Component-oriented Approaches for Software Development and Execution in the Extreme-scale Computing Era

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Overview

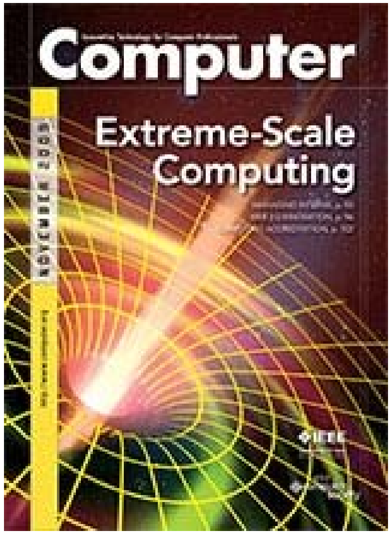
- Background – software crisis
- New challenges in the extreme-scale computing era
- Example component framework overview - GCM
- Problem-to-solution development pipeline
- Component-oriented integrated environment
- Case studies: Developing component-based codes, Componentising existing applications, Wrapping legacy codes
- Future research topics and conclusions

Background – Software Crisis

- Software vs Hardware – short-term and long-term issues
- Software crisis – legacy code and software development cycle problems
- Particularly difficult in fast developing and changing complex computer systems
- Need much shorter development cycle in order to be able to catch up with the pace of development of underlying hardware
- Need methodology for quickly adapting/porting legacy code

New Challenges – Extreme-scale Computing

- Where ‘just more of the same’ does not work
- We need to improve (in no particular order):
  - degree of parallelism,
  - performance,
  - cost,
  - footprint,
  - power,
  - reliability,
  - programmability,
  - productivity, etc.

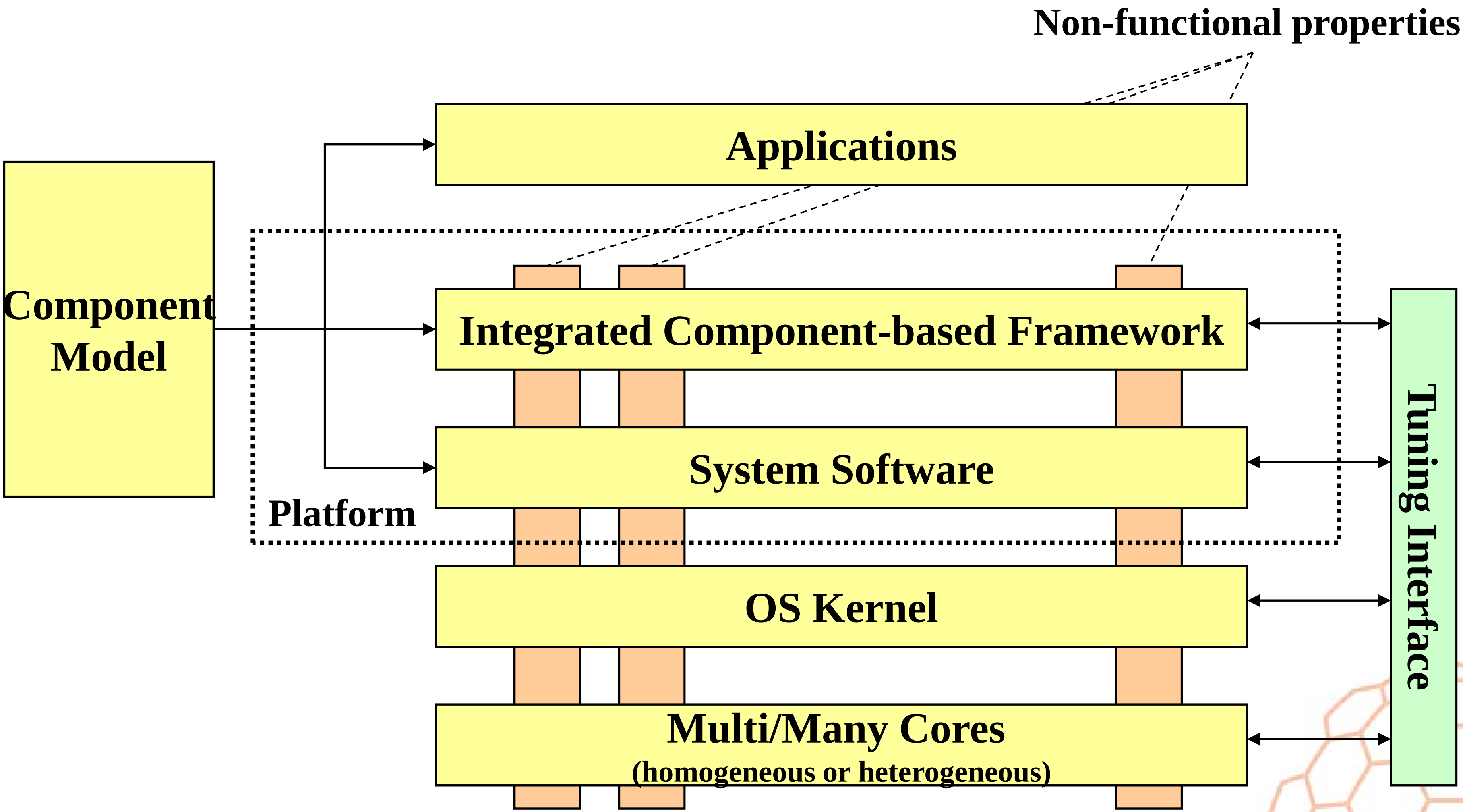


- The complexity is qualitatively harder and multidimensional – addressing this unprecedented conundrum of challenges is called ‘Extreme-scale Computing’.

