Numerical simulation software integration with TENT
Software Integration and Workflow Management
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Introduction

Workflows

- Today, many problems require **complex numerical simulations**. Examples:
  - Re-entry simulation of space vehicles
  - Aero dynamical and aeroelastical analysis of flight maneuvers
- Performing such simulations is **software technologically** complex
  - Invocation of many different codes *in correct order*
  - Usage of high performance computers
  - Transfer of data between the different codes
  - Collaboration with colleagues
- Complex simulations are **Workflows** of many codes:
What is TENT?
Answer for Users

TENT is an integration and simulation environment for engineering applications.

Essential features:

- Easy setup and configuration of simulation workflows with integrated applications
- Usage of distributed computing resources
- Online steering and visualization
- Project-based data management with support for cooperative working
- Multidisciplinary coupled simulations
What is TENT?
Answer for Computer Scientists

TENT is an *open and extensible framework* for tool integration and workflow management.

Essential characteristics:
- Component based
  - CORBA Peer-to-peer model
- **Extensible** Java-GUI
- Distributed computing (Grids)
- Flexible integration of existing tools
  - Large development library
- Data management
  - Open solution (WebDAV & XML)

Development based only on accepted *standards*
- CORBA, LDAP, FTP, HTTP, WebDAV, XML, ...
System Architecture

System components:
- Data Server
- Factories
- Name Server
- Coupling
- Scripting

System components:
- GUI
- Plug-In
- Scripting

Applications:
- Wrapper
- Wrapper
- Wrapper
- Wrapper

Applications:
- CFD
- CSM
- Visualization
- Filter
This page will help familiarize you with the TENT system. To get started, read the sections below and click on the related links.

Create a Simulation
To start, first [connect to a project]. Next create a Simulation within that.
Example GUI Plug-In

2D-Plot
Monitoring

![Monitoring Graphics](image_url)

- Options
- Calculation Step
- Calculation Step
- Calculation Step
- Calculation Step

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Distributed Computing

CORBA

Factory

Cluster (LSF, NQS, ...)

Divisions-/Companies

Workstation / PC

Local Server/Workstation

Grid

Worldwide

GUI

TENT-Factory: (CORBA-)Server for starting programs
Integration of Applications

Wrapper

Wrapper (application specific)

Application

Start

Control, Properties

CORBA-Interface

CORBA

Other TENT component

Other TENT component

Control
Integration of Applications
Wrapper Library (SDK)

- Wrapper development in Java or Python
- Some features
  - Generation of input files
    - Templating (replacement of parameters)
  - Parsing of result files
    - Extraction of values
    - General filter mechanism
  - Execution
    - Remote execution
    - Application control via pipes, TCP/IP sockets, CORBA, ...
- Wrapper code can be generated…
Integration of Applications
Automatic Generation of Wrapper Code

- To **reduce the effort** and **minimize coding errors**
- TENT specific Eclipse plug-ins for:
  - Generating new wrapper code
  - Extending existing code
Communication

- Control flow
  - Events and method invocations through CORBA

- Data flow
  - Small data set as parameter through CORBA
  - Massive data through GASS, FTP, GridFTP, Socket, ...

![Diagram showing control and data flow through CORBA interfaces](image)
Data Management
Project and Workflow Structure

- Free hierarchical structure of projects and data:
  - Cooperative working
    - User management and access control
    - Data exchange via data server
    - Similar to PDM systems
      - Check-Out, Check-In
Data Management
XML & WebDAV

Concept
- Storage of project data in XML format on a server
- Access to data using the standard protocol WebDAV

WebDAV: *Web Distributed Authoring & Versioning*
Extension of the HTTP protocol (locking, meta data, versioning, search, and access control)
Data Management
Data Provenance

- **Provenance** is information in addition to the standard logging which helps answer questions about origins of data

- Typical such questions are
  - Given some data item, what was the simulation case?
  - Given some parameter, in what simulation(s) has it been used?
  - What data has been recorded in a simulation with a specific parameter?
  - What simulations have been run using a given model (aircraft design)?
  - Given two/more simulations with the same setup, what is the result and the difference in provenance?

- TENT has integrated a provenance storing and querying service (developed in the EU GRID PROVENANCE project)
Scripting
Integration, Control and Automation

Applications do not have everything, so scripting is needed.

