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CONFIGURATION OF INFORMATION AND ANALYSIS METHODS: A SUMMARY

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ABSTRACT

Complex problems inspire researchers around the world to combine data, numerical modelling and methods for integrated environmental and socioeconomic modelling from different backgrounds. Several researchers have, however, chosen techniques to link these resources. This established an apparent wide variety of interfaces and frameworks: some of them use low-level interfaces; others are more abstract and object-oriented, some systems may require few or no changes to the code, others favour the basic rewriting of code. So why do we all use so many settings if the data, models and tools are connected? The basic idea is to deal in different approaches with so-called conflicting requirements, like generality, flexibility, ease of use, accuracy and performance. How do the various techniques work? In this study the common architecture of components (CCA), EMS (ESMF), FRAMES, Objet Modeller System (OMS) and Open MI are investigated. The following questions were considered in this article. Are they really inconsistent or substantially complementary?

Keywords:"integrated modeling, frameworks, interfaces, interoperability"

1. Introduction

"A variety of disciplines are merged with the environmental studies, such as science, hydrology, geomorphology, geology, chemistry and ecology. A wide range of models in these and other fields must be merged in order to meet current and future challenges. Traditional (sub) universal numerical models in interoperability have generally not been built (especially not beyond the scope of the initial developers)." In the field of information technology and semantics, there have been various "new" problems to interplay between scientists, information systems, models and tools across the disciplines, such as: what data may be communicated, what exchange should be done, and what is it? The (relative) isolation of many research communities around the world has addressed these problems, resulting in different practises, methodologies, standards, interfaces and standards. With international cooperation growing (particularly because of a few researchers and combined research patterns and toolboxes), we reach points of reference(Gladwell, n.d.)So how different are these approaches?

“To avoid confusion, the follows definitions which have been loosely based on the corresponding Wikipedia descriptions.

- **Architecture**A concise overview of the layout design general parts of a framework is architecture
- **Component**is a software package or module containing a range of linked features. Science components are often a cohesive physical process subdivision for the complete (or part of) domain of the simulation.
- **Environment**is a collection of central software (infrastructure) services used to initialise, start and complete the simulation components. In communication between separate components, the environment may or may not play a major role.
- **Framework**is a software architecture reusable implementation. It comprises an environment of runtime, library support, components, interfaces and conventions. It includes one or more parts.
- **Interface**is a formal and abstract specification of a component's functions/methods that can interact with the run time environment and other components..
- **Implementation**is an architectural or abstract component realisation.

- **Coupling**means the transference of data between components (sequential or parallel) at runtime. This may occur in memory or through intermediate data files."

2.CCA – Common Component Architecture

In 1998, the CCA Forum1 was established to set a standard for a high performance scientific architecture of components which contain HPC characteristics not accessible in other general component architectures such as "CORBA, COM.NET and JavaBeans. The CCA requirements are aimed to ensure (1) component performance is maintained, (2) component communication mechanisms are not exclusive to the intercomponents, (3) component parallelization is available and (4) pre-component and execution configuration is permitted In CCA, the Scientific Interface Definition Language (SIDL) is used to specify the language interface of a given component, to define ***use*** and to ***supply*** routine argue ports, such as the scalars, the arrays or the functions of the ports. CCAs are intended for the creation of a framework (2) communications, security, thread creation and management, memory management and mistakes, (3) instantiation API configuration for and couple of components, and (4) repository API access to component repositories. The framework should include: (1) SIDL support for generating actual component interface wrapper. The Babel devices are de facto standards to create the 'glue' wrapping code to enable plug-in interoperability between procedures written in Fortran, C, C++, Java or Python."(Kumfert, 2003)

A command-line utility and a graphical user interface allows configuration of the primary CCA-compliant Ccaffeine Framework that was built for parallel computing. CCA has demonstrated its interoperability with "ESMF and MCT and successfully coupled the Caffeine framework with the OpenMI 1.4 Java implementation by CSDMS developer2.

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TASCS3 are the current lead of CCA developments"(Bernholdt et al., 2006)"This virtual organisation is sponsored via SciDAC Energy Department's Scientific Discovery (SDAC) programme"

3.CHyMP – Community Hydrology Modeling Platform

"CHyMP is an endeavour of the CUAHSI Consortium to develop, deliver and support advanced simulation modelling in the Academy within the community-based 'development/user feedback' structure. This project has been started yet it aims for several important hydrological model communities to create and deploy (contrary to the wide variety of smaller, incompatible and unsupported models that exist today). The CHyMP is strongly connected to the focus group of CSDMS Hydrology. However, the programme should not be confused with the construction of a statewide Early Warning System for the Delft - FEWS National Weather Service (NWS) (CHPS). This requires a strong strategy and uses single-way data streams for file-based information transmission most of the time."

