SAINT PETERSBURG NATIONAL RESEARCH UNIVERSITY OF
INFORMATION TECHNOLOGIES, MECHANICS AND OPTICS

e-Science Research Institute, ITMO University

Modeling and Simulation Framework for Development of Interactive Virtual Environments

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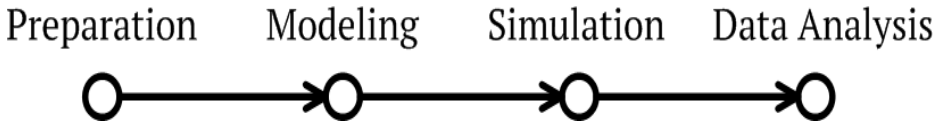
Motivation

- eScience domain complexities
  - Large amount of distributed and heterogeneous resources
  - Complex IT infrastructures
  - Complexity of domain tasks, multidisciplinary tasks
  - Domain specialists are not always IT specialists
- Workflow is the general formalism for complex problem solving in eScience
  - Workflow defines “how” to get the certain result (imperative way)
  - Workflow composition requires technological background
  - Workflow usually are executed only in batch mode

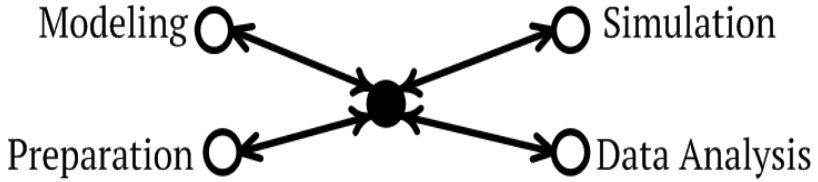
There is a need in the simulation infrastructure which is closer to domain area, automates the work with IT-related issues, and provides interactive way of working with user.

Objectives

- Shift to **system-level science** approach (2006, Foster, I., Kesselman, C.)
- Shift from sequential simulation flow



- to interaction-based **parallel**

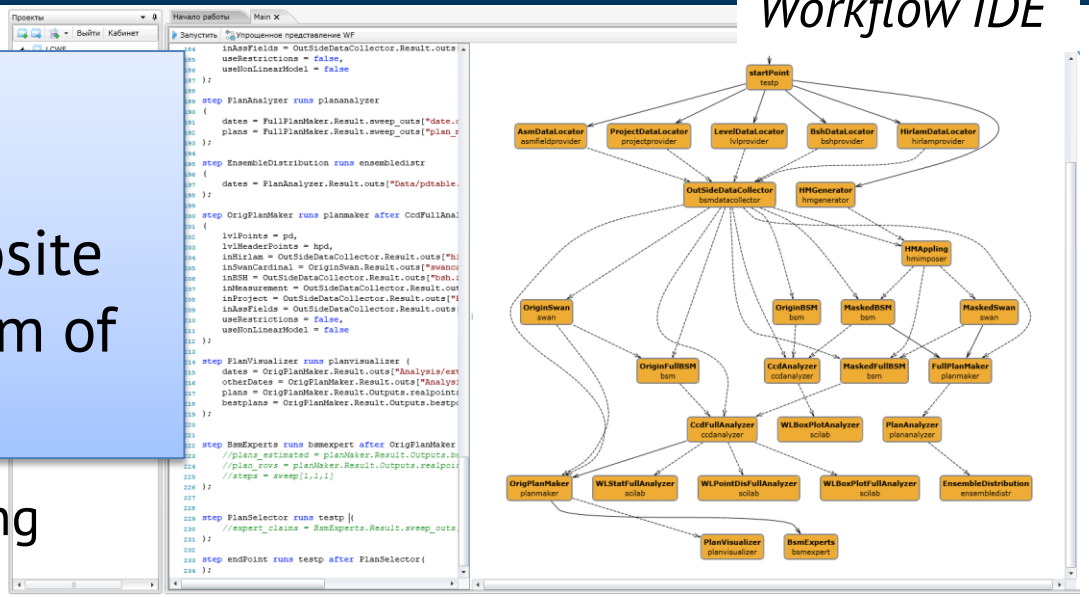


- Provide **support** for the user on each flow phase based on the knowledge (technological and domain)
- **Automatically** translate user actions to technological workflow actions (package restart, interactive communication, …)
- Three fundamental aspects: (1) domain semantics knowledge processing; (2) domain-specific visual representation; (3) automation of technological operations.

The CLAVIRE platform

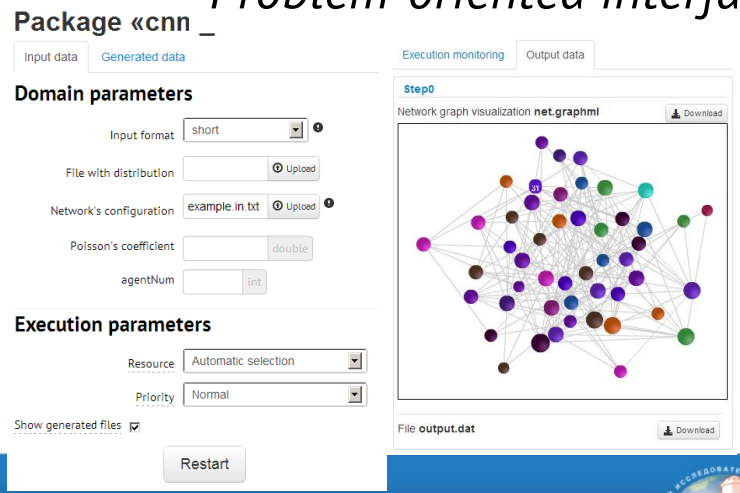
CLAVIRE (**cl**oud **a**pplication **vir**tual **e**nvironment) – the platform for abstract composite application execution in form of workflows

