Geographic Grid-Computing and HPC empowering Dynamical Visualisation for Geoscientific Information Systems

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Presentation Overview

Introduction

- History: standalone GIS applications on local hosts long over **ten years ago** (1994–1997),
- work: **proof of concept for dynamic visualisation of scientific information** realised on distributed computing and storage resources using a **fundamental scripting approach** (year 2000 onwards),
- **Grid-GIS framework** with many features implemented including several programming libraries providing a suitable API,
- problem of **dynamic cartography and geocognostic views** with hundreds of thousands of data points having to be connected with live, quasi real time data being very computing intensive had to be managed.

Part presented via following sections: selected basics, case studies and evaluation regarding the developments of a portable, modular, scriptable, and scalable solution using HPC and Grid Computing resources at the user level for solving the problem of bringing distributed resources and scientific content together.

Problems Addressed

- Current implementation of portable components for Geoscientific Information Systems (GIS) within the GISIG actmap-project, addressing **multifold computing problems** with the implementation,
- **Active Source** having extended the framework for conventional GIS new features enabled like the use of Grid Computing and cluster resources, scientific and dynamical visualisation, and High Performance Computing (HPC) in order to be used for Geographic Grid Computing,
- base of **scientific content** can for example be geophysical information (e.g. environmental or seismological data, geographical and spatial information using Geographic Data Infrastructures (GDI), as well as data from industrial, economic, cultural, and social sources),
- integrated solution for monitoring, accounting, billing supporting the **geo-information market** can be incorporated into this context (samples from year 2002 on), extended use of Web Services and GDI in the future.

Obstacles

Encouraging powerful computing resources for the use with spatial information and scientific visualisation in practice still does link with a bunch of obstacles:

- **Integrability** of concepts,
- **portability** of implementations,
- **interfaces** for data and application interchange,
- framework for the **use of computing resources**,
- **availability of sources**,
- **extendability of existing methods**,
- frameworks for **application of methods** needed,
- **reusability** of existing solutions, and many more.

The implementation of portable components within the GISIG actmap-project [Rüc2005] over the last years aims to extend the features and applicability of Geoscientific Information Systems (GIS) for these purposes (e.g. [CPG1999, Zer2000, Sch2001]).

Inter-GIS-Computing Targets: DynVis, Grid, HPC . . .

- enable the use of **computing resources for GIS, spatial information systems, dynamical visualisation, dynamical cartography, virtual reality, and multimedia presentation**,
- exploit **Grid Computing** for GIS,
- exploit **High Performance Computing** (HPC)/Supercomputing for GIS,
- exploit **Cluster Computing** for GIS.

Combined efforts [HET2007, OGC2007, OGF2007] can *upgrade* the motivating forces for Geographic Grid Computing bringing the necessary disciplines together.

Disciplines Working on the Content

- Base of scientific content can be **any information** that can be represented digitally.
- Favorable: ability for **multimedia presentations**, for example using geophysical information like environmental information or seismological data, geographical and spatial information using Geographic Data Infrastructures (GDI).
- **Data** for example from industrial, economic, cultural and social sources can be used in that way.
- Any of the informations can be combined with **user defined dynamical algorithms** with or without spatial context to form new **cognitive views**.

Grid-GIS Framework Implemented: GISIG operations and extendability

- **Scripting** does enable GISIG components to use distributed computing resources like HPC, Grid Computing and Cluster Computing resources with mechanisms from pseudo-interactive to batch use.
- **Arbitrary services** for a wide range of scientific fields can be built upon these mechanisms.
- Services and applications can act **on top of the Grid middleware** infrastructure like Globus Toolkit [Globus2006] and SGAS (Accounting/Pricing/Billing) for this purpose.
- In detail, **at any state** of the application **operations** can be done onto data, information, and configuration regarding nearly every piece of algorithm and implementation. Examples are regexp operations, substitution, item configuration, and remote control.
- **Multimedia objects** like source animations, videos, sound features and many more can be integrated into the data on base of canvas embedding and event binding, for example in order to support complex geocognostic cartographic views.
- It is possible to create **runtime functions in real time**, to do **replication**, to **clone** parts of applications, use **user defined servers and clients** even inside the application, to do user or **application defined history management**, or even to use data consisting of **GISIG Object Sources** (GOS) [Rüc2001b].
- Flexible **event databases** are integrated and can e.g. be used interactive and in batch mode via scripting.
- **Internationalisation** is possible at database level as well as on application and data level.
- **Security levels** can be defined and configured as well as sandbox models and trusted computing.
- Components containing all the parts needed, including bytecode and data, can be compiled into **self-contained executables** plus separate optional runtime-time containers.
- For extended use own **kernel modules** are possible.
- User applications can be configured for use with **workstations to PDAs**, while as the basic framework application is highly portable.
- Testing has so far been done with scripting, dynamical visualisation and cartography respectively mapping using Tcl/Tk [Tcl2006], VTK, PV-Wave, C, Fortran, Perl, and Shell.