4. ESMF – Earth System Modeling Framework

ESMF is an effective framework to increase climatic interoperability and reusability, digital forecasting and software data assimilation. ESMF supports super coupling and architecture of utilities; MPIs and opened MPs are supporting parallel(Donchyts et al., 2010). The component code lives on both levels and is called up and scheduled by the infrastructure libraries below. The layer consists of type, time, clock, alarm, parallel data and logging tools, etc. Coupler parts (physics and dynamics) are split into grid components (interpolation and mapping). Input and output arguments are combined into the input and output data structures. All components need the initialised, performed and final methods. The internal status of components can be optionally used. Arrays, field bundles and other States can be stored in these countries. A multi-dimensional array is disseminated that contains

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information types, ranks and the associated halos. Components may be wrapped in an ESMF Array structure for the adoption of ESMF in your current Fortran/C arrays.(Craig et al., 2005)A field is a scalar or vector physical field: it has data from the grid plus a metadata array. In a more elevated hierarchy, connecting components and grided components can be organised into grids that can be linked with other components. The drive module and the associated components usually have a single executable connection. Unix, Linux and Windows HPC are supported for ESMF. ESMF development covers (a) integration and viewing of modelling environment workflow management services; (b) automated connectivity, metadata production and execution, (c) online services, and (d) support for wide range of networks and digital techniques. The ESMF is funded by the United States Defence Department, NASA, NSF and NOAA Environments and Interoperability group through one-way connectivity from ESMF to OpenMI (NESII).

4. FRAMES – Framework for Risk Analysis of Multi-Media Environmental Systems

"FRAMES is a US Environmental Protection Agency's (EPA) operational modelling environment where models and modelling tools (e.g. data recuperation, analysis) can be collected and interacting." A FRAME employs preset link schemes and dictionaries to ensure the proper linkage of end-users of the components. 3MRA8 consists of a set of 17 modules put in FRAMES that mimic, in conjunction with various land-based waste handling units, discharge, fate transportation, exposure and risk (human and environmental) (e.g., landfills, waste piles). The results of the model are based on ten thousand separate simulations due to its many processes and characteristics(Lloyd et al., 2011). The components of 3MRA rely on very simplistic formulations for each domain, which is the contrary of the climate model components linked by frameworks like ESMF, to keep the total simulation duration within limited limitations. Nevertheless there is a rising desire for more detailed representations. For FRAMES v3, a (optional) quicker two-way communication method in memory will be substituted by the present one-way file-based communication approach. This is required for complicated model components and more complex component interactions (which result in greater data interchange). This new type of connection is OpenMI based.

5. HLA – High Level Architecture

"The High Level architecture (HLA) is the general purpose architecture for distributed real-time training/simulation environments developed by the defence modelling and simulation bureau (DMSO) of the US DoD. Typically, this concerns closely connected networks where frequent but often tiny data transfers occur. The HLA baseline definition was finalised in 1996; the IEEE 1516 standard was ratified in 2000. It defines a common method of recording information and defines a.o. a federative object model (FOM: exchange of data during simulation) and a simulation object model (SOM: description of components/federate a simulation object model). a.o." It defines the architecture (runtime infrastructure, Federated and environment components' interfaces) and an object model (OMT). (OMT) The exchange of data takes place through RTI.(Krause, 2002)

"HLA is not an implementation; it just provides an architectural sketch. The existing HLA RTI implementations (by a.o. Raytheon, MAK, Pitch, and http://sourceforge.net/projects/ohla/) are not 100% compatible because the IEEE standard contains some errors and doesn't fully prescribe the interface implementation. A dynamic link compatible (DLC) API has been defined (SISO-STD-004.1-2004) to make the implementations more consistent. All compatibility issues should have been resolved by the new HLA Evolved IEEE 1516-2010 standard"

6. Kepler

Kepler provides a global workflow environment that enables a number of scientific and engineering areas like time, discretion and dynamics to apply the dynamic and parallel data flow concepts. The application enables the user to graphically assemble workflows through the use of direct sequence graphs (actors). It is a Java-based software. Kepler provides the standard library of 350 players for a variety of tasks including digital integration, image processing and Web access capabilities, typical read and write files, charting and execution of external command line applications. The software is administered by a team of Davis, Santa Barbara and Universities of San Diego.(Lloyd et al., 2011)Taverna is a similar Java-based workflow system created by the OMII part of the University of Manchester, Carole Goble. in my Grid project..

