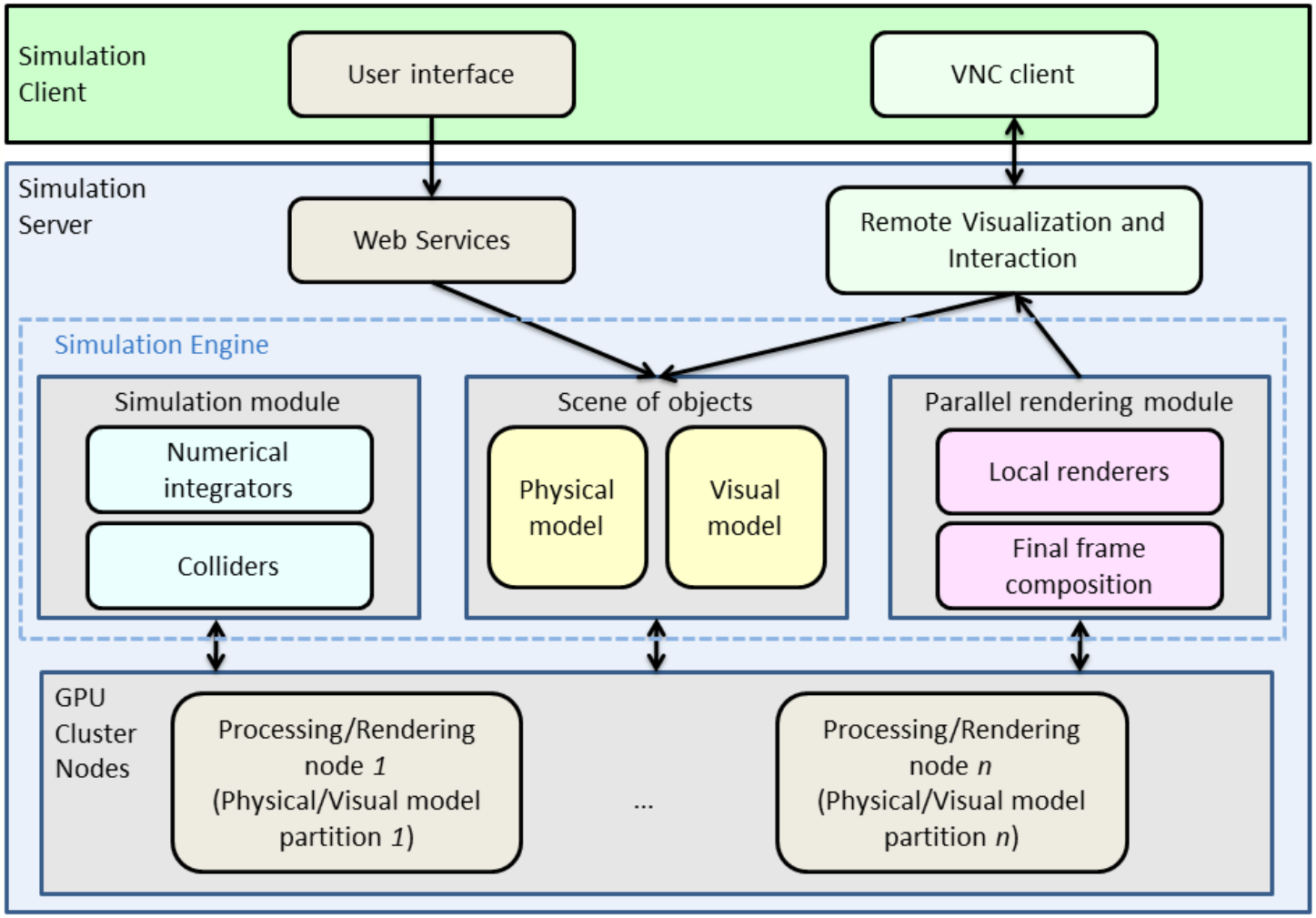
- Cluster level
  - Extended model



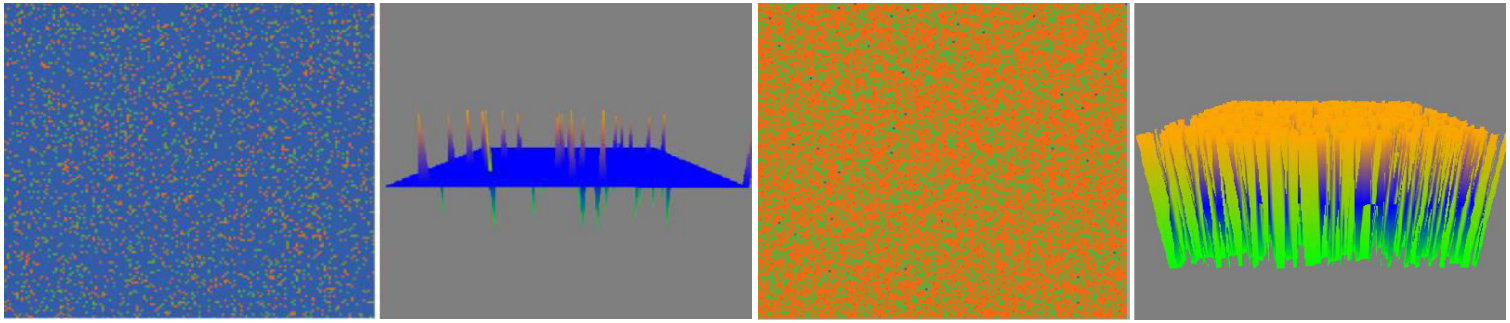
Parallel and Distributed Computation

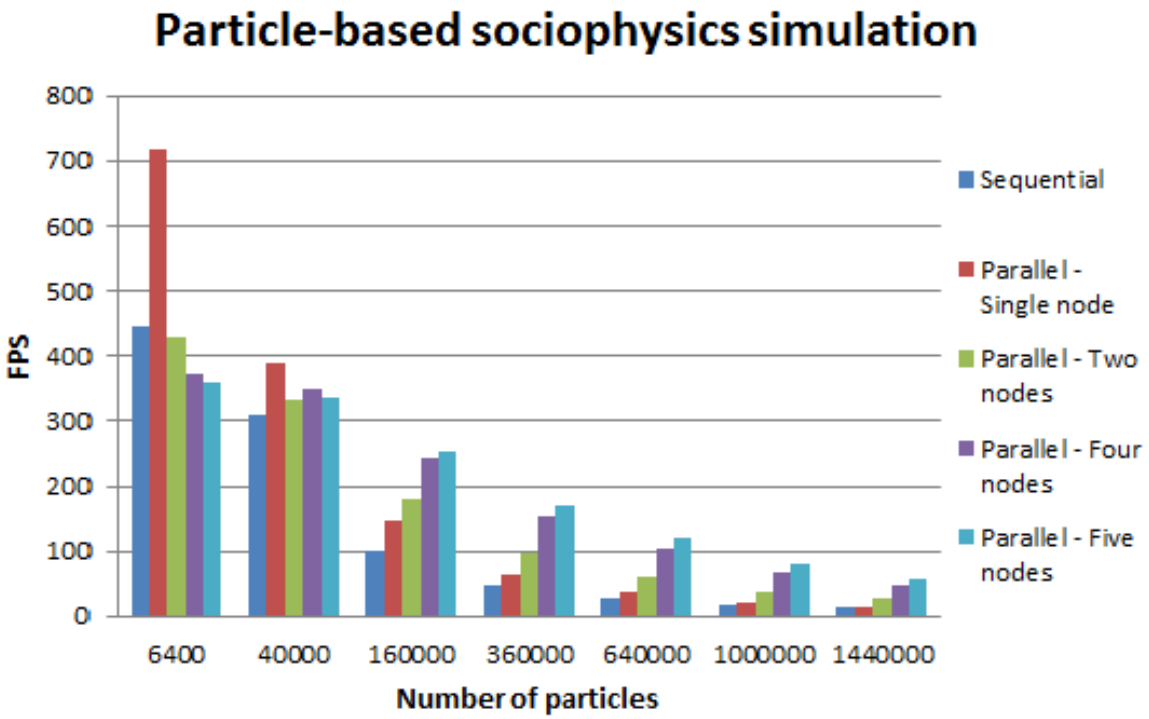


ParTSim Architecture

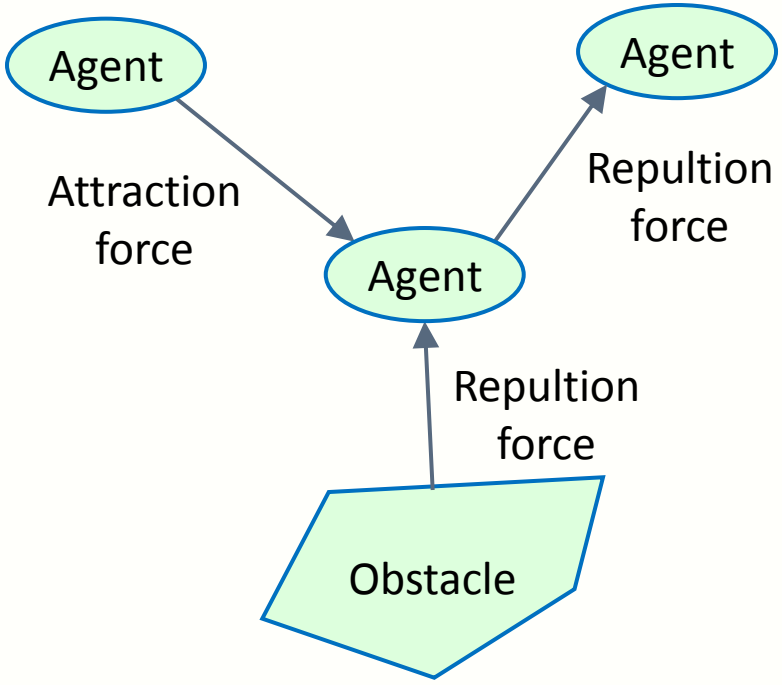


Model Execution

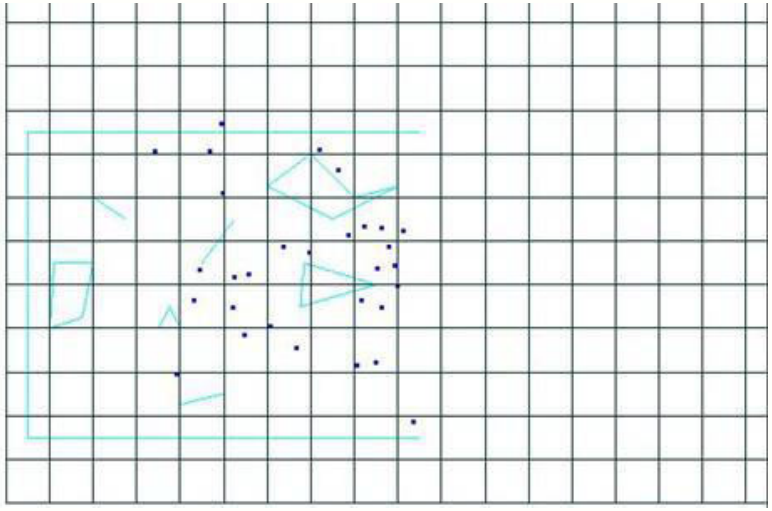


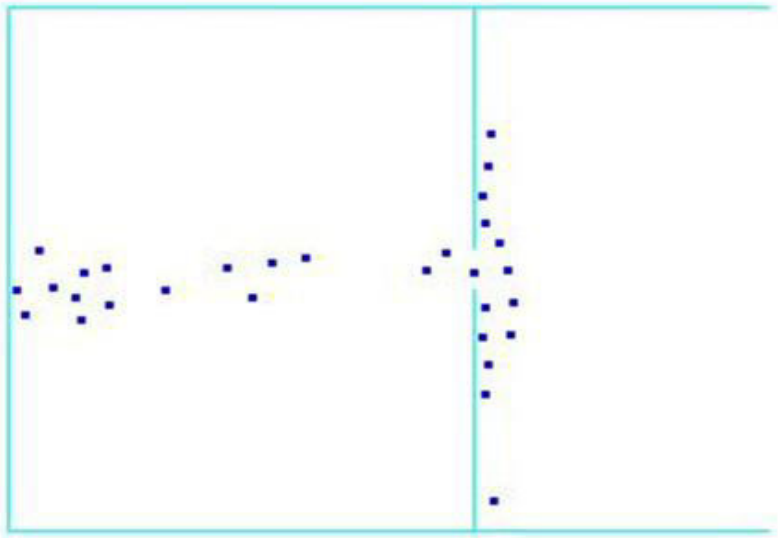


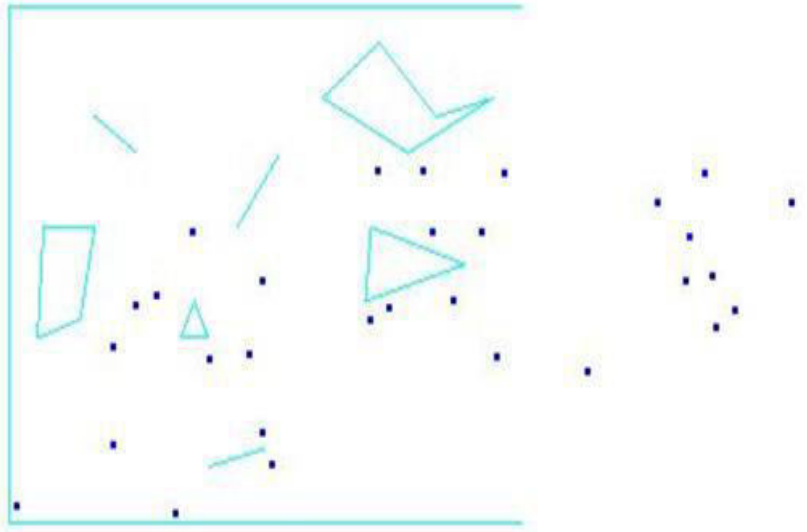
Crowd Dynamics in Sociophysics

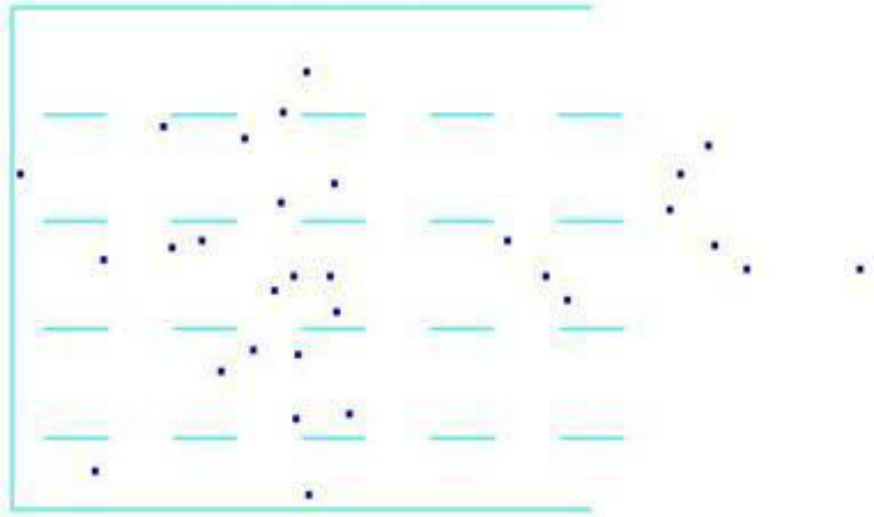


Crowd Dynamics in Sociophysics