Selected Insights to Active Source Framework

- In the following passages some small feature snipets from the implementation are presented.
- The following examples for using the Active Source framework as being part of GISIG will show a tiny part of the multitude of possible applications.
- The features shown give an impression of the connections available now between the GIS and the Grid world and its application background in Grid Computing, reaching from GISIG Object Sources to remote control, IPC, and the use of cluster resources.
- The concept has been described in detail in [Rüc2001b].
- Parts of the Implementation base are available on the Internet [Rüc2005, Rüc2001f, Rüc2001e, Rüc2001c, Rüc2004, Rüc2001d, Rüc2001a, Rüc2001g]

Active Source

Listing 1 shows a simple code fragment of a data set for an Active Map layer based on GISIG Active Source. Active Source can be pure source code or bytecode. The fragment shown is in parts a native data language representation. Ellipses (. . .) are shown for those parts of the real data set missing here for compactness.

```
#====================================================================
# GIS Active Map layer -- (c) Claus-Peter R"uckemann,␣1995--2007
#====================================================================
line 0.0 0.0 0.0 10000.0 -tags {itemshape gridline} -fill grey -width 1
line 0.0 0.0 10000.0 0.0 -tags {itemshape gridline} -fill grey -width 1
line 20.0 0.0 20.0 10000.0 -tags {itemshape gridline} -fill grey -width 1
line 0.0 20.0 10000.0 20.0 -tags {itemshape gridline} -fill grey -width 1
polygon 91.012 145.236 82.368 131.592 91.012 145.236 -tags {itemshape}
oval 384.0 204.0 388.0 208.0 -tags {itemshape city muenster} -fill yellow
oval 404.0 196.0 408.0 200.0 -tags {itemshape city minden} -fill yellow
oval 372.0 224.0 376.0 228.0 -tags {itemshape city koeln} -fill yellow
...
bitmap 432.0 232.0 -bitmap "@/home/cpr/gisig/images/letters.xbm" ...
copycut::/home/cpr/.../earth.gif copy [image create photo -file ...
copycut:0101-zoom:/home/cpr/.../earth.gif copy [image create photo ...
image 180.0 400.0 -image [image create photo "/home/.../smilee.gif" ...
```

Listing 1: GISIG Active Source code fragment.

Object Graphics

An example fragment of an object graphics data set with completely native data language is given in listing 2.

```
$w create polygon 1.33039 0.57027 1.36029 0.59123 1.34591 0.50223 \
... 1.30943 0.73852 1.21301 0.62593 1.33039 0.57027 \
-fill gold -width 1 -tags {itemshape country germany}
$w bind germany <Button-1> {showName "$text_country_name_germany"}
$w bind germany <Shift-Button-3> {exec wish actsel$t_suff}
$w create oval 0.97 0.54 0.98 0.55 -fill blue -width 1 -tags {itemshape pointdata location1}
$w bind location1 <Button-1> {showName "Location␣1"}
$w bind location1 <Shift-Button-3> {exec browedit$t_suff}
$w scale all 0 0 400 400
```

Listing 2: Object graphics code fragment.

Remote Control

Listing 3 shows a code fragment of an example for remote control of objects in active instances of two components (actmap and actsea).

```
send {actmap} $w move germany 50 50
send {actsea} .text insert 1.0 CPR
send {actsea} {.text insert 5.6 "some␣linebreaks,\n\ntoo"}
send {actmap #2} { \
       $w move germany 150 50 ;\
       $w move france 50 50}
```

Listing 3: Remote control code fragment.

Inter-Process Communication (IPC)

The example in listing 4 shows handling for child process and `fileevent` using a channel.

```
proc was {arg} {
  global jobFinished
  puts "Still␣at␣$arg"
    if {![eof $arg]} {
        gets $arg data
      if [eof $arg] {
          set jobFinished 1
          catch {close $arg}
          puts "EOF␣reached"
          return
    }}}

set f [open "|calc␣" r]
fconfigure $f -buffering none -blocking no
fileevent $f readable "was␣$f"
vwait jobFinished
exit
```

Listing 4: Child process and `fileevent` (channel).