Component-based Platform

- The new challenges require major breakthroughs in hardware and software – e.g. the introduction of multi/many core architectures.
- The higher level of complexity involves a wider range of requirements and resources → Dynamic intelligent properties and flexibility → Component-based design methodology
- To develop the design methodology of a generic component-based platform for both applications and system frameworks to have a single, seamless, “invisible” system image.

Component-based Platform Architecture



Example Component Framework Overview

Starting point: Fractal component model.
The main technical features of the component framework are:

- Support for primitive and composite distributed components and hierarchical composition.
- XML based architecture description language (ADL).
- Collective interfaces to comply with specific multi-way communication requirements.
- A comprehensive runtime API.
- Support for non-functional aspects such as component control, skeletons, and autonomy.
- Advanced component scheduling/deployment via the notion of virtual nodes and deployment descriptors.

GCM and GridCOMP

GCM

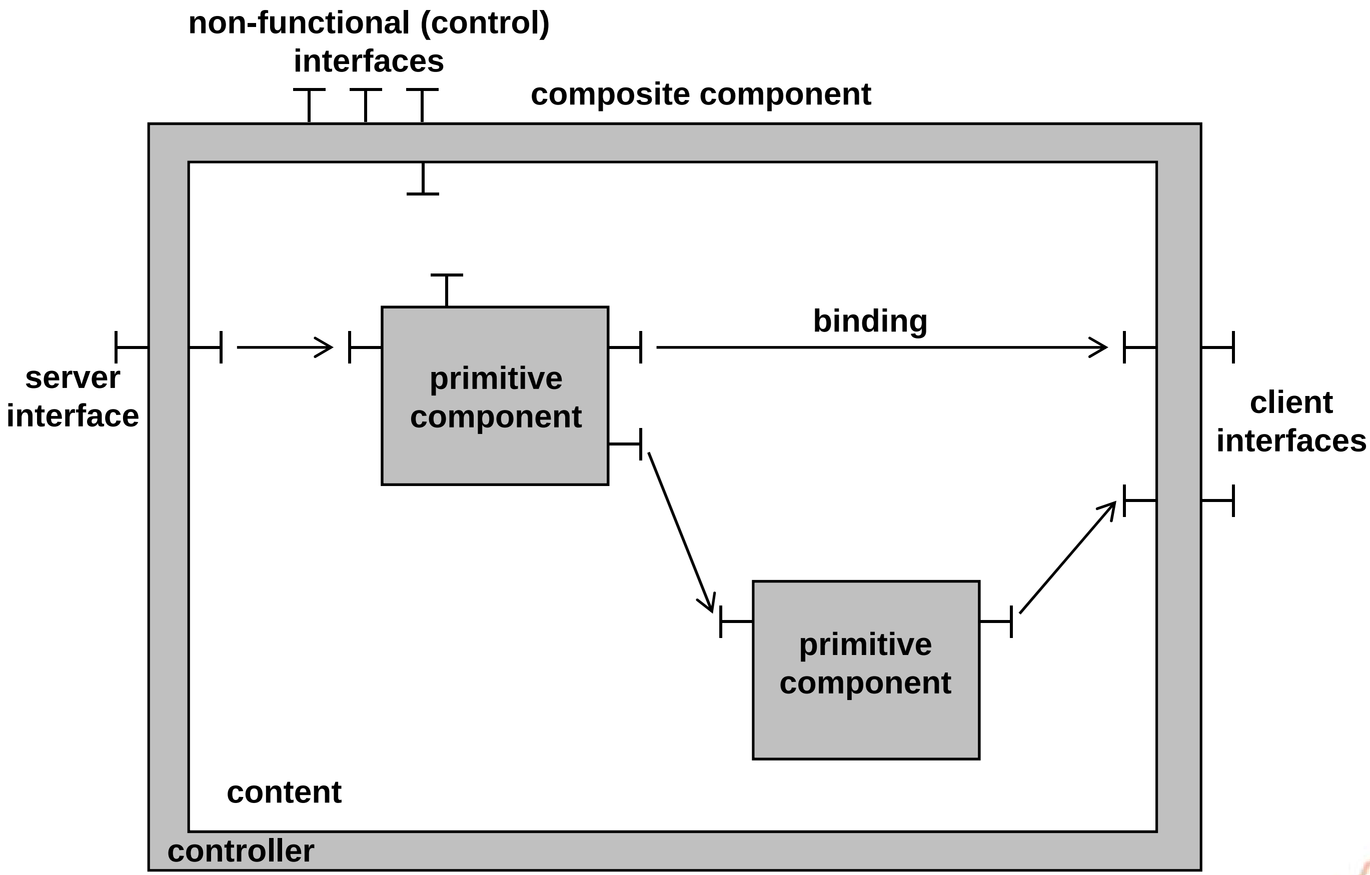
- **A new advanced Grid Component Model (GCM) providing high level of abstraction and specifically designed for large scale dynamic Grid infrastructures.**
- **Specified within the CoreGRID Euopean project.**