Workflow IDE



- General WF primitive is existing software packages (legacy)
- Different computational resources are supported (PC, clusters, Grids, IaaS)
- Formal knowledge about platform components:
  - DSL for composite application description (EasyFlow)
  - DSL for software packages description (EasyPackage)
  - Resources' description

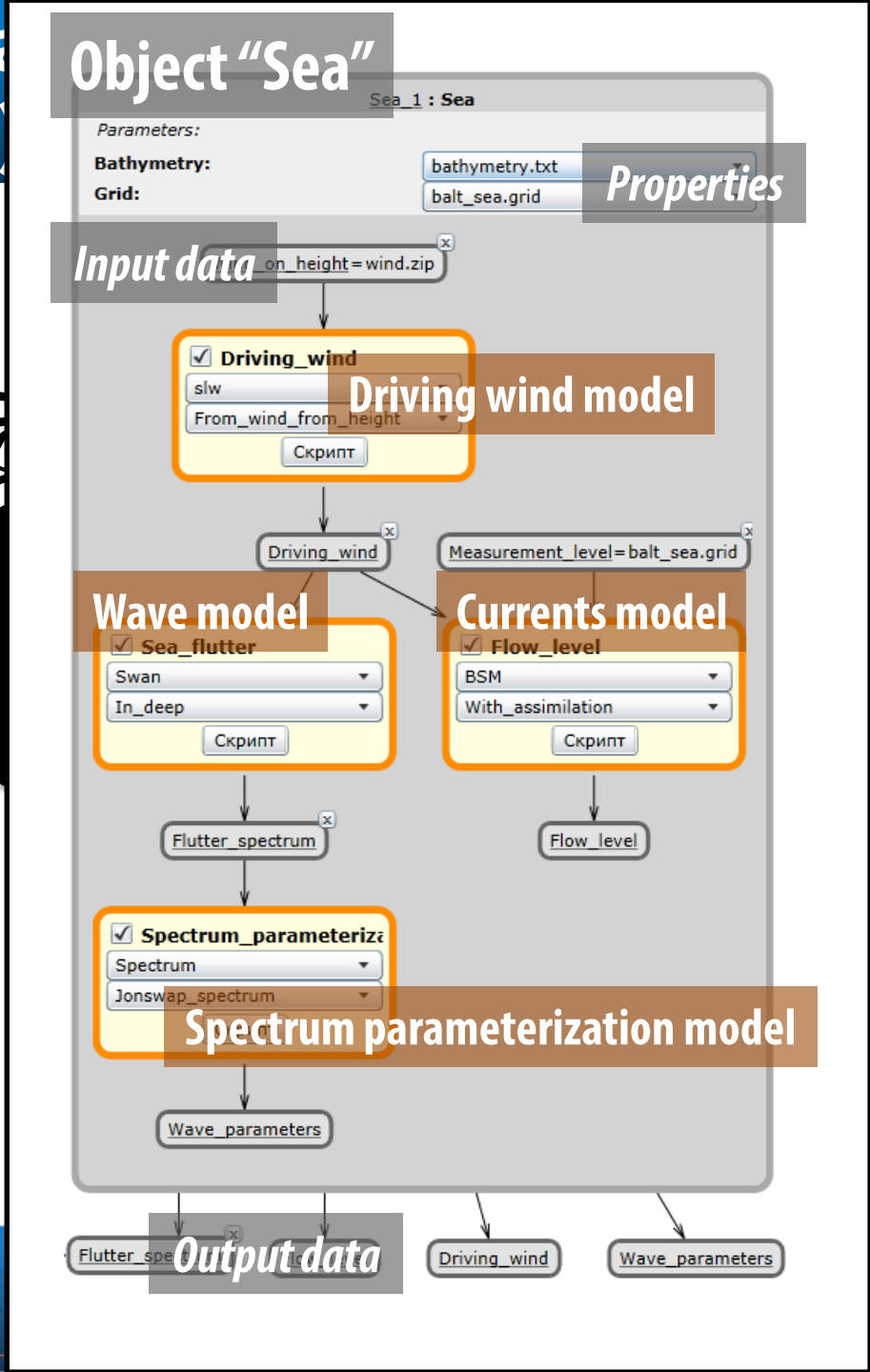
Problem-oriented interface



Domain knowledge mana
Simulation Objects (VSO

- **Object** is an abstraction which represents real-world entities: sea, city, hurricane, vehicles…
- **Model** describes one side of the object (e.g. sea's temperature)
- Objects are connected with relations and form a system's **structure**
- Type of **relations**: Inheritance, Composition, Data transfer
- System structure is translated to **workflows**
- **Ontology-based** knowledge description

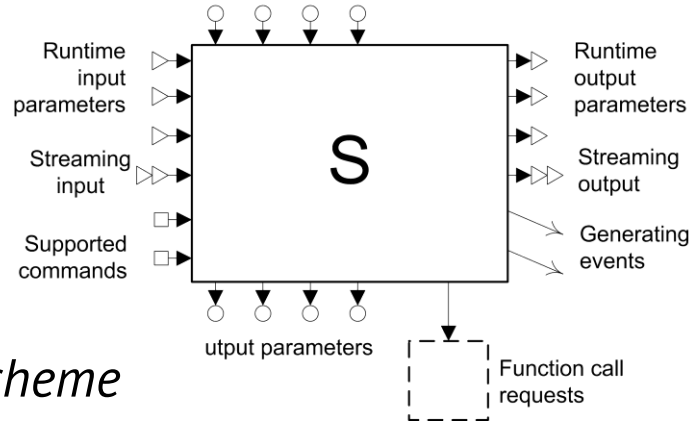
CLAVIRE VSO



Interactive Workflows (IWF)

IWF is a model and technology to exploit and emulate the interactive software capabilities within the workflows.