- Very powerful functionalities for application communication,
- basic ability is to execute a script containing an algorithm when a channel gets readable or writeable, this way file event handler between a channel and a script or event can be created,
- for example GISIG IPC via Tool Command Language (TCL) provides a flexible `fileevent` and send (e.g. X send) and goes far beyond the features of other modern shells.

Computing Resources

- With the scripting features various resources can be used via Grid, Cluster, and High Performance Computing at this level.
- Examples for batch systems successfully been used are
  - Portable Batch System (PBS) [OpenPBS2006],
  - Cluster Computing software like Condor [Lew2005],
  - and LoadLeveler.
- Tests with Sun Grid Engine [SGE2006] are under way.

The example in listing 5 shows a Condor job using distributed resources on a cluster.

```
universe = standard
executable = /home/cpr/grid/job.exe
should_transfer_files = YES
transfer_input_files = job.exe,job.input
input = job.input
output = job.output
error = job.error
log = job.log
notify_user = ruckema@uni-muenster.de
requirements = (Memory >= 50)
requirements = ( ( (OpSys=="Linux")||(OpSys=="AIX"))&&(Memory >= 500) )
queue
```

Listing 5: Condor cluster job.

Selected Case Studies

The following case studies show various GIS applications, for example geocognostic views and dynamic cartography, using data, information and events from distributed storage resources, using distributed computing resources for live plotting and raytracing as well as different hardware resources.

Spatial Data and Active Source

GISIG Active Maps can consist of vector and raster layers as well as of multimedia parts and events. The example shows a dynamical event-driven city map containing environmental and infrastructure data, delivered from distributed sources (figure 1).

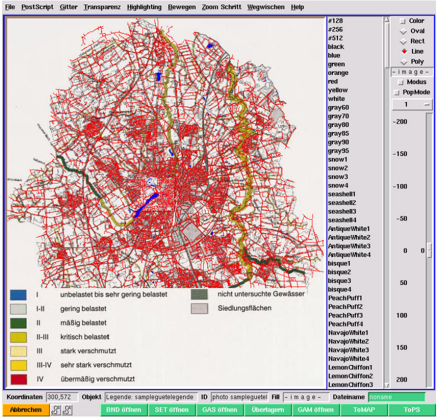

Figure: Active Map with vector layers, raster layers, and events.

Geocognostic Views

Most flexible geocognostic views can be developed using the local and background computing resources. The example shows cartography combined with aerial data, and vector data all bound together by events (figure 2). View: highly zoomed area of the previously presented map, here in different thematical geocognostic context.

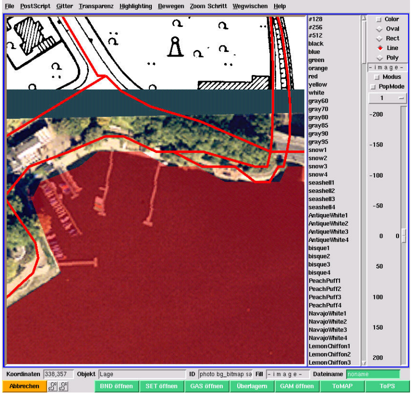

Figure: Active Map combined geocognostic view with map data, aerial data, and vector data.

Configuration for Hardware

The configuration of GISIG components is very flexible and adaptable to the hardware medium. Figure 3 shows the same application used for the previous to examples configured for PDA-like hardware.

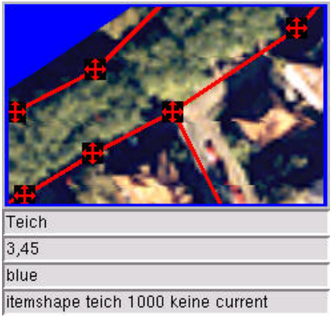

Figure: Active Map with PDA-like configuration.

Data, event mapping and so on are identical, only appearance of the application differs depending on hardware and configuration.

Cartographic Mapping

The number of objects handled in object source is only limited by the system and hardware used. Figure 4 shows a worldmap (hundred thousands of vector points in source). Any part delivered from computing and storage units on distributed resources.