GridCOMP

- **EU project: Grid programming with COMPonents.**
- **INRIA, ERCIM, Univ Westminster, Univ Pisa, CNR, IBM ZRL, Atos Origin, Grid Systems, Tsingua Univ, Univ Chile, Univ Melbourne**
- **Design and implementation of a Grid component framework based on GCM.**
- **Includes the development of a Grid IDE and several use case applications.**
- **Middleware reference platform implementation.**

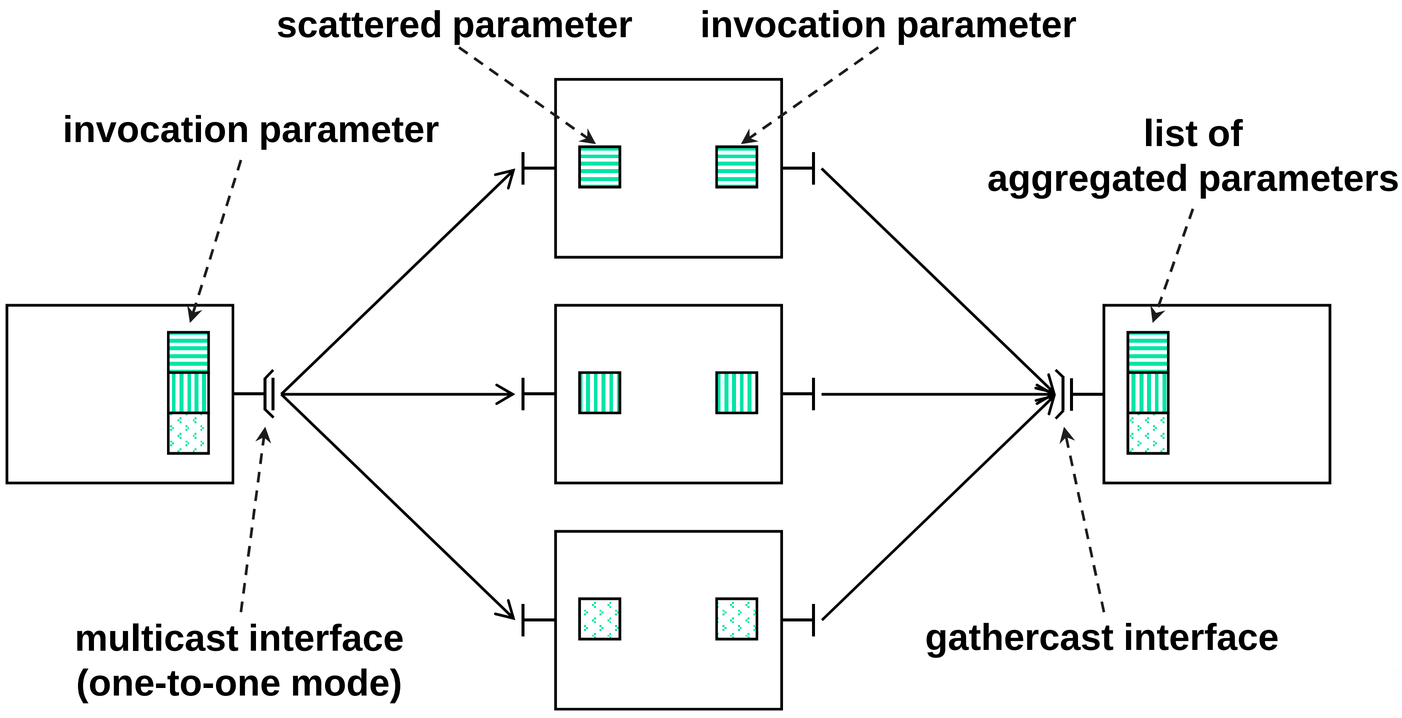
GridCOMP Component Framework Overview