Publications

- Ilies D.R., Sabou A., Gorgan D., “Real Time Visualization of Crowd Dynamics Scenarios”, RoCHI Conference (in press), (2015)
- Catana M.C., Gorgan D., “Analyzing Computer Game Strategies through Visual Techniques”, RoCHI Conference (in press), (2015)
- Sabou A., Gorgan D., “A parallel, distributed, high-performance architecture for simulating particle-based models”, in 2014 16th International Symposium on Symbolic and Numeric Algorithms for Scientific Computing (SYNASC), (2014).
- Sabou A., Gorgan D., “Interactive particle-based simulation of sociophysics models”, ICCP 2014 IEEE International Conference on Intelligent Computer Communication and Processing, pp. 411-416 (2014).
- Gorgan D., Bacu V., Mihon D., Rodila D., Abbaspour, K., and Rouholahnejad, E.: Grid based calibration of SWAT hydrological models, Journal of Nat. Hazards Earth Syst. Sci., 12, pp. 2411-2423, (2012).
- Gorgan D., Bacu V., Mihon D., Stefanut T., Rodila D., Cau P., Abbaspour K., Giuliani G., Ray N., Lehmann A., Software platform interoperability throughout enviroGRIDS portal, in International Journal of Selected Topics in Applied Earth Observations and Remote Sensing – JSTARS, Vol. 5/6, pp. 1617-1627, (2012).

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Many thanks for your attention!

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TECHNICAL UNIVERSITY OF CLUJ-NAPOCA

Dorian Gorgan
Computer Science Department
Technical University of Cluj-Napoca
http://users.utcluj.ro/~gorgan
dorian.gorgan@cs.utcluj.ro