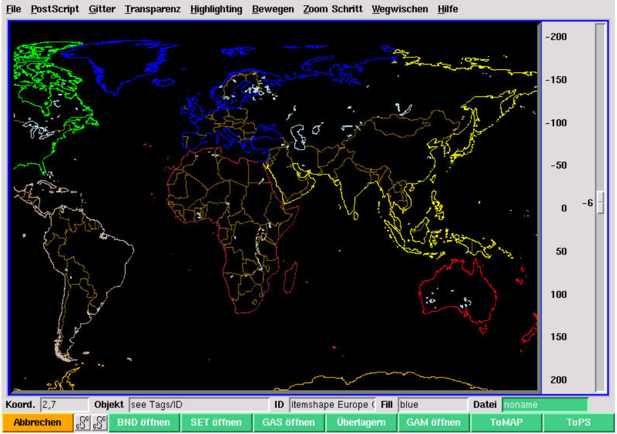

Figure: Active Map vector worldmap.

Synthetic Data and Raytracing

Figure 5 shows an interactive dynamical presentation with data samples for a synthetic stone texture palette (raytraced, POV-Ray on distributed computing resources). Samples can be closely linked with GISIG components as well as loosely linked with any applications (e.g. Live plot, 3D).

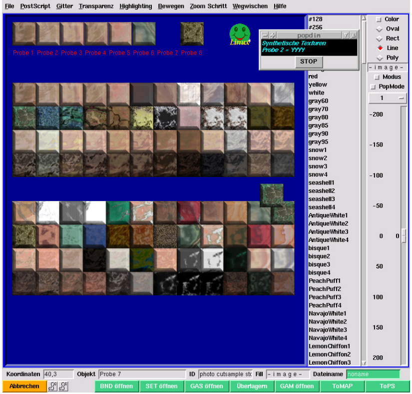

Figure: e-Science application with raytraced synthetic texture data.

Dynamical Cartography and Visualisation with GISIG actmap

Figure 6 shows two examples for event-driven, dynamical applications that can be used standalone as well as in combination and using event links to distant resources. Any part of this concept can be used by event steering for highly dynamical interactivity.

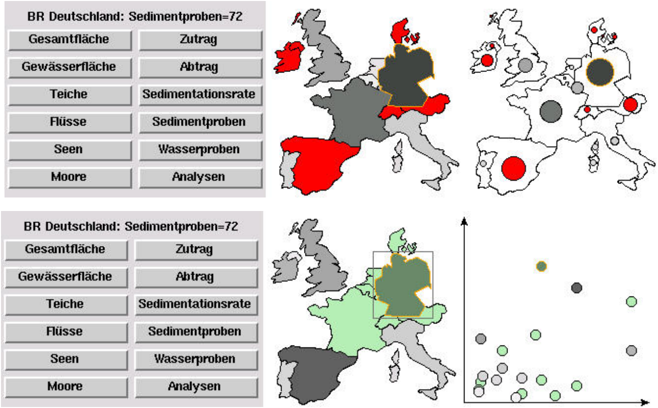

Figure: Dynamical cartography, event-driven.

Geographic Markup

Keyhole Markup Language (KML, KMZ), Geographic Markup Language (GML). The following Listingshows a significant markup fragment for Points of Interest (POI).

```
<?xml version="1.0" encoding="UTF-8"?>
<kml xmlns="http://earth.google.com/kml/2.2">
<Document>
  <name>rrzn.kmz</name>
```

. . .

```
  <Placemark>
    <name>Regionales Rechenzentrum für Niedersachsen (RRZN), Hannover</name>
    <LookAt>
      <longitude>9.723308814322449</longitude>
      <latitude>52.37963595216673</latitude>
      <altitude>0</altitude>
      <range>110.9696384488645</range>
      <tilt>-7.281218921111272e-011</tilt>
      <heading>0.0003858670452432517</heading>
    </LookAt>
    <styleUrl>#msn_ylw-pushpin_copy1</styleUrl>
    <Point>
      <coordinates>9.723308814322449,52.37963595216673,0</coordinates>
    </Point>
  </Placemark>
</Document>
</kml>
```

Listing 6: KML Example.

Evaluation and Lessons Learned

- **Implementations already available**,
- still work in progress, **new fields for application** currently under development,
- implementation based on GISIG actmap is **portable**,
- can be used to **integrate various concepts**,
- delivers **flexible interfaces**,
- enables the **use of the computing resources** needed, especially **Grid Computing, HPC and Cluster Computing**,
- for data and components, **sources** can be made available to **any desireable extend**,
- **extensible** by a wide range of means and can integrate a lot of existing frameworks while parts still being most reusable,
- various **distributed resources** –computing and storage resources– can be used with this concept for many scientific problems.