Hierarchical composition: all three components can be distributed



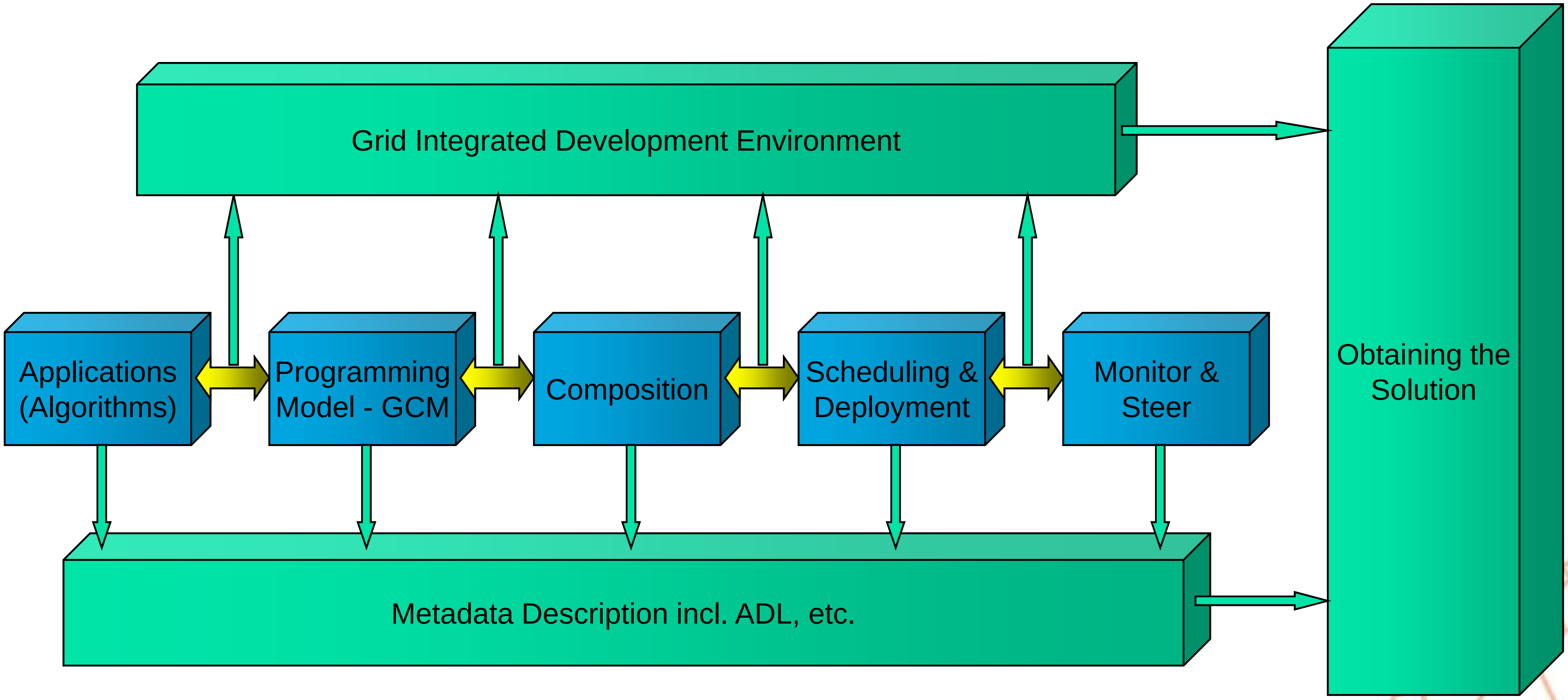
GridCOMP Component Framework Overview

Collective interfaces: The framework takes care of parallel invocations, data distribution, and synchronization.



Component-Centric Problem-to-Solution Pipeline

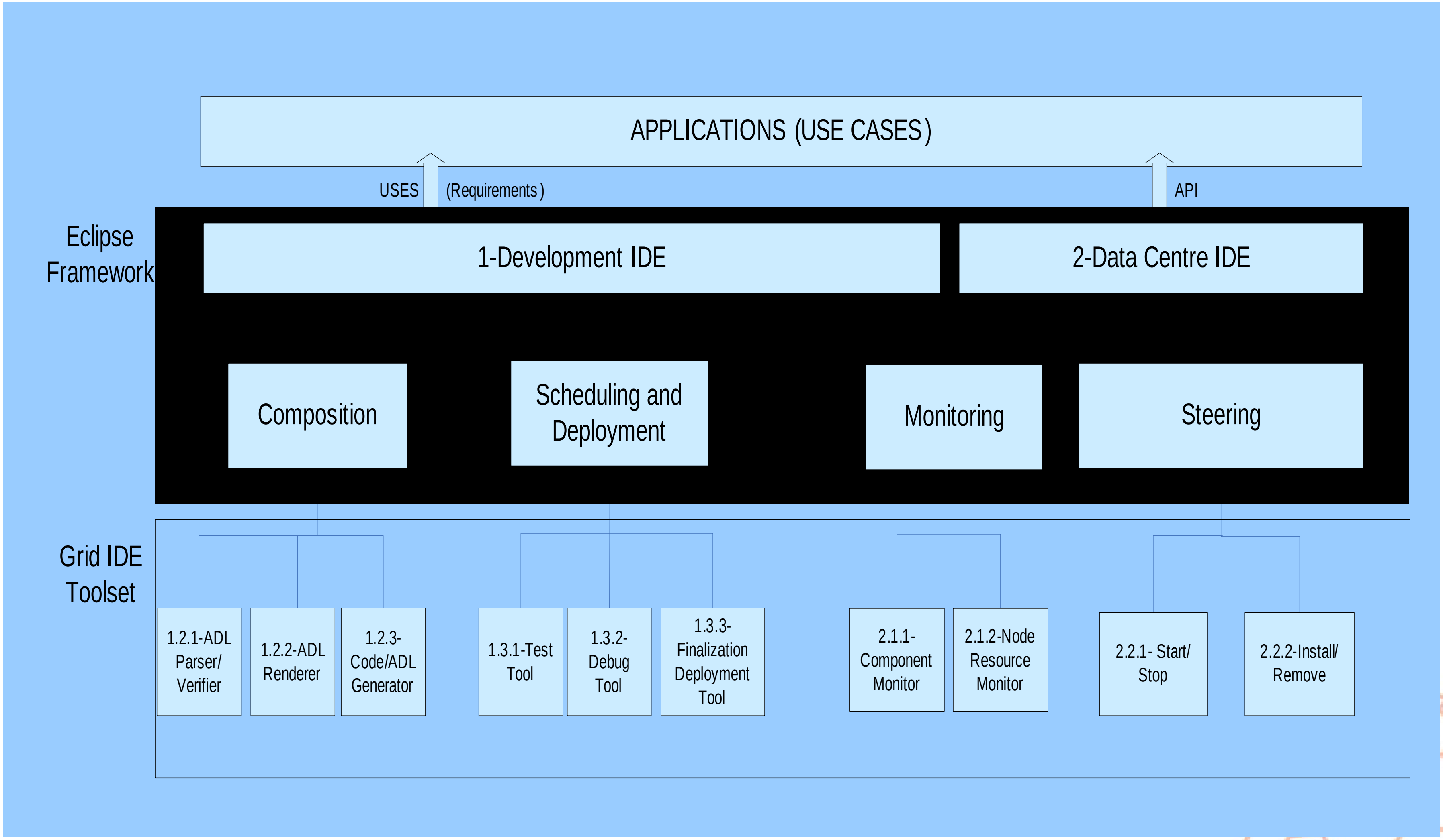
- Main issues: composition and dynamic properties – deployment, monitoring and steering
- Component-based Grid platform design methodology