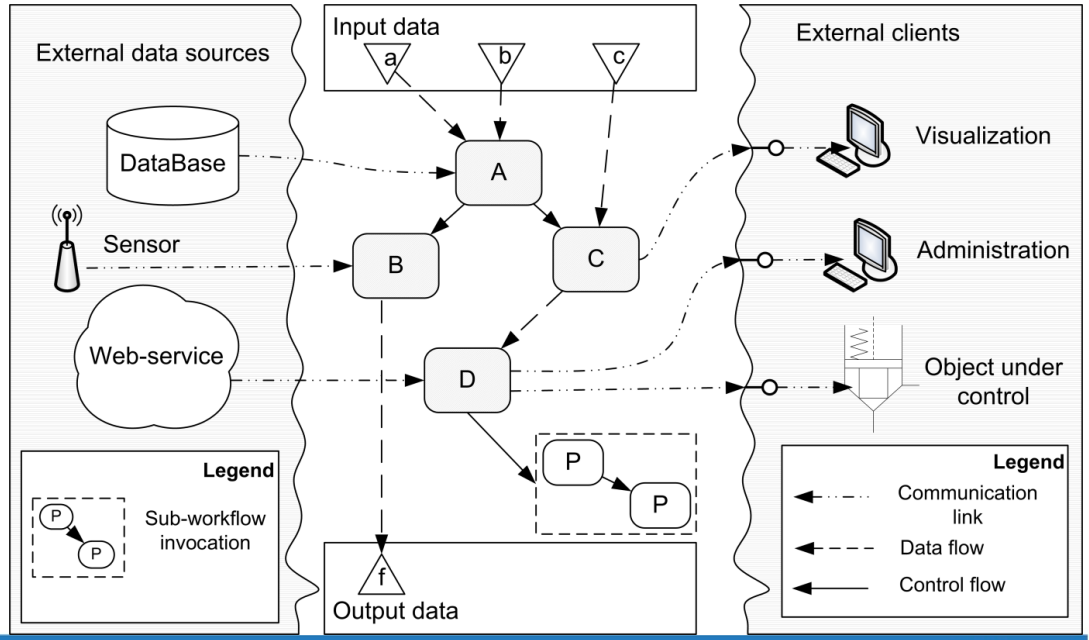
Interactive block scheme



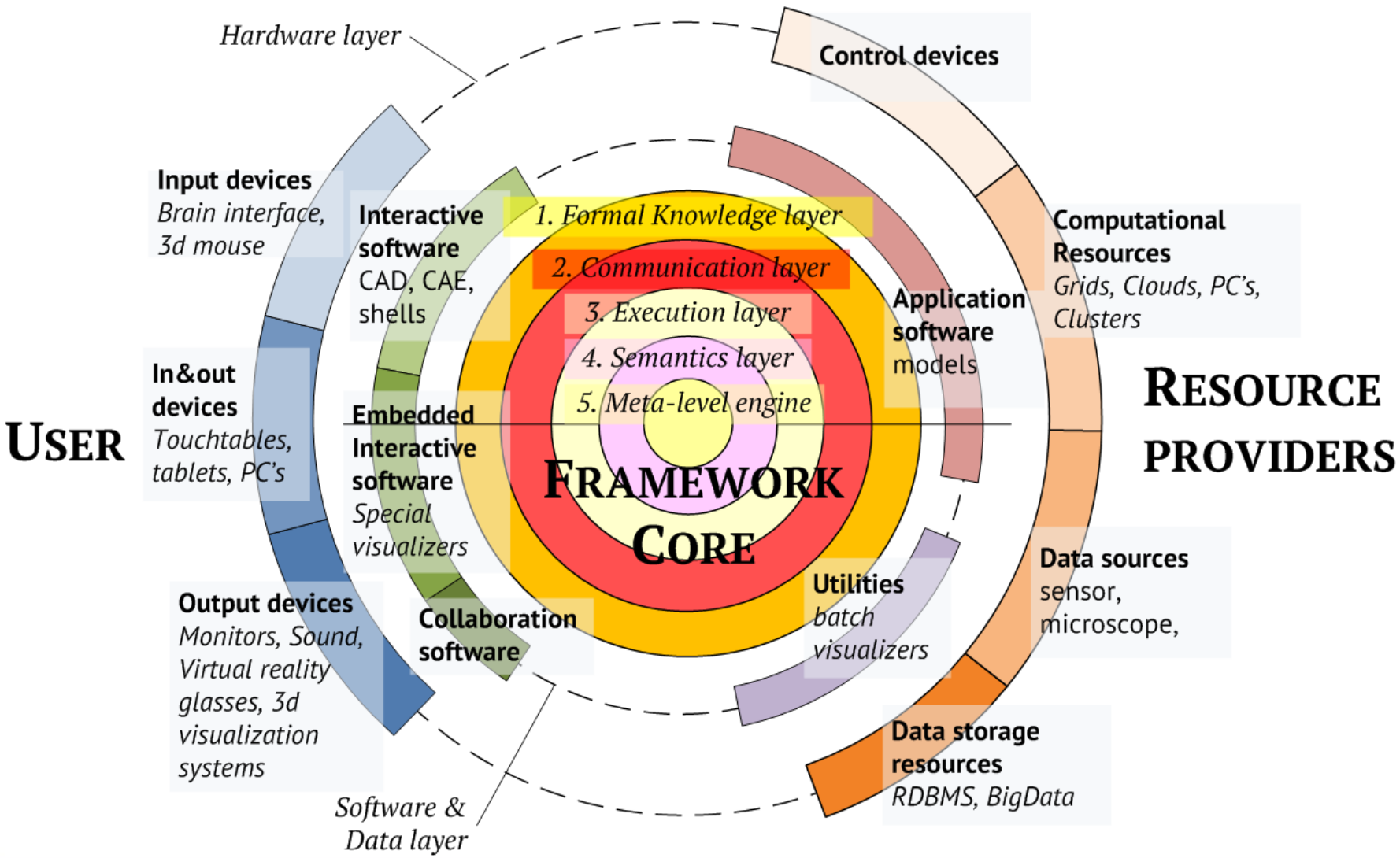
Use cases:

1. Distributed simulation
2. Network communication with software at runtime
3. Computational steering
4. Data streaming
5. Workflow modification at runtime
6. Control of simulation software

Interactive WF scheme



Conceptual scheme of architecture



Technological scheme of architecture

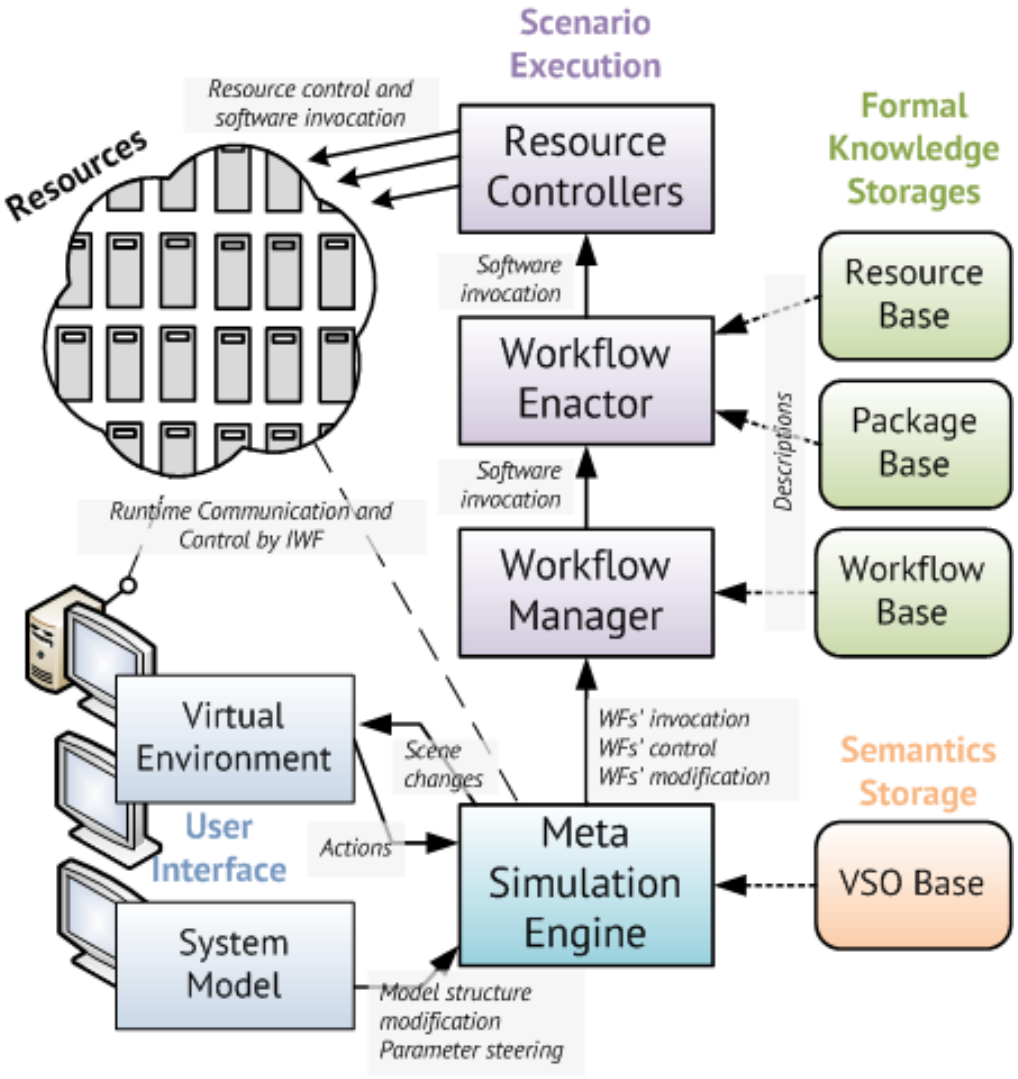
VSO – domain semantics processing

CLAVIRE – workflow execution platform

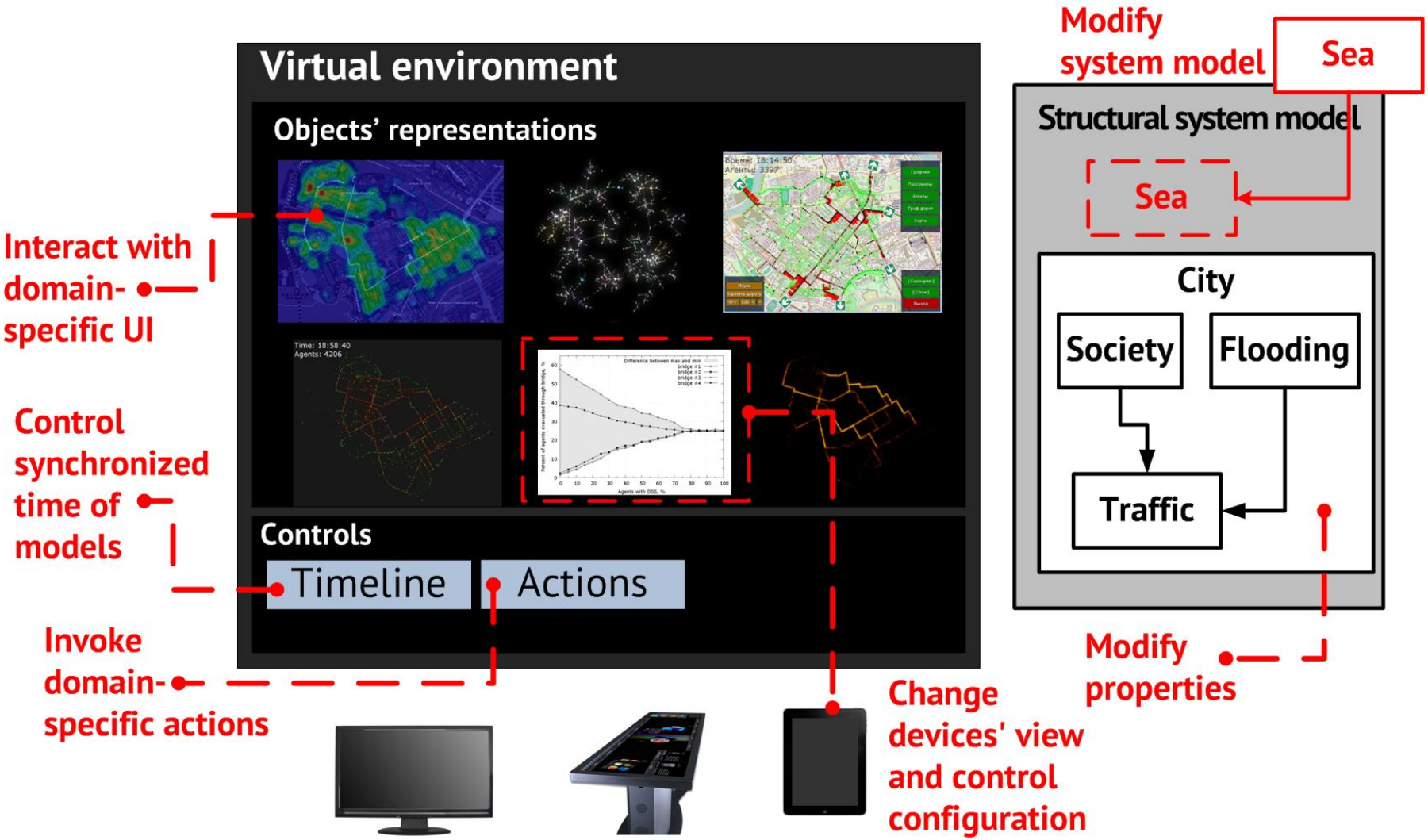
IWF – middleware for communication

Meta-Simulation engine

- Orchestrates complex scenarios execution with use of the WMS
- Synchronizes time of parallel models
- Translates user interaction into workflow actions →