7 MCT – Model Coupling Toolkit

MCT is an MPI collection of Fortran90 modules that can be used to construct grid parallel integrated templates (both structured and unstructured). Version 2 of the toolkit has been designed to build and use the CCSM3 cp community climate system coupler. (Jacob et al., 2005)"It is used to store the local data to be shared in a 2D parameter location array using an Attribute Vector type; it is a global segment map that describes the globally partitioned numerical grid throughout several processes. On the basis of these data types, MCT provides the efficient parallel MxN data transmission and MxM data redistribution, intergrid interpolation with multiplication of matrix vectors, spatial integration and average time. MCT is suitable for single or more executable systems and enables sequential or simultaneous execution. Included in the ESMF which is utilised for CCSM4 include most of what has been understood and implemented in MCT and cpl6."

8 OASIS and PALM

"In order to build a shared software infrastructure, earth systems modellers grouped at ENES began the PRISM (Partnership for Research Infrastructures in Earth System Modeling) initiative. CERFACS developed the open source OASIS3 andOASIS4 frameworks, based on their earlier work."(Valcke & Morel, 2006)"The OASIS frameworks include a driver, transformer and an interface library based on the PRISM system model (PSMILe). Initialisation, variable definition, receive and put and finalise phone calls to the PSMILe are all part of the unique OASIS3 executable component. The driver component initialises and connects the components on a performance basis based on setup files. It also calls the data transformer tore divide and/or regrid data; data will be supplied that does not require any of these activities."

9 OMS – Object Modeling System

"The OWS has been developed by the Department of Agriculture (USDA), in partnership with other agencies and organisations, which work on agri-environmental modelling in a domain-specific, reusable framework with interconnected Java classes. OMS offers an integrated environment for programming, simulation, and analysis. Single Java classes with an execution method, optional initialization and ending of methods are individual components. Component methods, input and output variables and Java annotations like @In, @Out, @Unit, and @Execute identify and explain them. Time and space loops from components are pushed to the point that most input and output arguments are scalar; each

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component is pretty straightforward. In conjunction with OMS and special model developers, several watershed models, including the SWAT (Soil and Water Assessment Tool), J2000"(Krause, 2002), and the PRMS, have transitioned to OMS modules, directly from delivery into the use component. While OASIS3 components can be multifunctional, the driver and transformer are single-threaded (they are parallel in OASIS4). OASIS3 (transformer) only allows scalar2D grid data and requires grid coordinate data to be given with the use of net CDF files. The OASIS4 PSMILe interface supports the vector volume and grid specification (1D, 2D and 3D); so data files for grid information are no longer required. CERFACS developed the closely related proprietary PALM framework for oceanographic data-assimilation applications for the MERCATOR project, along with these innovations. PALM offers dynamic complementation and removal during performance using MPI2 characteristics, in contrast to the OASIS couplers. However, the parallel interpolation characteristics of OASIS4 are now lacking.

10 OpenMI – Open Modeling Interface

"Researchers from a.o. Delft Hydraulics (now in the Deltares part), DHI and Wallingford Software have created version 1.4 of the OpenMI Standard20 inside the HarmonIT EU-funded project (now part of MWH Soft). This interface standard allows end users to use couples of components generated without recompilation by various developers. It involves the implementation of simulation engines, such as ***related components*** giving the technique for (1) initialising the component, (2) querying (providing and accepting) ***exchange items***, (3) defining linkages, (4) obtaining component values and (5). The exchange item is a quantity specified in a ***Set of Elements*** (set of either labels or coordinates). The data interpolation to the element set of the requesting component is responsible for the provision of components."(Gijsbers et al., 2010)"The standard's first version is based on a pull-based approach solely since there is no value setting procedure. After all components and their connections are initialised, a simulation begins by asking for the ***end*** part of the data workflow. The appropriate computation will then be started and, if needed, the values from the linked components will then be requested without any central framework intervention. Deadlocks in cyclic workflows are averted by requiring a component, without calling other components, to deliver ***best guess*** values if they are waiting to obtain data owing to an existing Get value() call. C#21 was used to construct a first reference implementation of the standard. Altera offered a Java implementation; OpenMI was later merged in the SEAMLESS Integrated Framework with formal ontologies. Although both reference implementations use only one execution thread, the OpenMI standard does not necessarily necessitate this. OpenMI proved to be compatible with remote, multi-threaded and web-based engines. In 2007 the OpenMI Association was formally established to own the standard and its related implementation of reference (s). The future version 2.0 of the details standard) introduces a set values () approach and isolates temporal progress from the get values() function, making it easier to use OpenMI while connecting to (geospatial) data bases and assimilating information."