Strategy: Eclipse Framework for GIDE

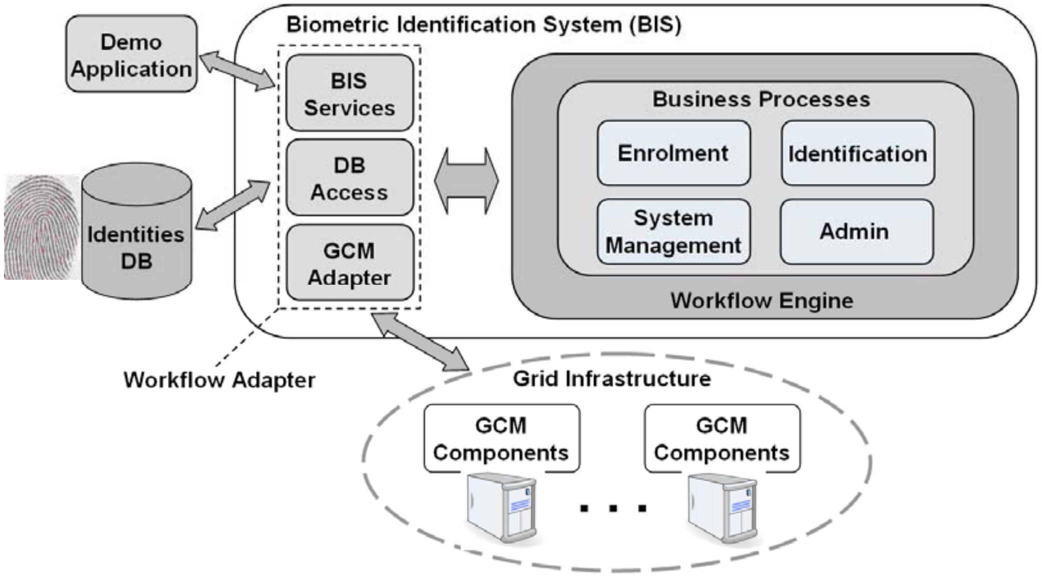
- Simplify complexity through graphical composition/tools
- But, allowing ONLY graphical composition can be inflexible and inefficient
- Support for 3 levels of Development
  - Graphical Composition
  - Based on GCM and using ADL
  - Source code level
- Seamless integration with Eclipse
  - Widely supported with many potential plug-ins

Grid IDE Architecture - Core Block Diagram



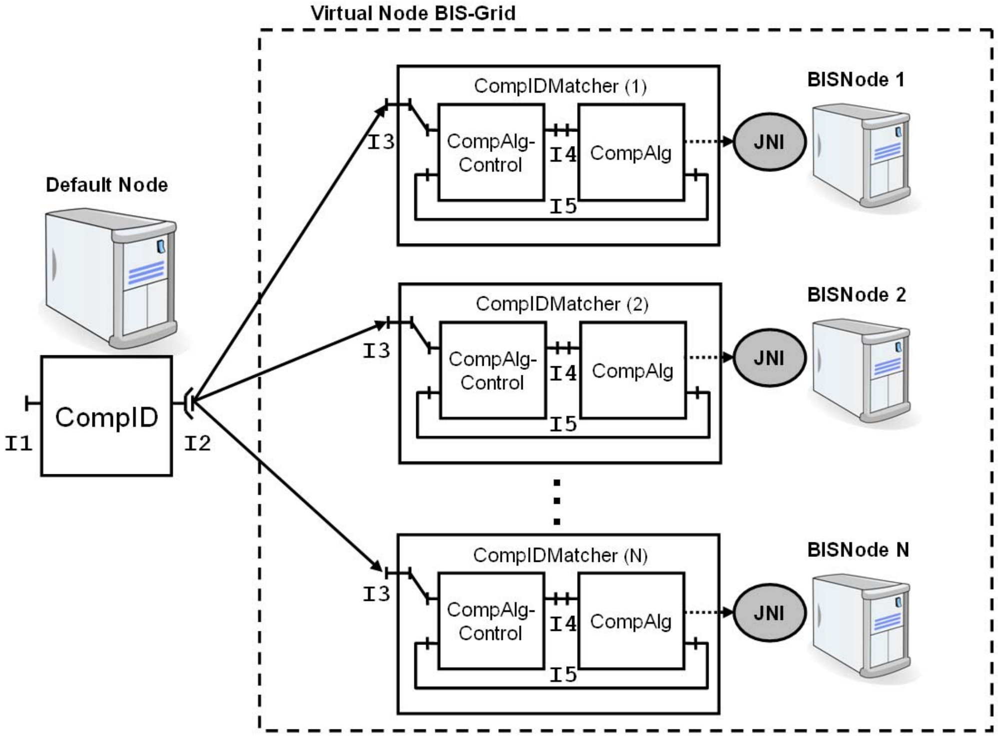
Case Study: Biometric Identification System (BIS)