- Usage of scripting in TENT
  - Integration of applications
  - Workflow control (loop constructs, conditional constructs, coupling control)
  - Test scripts for quality assurance automation
  - Debugging
  - Command journaling

- Technique
  - Embedded Python interpreter
  - Script interpreter in the GUI
  - Script console in the GUI
  - Scripting block in workflows (control and code integration)
Application Systems

Space reentry vehicles

Turbine engines

Automobile design

Flight maneuvers

aerialcraft

Application Systems
Example Application 1
Flight Maneuver Simulation

- Interactive simulation environment for the simulation of a freely flying, fully configured, elastic warplane
- Project SikMa: X-31
Flight Maneuver Simulation Model

- Simplified model for wind tunnel experiments
- Simulation for validation of experiments

PSP Measurement: Re=2.07 α=18°

τauce: Re=2.07 α=18°
Flight Maneuver Simulation Results

- Coupled simulation: Aerodynamic – flight mechanics – aeroelasticity
- Computing times: ~ 7 days on large computing cluster (> 64 procs.)
- Important: Online monitoring and restart capability
Flight Maneuver Simulation Integration in TENT

Coupling Control

Wrapper Aero elastic

Wrapper flight mechanics

Wrapper fluid dynamics

Aero elastic (MATLAB)

Structure solver (NASTRAN)

Flight mechanics (SIMULA)

CFD solver (TAU code)

HPC machine

CORBA Files

Filetransfer

Data

IPC

Host/Files
Flight Maneuver Simulation - Deployment

Desktop machine

GUI

Visualization

Filetransfer

Programmstart

Filetransfer

TENT-Daten/Monitoring

Host/Filesystem

Netzwerk

Desktop machine

Wrapper Flight mech.

Coupling Control

Wrapper CFD

Server

Batch-System

TAU Code

Cluster

Data server

Flight Maneuver Simulation - Deployment
TENT

This page will help familiarize you with the TENT system.
To get started, read the sections below and click on the related links.

Create a new Simulation
To start, first select a project or create a new project. Next create a Simulation within that.
Flight Maneuver Simulation
Online Monitoring of Results
Example Application 2
Space Re-Entry Simulation

- Simulation of thermal heavily loaded parts of the X-38 space re-entry vehicle
- Fluid-Structure-Thermal coupling
Space Re-Entry Simulation Model

- Simplified model for wind tunnel experiments
- Simulation for validation of experiments
- Focus on flaps and gap
Space Re-Entry Simulation
Results

- Coupled simulation
  - DLR-TAU code for aerodynamics
  - ANSYS and MSC/NASTRAN for heat transport and deformation in the structure
Coupling with TENT
Use of coupling library MpCCI

- TENT GUI
- CORBA
- Visualization
- Filetransfer
- MpCCI
- IPC
- Host/Filesstem
New Technologies
Technology Upgrade for TENT

- **TENT used modern technologies of the past 10 years**
- **Technology upgrade for the next 10+ years in project SESIS**

### TENT
- GUI with Plug-Ins (proprietary development)
- Single role for all users
- Single communication protocol (CORBA)
- Authentication with user name & password
- File-based data management
- Modularity in sub systems

### RCE (Project SESIS)
- GUI Plug-Ins Framework (Eclipse)
- Multiple user roles
- Various protocols (Web Services, Java RMI, CORBA, …)
- Authentifizierung with certificates (single-sign-on)
- Data management with complex data structure (and files)
- Everything is modular

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Project SESIS

Goals

*Design in 7 Days* in a virtual organization

- Early ship design for creation of offers
- Reduction of design times
- Distributed design und simulation
  - Shipyards organizing ship building process
  - Integration of supplier in design process

Quelle: Flensburger Schiffbau-Gesellschaft mbH & Co. KG
Project SESIS
System Design

- System designed with a **Plug-In architecture** based on the **OSGi** platform
  - RCE (Reconfigurable Computing Environment)
- Advantages
  - Consistent modularization
  - Good extensibility and scalability
  - Specificity by configuration
  - Use of many existing Plug-Ins (see *Eclipse!*
Project SESIS
Base-System Layer

- Usage of databases and Grid middleware solutions
- SESIS supports
  - Communication
  - Updates
  - Privilege management
  - Services discovery

Installation of identical base system on every machine
Specificity by loading additional plug-ins
Usage Scenario
Virtual Organization
SESIS Graphical User Interface

Eclipse RCE w/Plug-Ins