11. TIME – The Invisible Modelling Environment

"TIME assists developers in designing, testing and providing models for environmental simulation;(Rahman et al., 2005). It is a.NET framework, comprising standardised data IO object libraries, GIS operations, data visualisation, uncertainty assessment and nonlinear optimization. A GUI based on metadata tags for component variables is automatically built for the model. E2/Water CAST expands the TIME framework with capabilities to link the hydrological sub catchment models to the tidal boundary in estuaries through streams."

topic	CCA	ESMF	HLA	Kepler	MCT	OASIS	OMS	OpenMI	TIME
defines framework	✓	✓	✓	✓		✓	✓		✓
defines interfaces	✓	✓	✓		✓	✓	✓	✓	
provides (reference) implementation	r✓	✓		✓	✓	✓	✓	r✓	✓
defines object model		✓			✓	✓		✓	
code invasiveness [Lloyd et al., 2009]	−−	+	?	?	?	?	++	−	?
plug & play (and graphical coupling)	✓		(✓)	✓				✓	✓
support for HPC environment	✓	✓	✓		✓	✓			
C/FORTRAN support	✓	✓	(✓)	W	✓	✓	W	W	W
Java support	✓		(✓)	✓			✓	✓	
.NET support								✓	✓

Table 1: Comparison of coupling technologies(Jagers, 2010)

12 Comparing developments and conclusions

The emphasis on the end user and the cooperation side is different from the rest of FRAMES and CHyMP. Other models like CSDMS, Delta Shell, Open WEB and EMHUB are equally applicable (local and web-based). Instead of developing another coupling technology, these projects prefer to accept (and adapt), so I will ignore it. In this comparison. In addition, it should be emphasised that the CCA, HLA and OpenMI architectures and interfaces are established in principle only, while others are actually implemented as goals. There is no standard HLA body, however at least one is designed by CCA and OpenMI developers. The CCA, ESMF, OASIS, OMS, OpenMI and TIME interfaces are equivalent in that each initialises, executes, finalises and sets concepts. However, a comparison found that the amount of code necessary varied considerably: Due to the basic Java approach and the intentional use of annotations, OMS3.0 requires the lowest linguistic interoperability for each element. CCA, HLA and Kepler are not subject to a certain (spatial) object model. ESMF, MCT and OASIS use numerical grids as spatial information representations, while OpenMI used a typical OGC approach. OMS usually reduces spatial loops from model components to scalar or not required component variables for complex objects. It is the same for TIME and allows for raster and network information. "The OMS and TIME type objects can be extended to Java or C#. With the graphical interface, CCA, HLA, Kepler, OpenMI, and timer allow end-users to link pre-compiled components from different developers during execution. ESMF, MCT and OASIS concentrate on the user community with their key FORTRAN and C languages. Only indirectly Kepler, OMS, OpenMI, and TIME support for FORTRAN and C users. OpenMI and TIME only support the.NET platform. HLA-supported languages depend on their implementation (generally Java or C). CCA is the only architecture that deals with SIDL and Babel's multilingual compatibility. A trend guides the coupling components. In order to ensure that connections are legitimate and prospective relationships are automatically detected, ontologies and other metadata conventions are important. These agreements already apply to a certain degree to operational frameworks such as FRAMES. In cooperation with the US Earth System Curator and European METAFOR programmes, ESMF and OASIS(Component) developers are involved in climate research." Climate research includes Climate& Forecast Conventions. Although all the methods described were constructed according to a common notion of component architecture, various components of the integrated modelling problem have been tackled (generality, flexibility, usability, precision and/or performance). Similarities could be used on their interfaces to develop a generic wrapper generator (see, for example. This would improve movement of components between compatible frames.

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