- **Identify people solely on their biometric information (1:N match)**
- **Use fingerprint biometrics**
- **Consider multiple fingers per person to work reliably on large user population**
- **Use distributed matching to achieve real-time performance**
- **Based on business process (workflow) engine for adaptability**



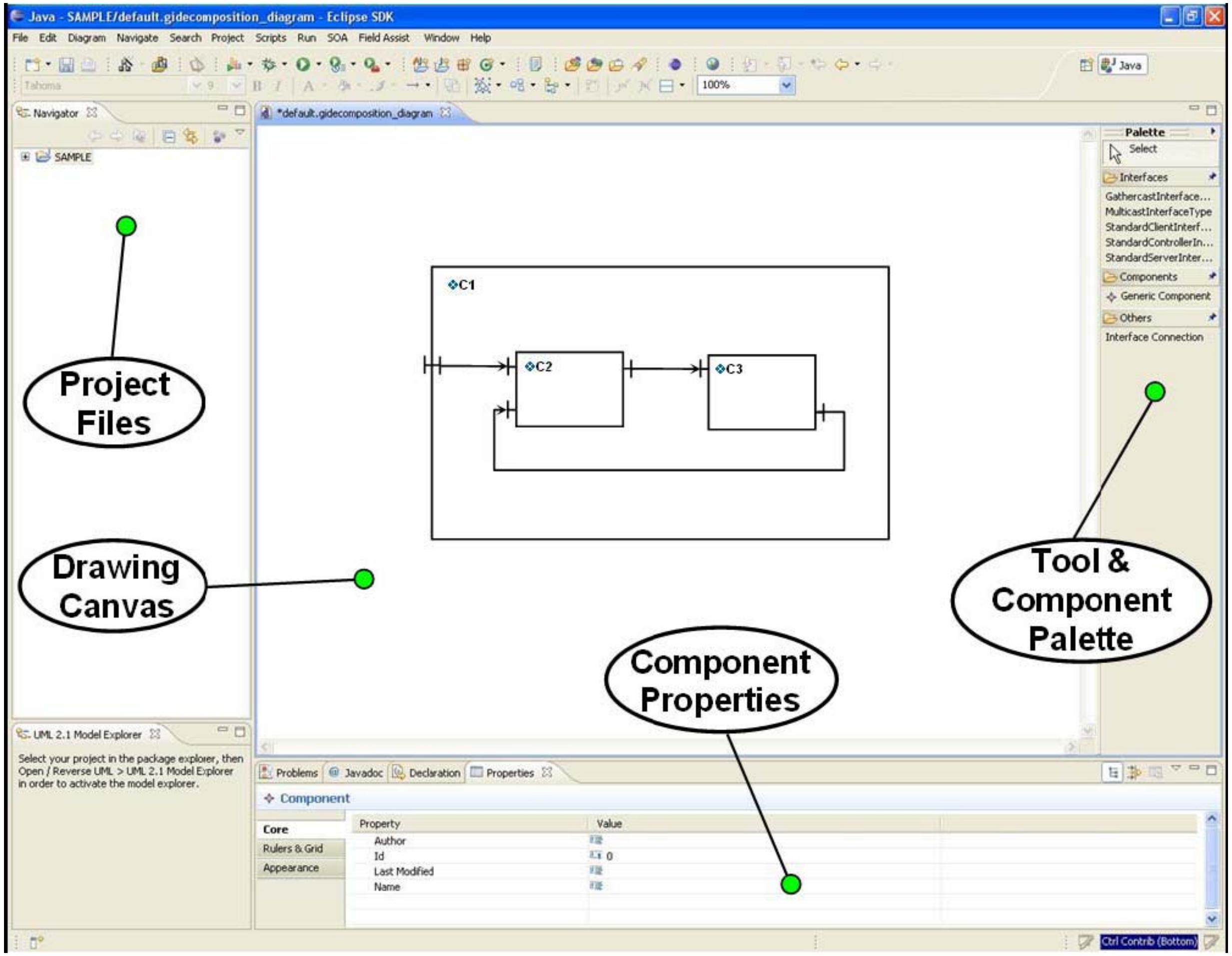
Case Study: Biometric Identification System (BIS)