User Interaction



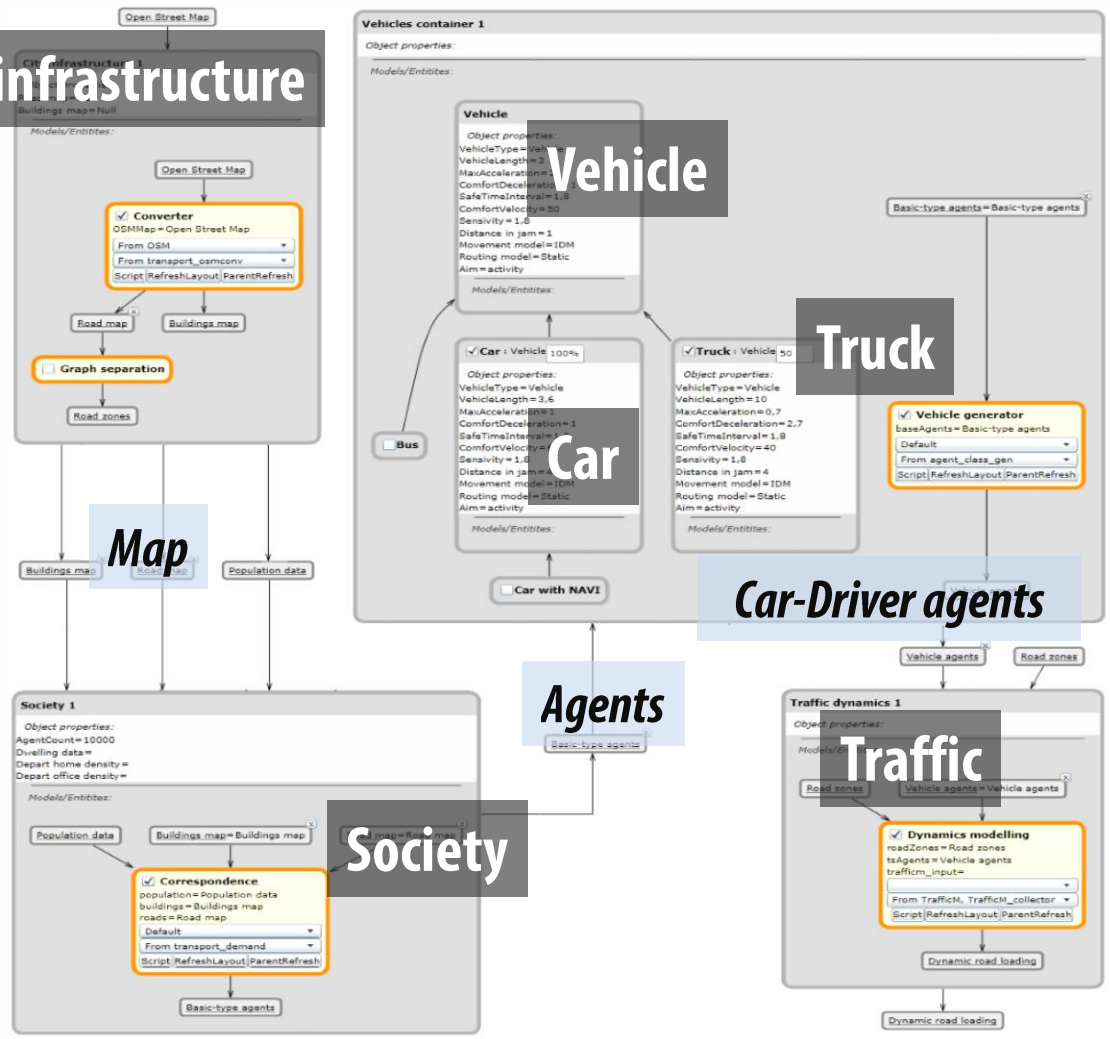
Core application: Urban traffic simulation

Application consists of:

1. Preparation of simulated urban area
2. Get traffic demand from the virtual society model
3. Configure classes of traffic agents
4. Agent-based traffic dynamics simulation

Is extended for the scenarios

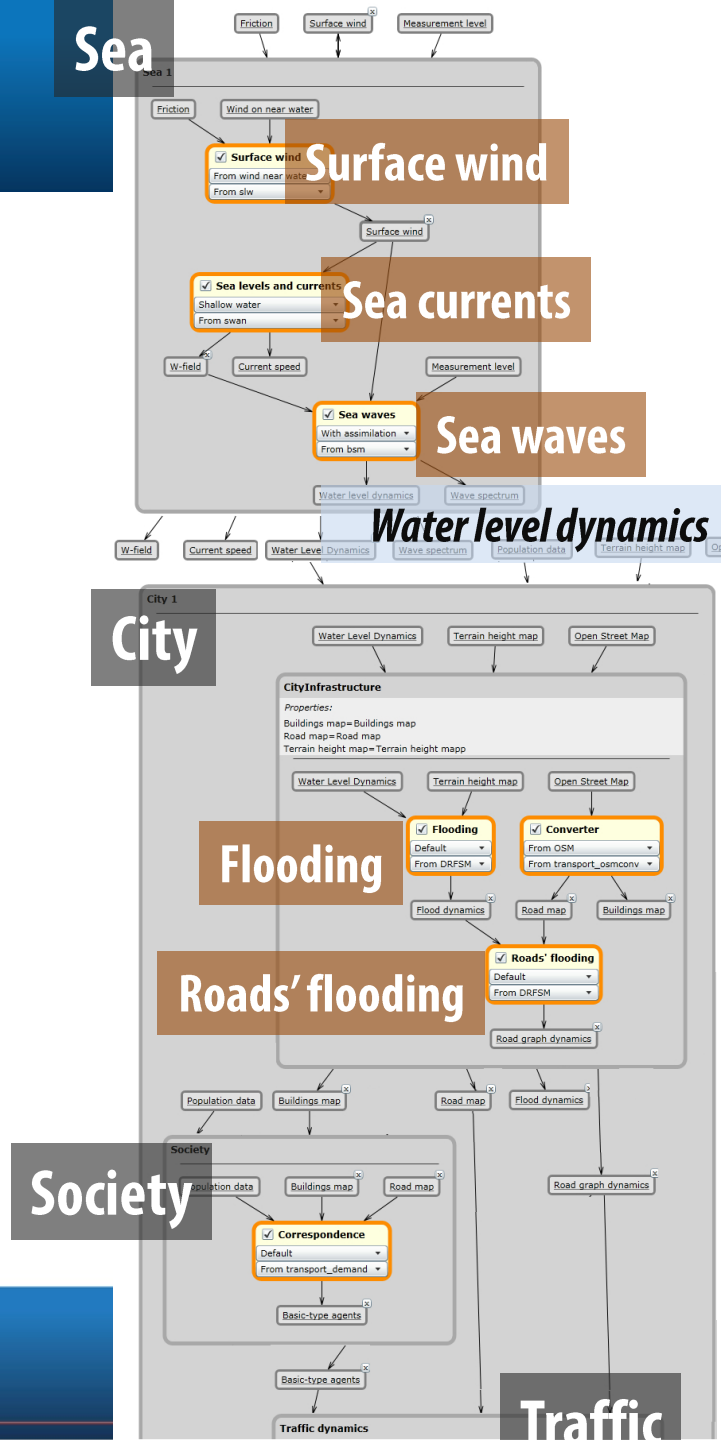
1. Vehicular evacuation in case of flood →
2. Infection propagation simulation (pedestrian mobility) →