Grid-GIS house

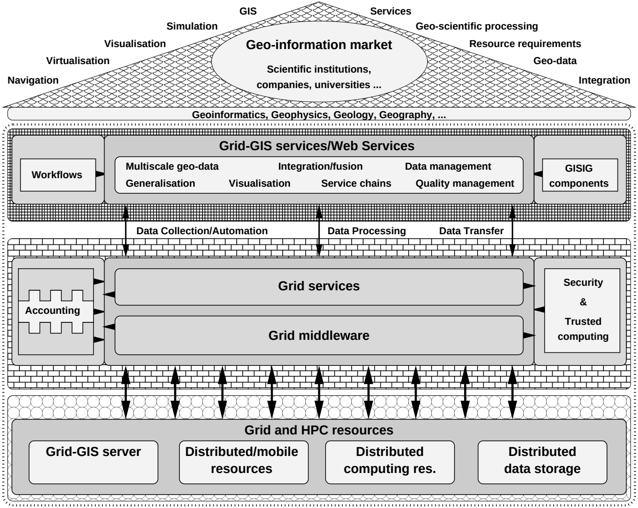

Figure: The "Grid-GIS house": GIS and computing resources (1999–2007), including GISIG.

Bricks for the Grid-GIS house

- Figure 7 shows the **Grid-GIS framework**, the "Grid-GIS house" as it can be used with GISIG.
- The framework still has to be upgraded regarding **inter-level connectivity** and still has to be extended using **Web Services** and common standards.
- Basic **fundamentals are Grid and HPC resources** namely computing and storage resources.
- Based on this layer **Grid middleware and Grid services** are installed. Special services can be created for nearly any application needed at this level. Future joint efforts like HET [HET2007] can help to build the necessary meta-organisation background for HPC and Grid Computing.
- Main issues for enliving the "Grid-GIS house" under aspects of the geo-information market are **Grid accounting** as well as **trusted computing** and **security at the service level**.
- **Grid-GIS services** and Web Services interfacing with GISIG namely the actmap component are sitting on top of that layer providing the interface for the geo-information market while providing usage of Grid services for data collection and automation, data processing, and data transfer.

Future Work

- Various features already implemented, new fields of application currently under development,
- integrate **geographic markup** into the framework,
- support for **Points of Interest** (POI),
- support for **Service Oriented Architectures** (SOA), benefit: simple, no extensive codes needed for client side,
- support for **Web Services**, Web Services Resource Framework (WSRF),
- support for **Geographic Data Infrastructures** (GDI),
- support for **Open Grid Service Architecture** (OGSA) and Open Grid Services Infrastructure (OGSI),
- use concept for integrated "holistic" **monitoring/accounting/billing** [RGB2007] [RMR+2005, Rüc2006] developed within D-Grid project [D-Grid2007], support a working **geo-information market**,
- create **business model** for **integrated Grid and HPC** and implementation of an economic framework,
- overcome differing **models for Grid and HPC monitoring, accounting, and billing** [RMv2006, EGM+2003, SGE+2004, GEJ+2006, BCM2005, EGE2005],
- the concepts could be presented at one of the next conferences for business and computer sciences (depending on sponsors),
- the implementation (scheduling and parallel processing) could be presented at the next Euro-Par `http://www.europar.org` (depending on sponsors),
- Interdisciplinary work [OGC2007, OGF2007] should be encouraged, beyond HPC and Grid addressing business interests and telecommunication.

Summary and Concluding Remarks

- **Insight into the employment of scripting languages and source code based persistent object data**,
- **enabling the use of computing resources** for geoscientific information systems,
- basic concept of object graphics based on **Active Source** has been developed within the GISIG actmap project.

- **Dynamical cartography and visualisation using event-driven databases and distributed computing resources** successfully adopted for different use cases.
- implementation offers a wide range of applications for dynamical visualisation and to **remotely controlled** and **multimedia cartography** and presentation using **computational intensive processes**.
- concept put into practice for **Grid Computing, Cluster Computing, and HPC**,
- prototype offers flexibility for application and **steering of resource usage**.
- **Integrability, portability, interfaces, computing framework, availability, extendability, application of methods, and reusability** have been demonstrated,
- several **obstacles** for use of GIS with Grid Computing & HPC have been **overcome**,
- **conformity with standards will have to go on**,
- basic work done for showing the **direction of developments**,
- future interdisciplinary developments will more closely combine existing means with the use of **Web Services and Geographic Data Infrastructures** in order to encourage the ongoing achievements from the interaction of GIS, Grid Computing, and HPC,
- **building the "Grid-GIS house" for the geo-information market**.

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Thank you for your attention!

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