Grid component architecture, bindings, and deployment



1. **Biometric matching component *CompIDMatcher* is deployed on each node**
2. **DB of known identities is distributed across the nodes**
3. **Identification requests are broadcasted via multicast interface I2**
4. **Each node searches its part of the DB**

Development – IBM ZRL BIS Use Case

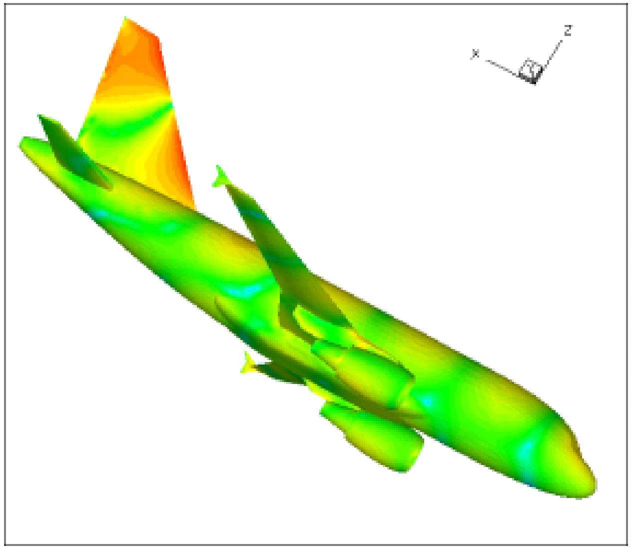


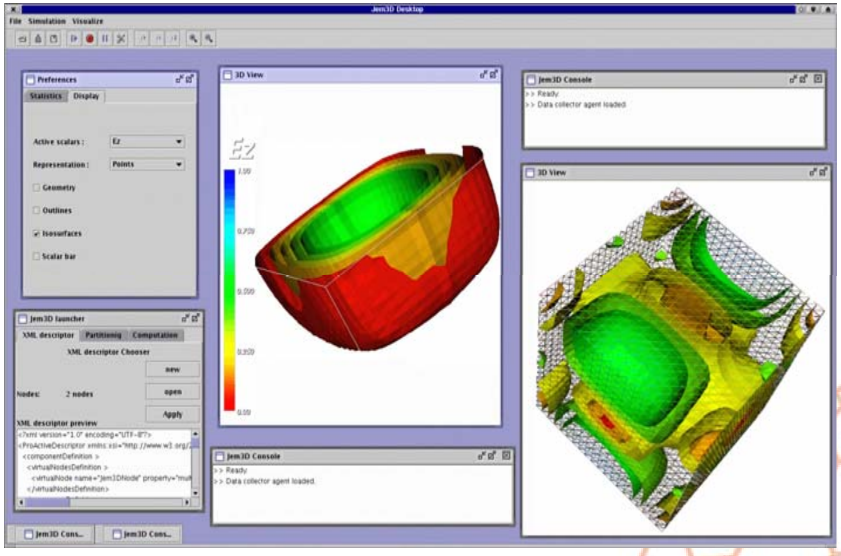
Componentizing existing applications

- Methodology: – manual with on-going activity on identifying parts for automatic support and tools
- Sample Code: Jem3D – 3-dimensional Maxwel’s equations solver for aircraft wing design
- Experimental Results: Componentising a Scientific Application – Jem3D

