The GEONAMICA® software environment for dynamic spatial modelling

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It is not completely new!
Common characteristics

- Spatial Decision Support Systems
- Integrated model
- High model complexity
- Models that can evolve over time
- Systems that require a powerful engine
- Interactive systems
  - Computation time
  - Usability
  - Development
What is GEONAMICA®?

- **Object oriented application framework**¹ to build integrated spatial decision support systems
  - Generic components and architecture for SDSSs
  - Provides skeleton (software) application

- **METRONAMICA**: template SDSS
  - No programming required to set up an application

- **MedAction, Xplorah, LUMOCAP, …**
  - ISDSSs built with GEONAMICA®

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Benefits of a framework

- **Reusability**
  - Design reuse
  - Implementation reuse

- **Modularity**
  - Decomposition of system in prescribed way

- **Extensibility**
  - Functionality can be extended easily

- **Inversion of control**
  - Framework decides when things happen
What comprises GEONAMICA®?

- Data structures & common procedures for map data, time series data and cross-sectional data
- Modelling framework and simulation engine
- Components to build graphical user interfaces (GUI)
Modelling framework

- Builds on Discrete Event System Specification (DEVS) formalism
- Decomposition into model blocks:
  - Variables
  - Computation routines
  - Output ports
  - Input ports
  - Interface ports

- Hierarchical model specified at run-time
Model connection

Model block A

Variable A1

Input ports

Model block B

Variable B1

Output ports
Simulation engine

- Variable stores value for one moment in time
- Computation routine calculates next moment in time

- Adaptation of DEVS implementation
  - Different types of variables
  - Order of computing model blocks
Variable types

- Derive precedence relations for calculation of model blocks automatically

1. Is the value of the variable dependent on the value of another variable?
   - yes, endogenous
   - no, exogenous

2. Is the variable value dependent on the lagged value of another variable or its own lagged value?
   - yes
   - no

3. Can the value of the parameter change over time – that is, does it follow a time line?
   - yes
   - no

- Accumulating variable
- Transitory variable
- Dynamic parameter
- Static parameter
GEONAMICA® overview

- Application
  - User interface
    - Model controller
      - Model block A
        - Variable A1
      - Model block B
        - Variable A2
      - Model block C
Summary - features

- Modularity
  - Decomposition into model blocks
- Highly automated
  - Derivation of computation order
  - Common procedures for model blocks
- Can build efficient system
- Tailor-made user interface
Current development

- Compute model blocks in parallel
- Improve support for map data
- Platform independency
  - Web-based applications

- Longer term:
  - Allow GEONAMICA® to incorporate models that comply with compatible standard
  - Create visual modelling environment
Thank you!

Questions?
A simple use case

- Model block A:
  - $X_t = f(Y_{t-1}, Z_{t-1})$
  - $Y_t = g(Z_t)$

- Model block B:
  - $Z_t = h(X_t)$

⇒ Calculate $X$ before $Y$ and $Z$
  Calculate $Z$ before $Y$

⇒ Computation order: $X$, $Z$, $Y$

⚠️ $X$ and $Y$ must be calculated ‘simultaneously’
Computation order

- 2 kinds of relations
  - Lagged
  - Non-lagged
- 6 kinds of connections

<table>
<thead>
<tr>
<th>Relation</th>
<th>$X_{t-1}$</th>
<th>$X_t$</th>
<th>$Y_t$</th>
<th>Meaning</th>
<th>Brief</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Y_t = f(X_t)$</td>
<td>-</td>
<td>T</td>
<td>T</td>
<td>$X$ must be calculated before $Y$ is calculated.</td>
<td>$X &lt; Y$</td>
</tr>
<tr>
<td>$Y_t = f(X_{t-1})$</td>
<td>-</td>
<td>T</td>
<td>A</td>
<td>This is impossible, since all accumulating variables must be calculated before all transitory variables.</td>
<td>-</td>
</tr>
<tr>
<td>$Y_t = f(X_t)$</td>
<td>-</td>
<td>A</td>
<td>T</td>
<td>This is ok; all accumulating variables are calculated before all transitory variables.</td>
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<td>-</td>
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<td>$Y$ must be calculated before $X$ is calculated.</td>
<td>$Y &lt; X$</td>
</tr>
</tbody>
</table>
A simulation step

- Process user input
  - Recalculate transitory variables
- Advance simulation time
- Calculate accumulating variables
- Calculate transitory variables
- Present results to user

- How to prevent user from changing parameters during a simulation step?
UI-model interaction

- Model output can be accessed through output ports
- Model parameters can be set/ altered through interface ports
  - Cache parameter value
  - Update real parameter with cached value before we take a simulation step

- Model tells UI when variables have been computed