Example 1: Model Coupling

Application: **Traffic evacuation dynamics coupled with flood model**

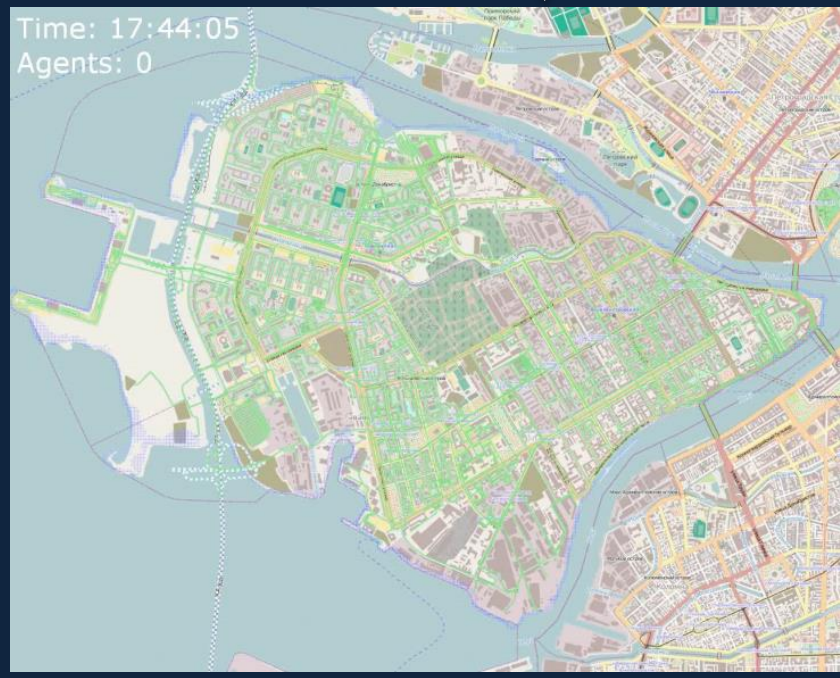
- Dynamically add model to system
- Space and time synchronization by intermediate “roads flooding” model