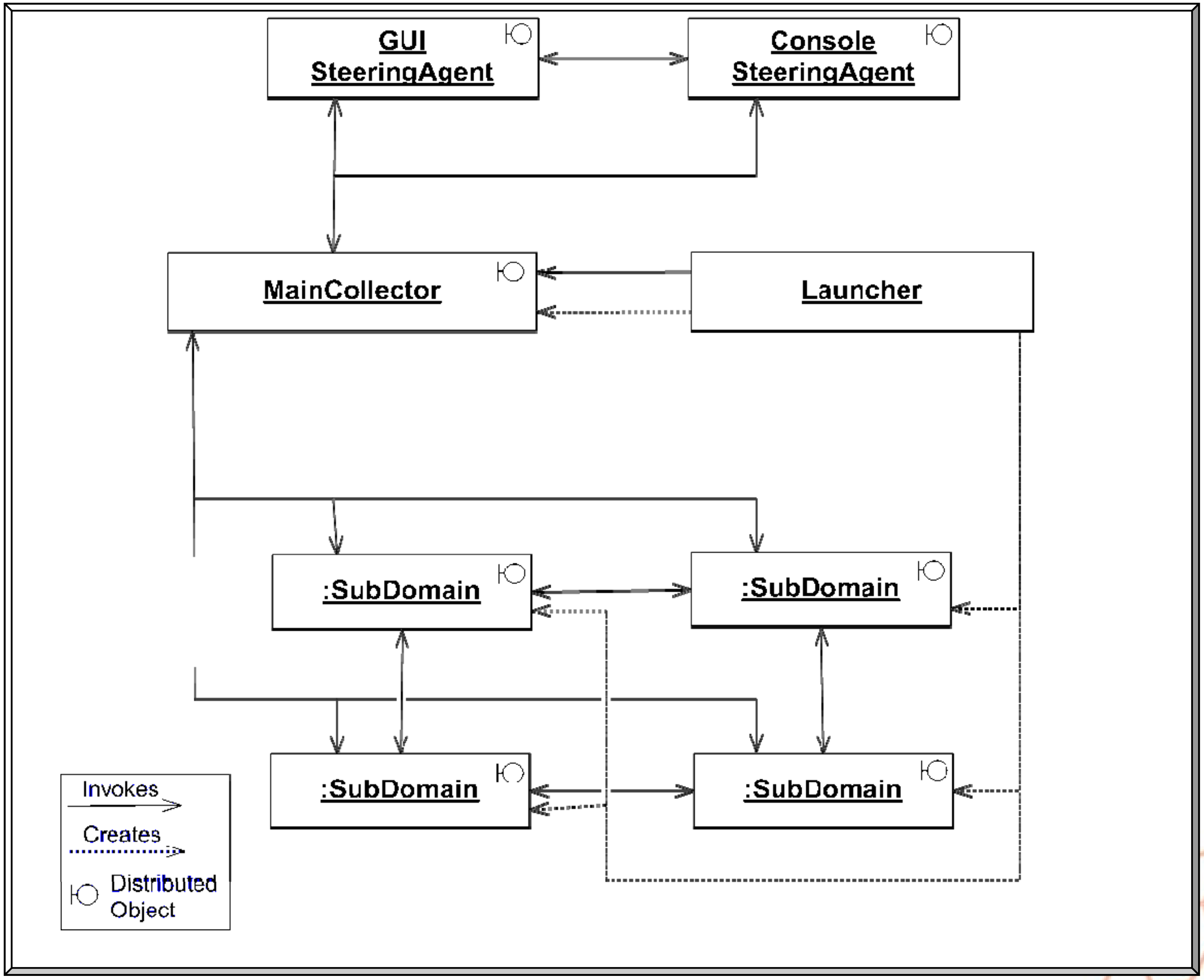
Componentising a Scientific Application – Jem3D

- numerical solver for the 3D Maxwell's equations modelling the time domain propagation of electromagnetic waves
- follows typical "geometric decomposition" parallelisation





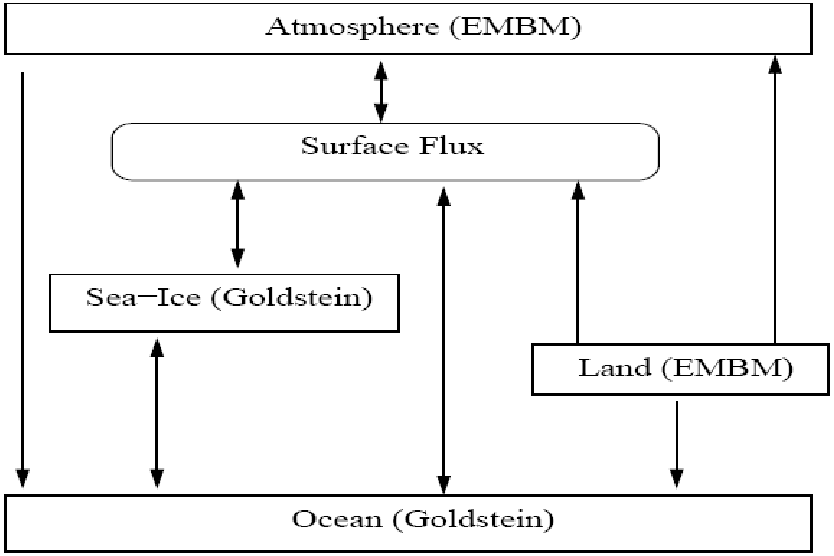
Jem3D Architecture



Wrapping Legacy Software

- Methodology: (semi-)automatic or manual
- Sample Code: GENIE Application (Environmental Modelling)
- Motivation: Enable legacy applications to evolve as a part of the scalable problem solving environments within modern Grid systems.
- Framework: Componentising existing applications along with domain-specific metadata so that issues arising thereof can be addressed using this metadata.
- Experimental Results: Domain-Specific Metadata for Model Validation and Performance Optimisation

Domain-Specific Metadata for Model Validation– Legacy Applications



GENIE is an interactive, legacy code for Earth system modelling. Our hypothesis is that componentising the application and using domain-specific metadata will help transforming it into a scalable yet efficient software system.

Summary

- Productivity based on higher level of abstraction
  - Enables the use of new modern technologies such as graphical composition
  - Source code generation
  - Repositories for components re-use
- The use of behavioural skeletons reduces further the development effort
- Optional features
  - Dynamic composition validation using OCL
  - Static composition validation while generating final ADL file(s)
  - Domain-specific validation
  - Dynamic verification
- GIDE prototype - an Eclipse plug-in using GMF.

Conclusions and Future Research

- Created the core framework using Eclipse
- Robust and friendly
- The full prototype of the GIDE toolset has been completed
- The hierarchical component composition results are promising – higher development productivity and easier software components re-use
- Develop the design and development methodology for building modern component-based software

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