Evacuation simulation

Flood model

Water level dynamics



Agents' evacuation behavior extension

TRAFFIC SIMULATION PACKAGE

DYNAMIC ROAD GRAPH MODEL

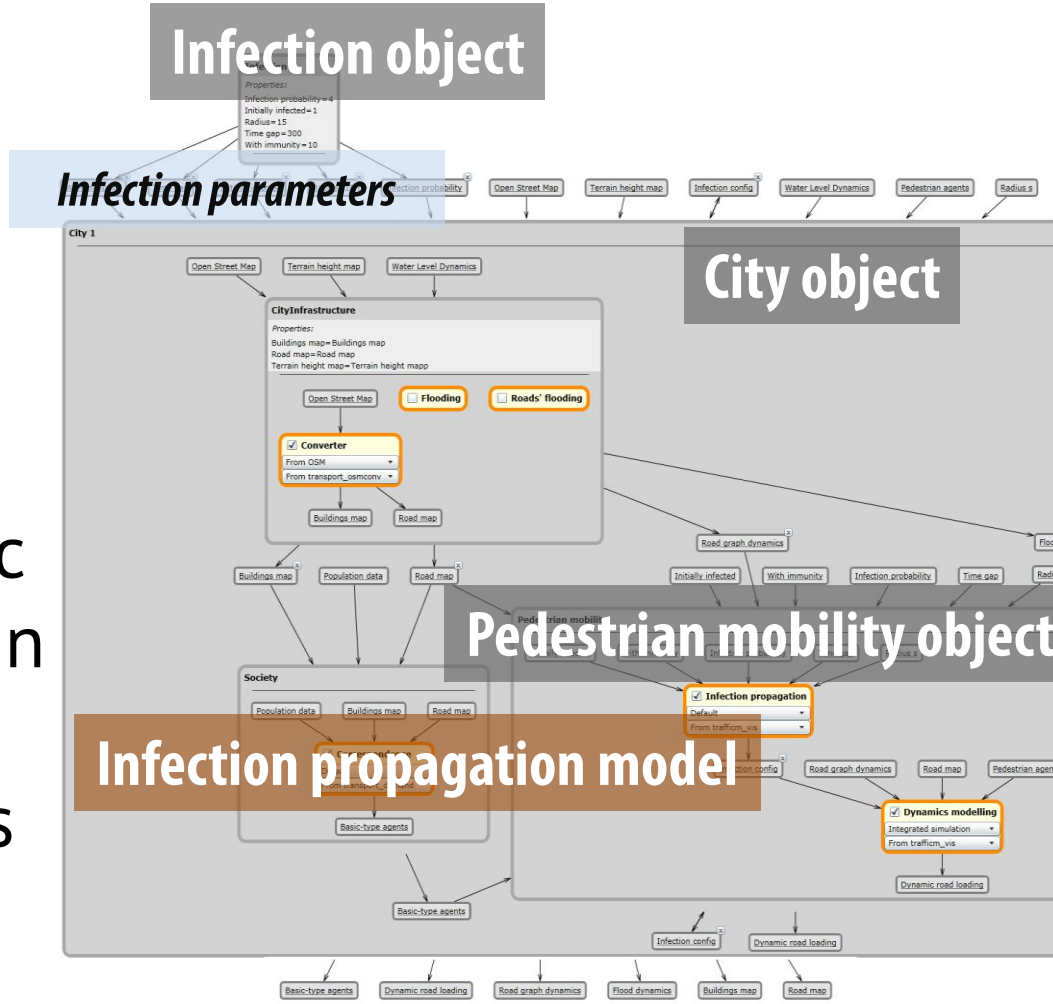
Flood dynamics data

Traffic model coupled to flood model

Example 2: Complex Visualization

Application: **Infection propagation in urban environment**

- Data analysis from different perspectives
- Several domain-specific visualization software in parallel
- Data from simulation is streamed to visualization packages



Traffic Simulation Package

Agents data streaming

Infection transfer data streaming

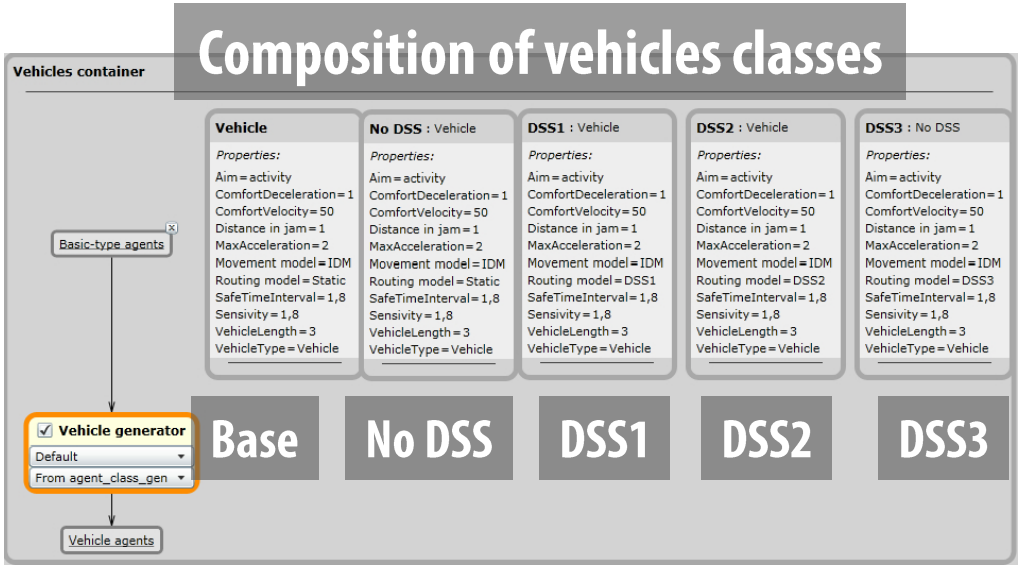
Infection propagation dynamics visualization

Infection transfer location dynamic heatmap

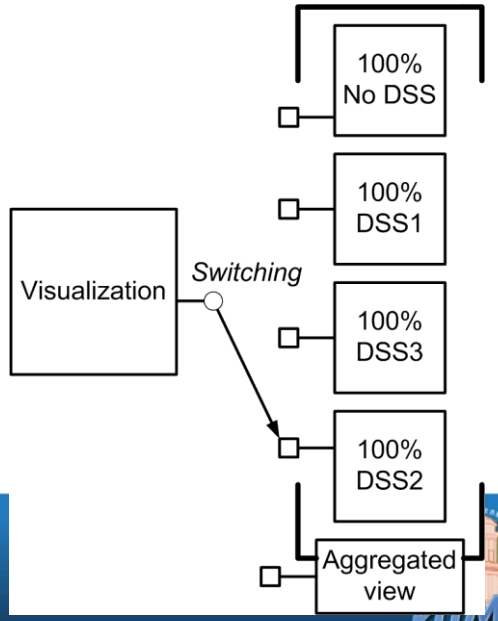
Infection Transfer Chains Analysis UI

Example 3: Model ensemble management

Application: **Evaluation of DSS in flood evacuation with use of transport**



- Ensemble element – model with certain agent composition (100% DSS1, 100% DSS2…)
- Ensemble manager component controls the models in ensemble
- Move visualization focus between models
- Special aggregated data view with statistics on models in ensemble



Ensemble of vehicular models with different DSS

Conclusions

1. The implemented applications showed the capabilities of the proposed solution to meet the challenges base
2. Used technologies provide ***user*** with ***support*** on each phase: modeling, simulation, analysis
3. System-level science approach with use of VSO leads to ***simplification*** of model ***composition*** phase comparing to workflows, but limits the packages' use cases
4. Interactivity requires ***optimization techniques*** to be applied (batch packages interactive wrappers, user activity prediction to create ensembles in advance)
5. The technology depends on the consistency and completeness of ***domain semantic*** storage
6. New approach to the ***user interface design*** for environment should be used. Standard "forms" doesn't represent interactive capabilities well

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Questions?

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