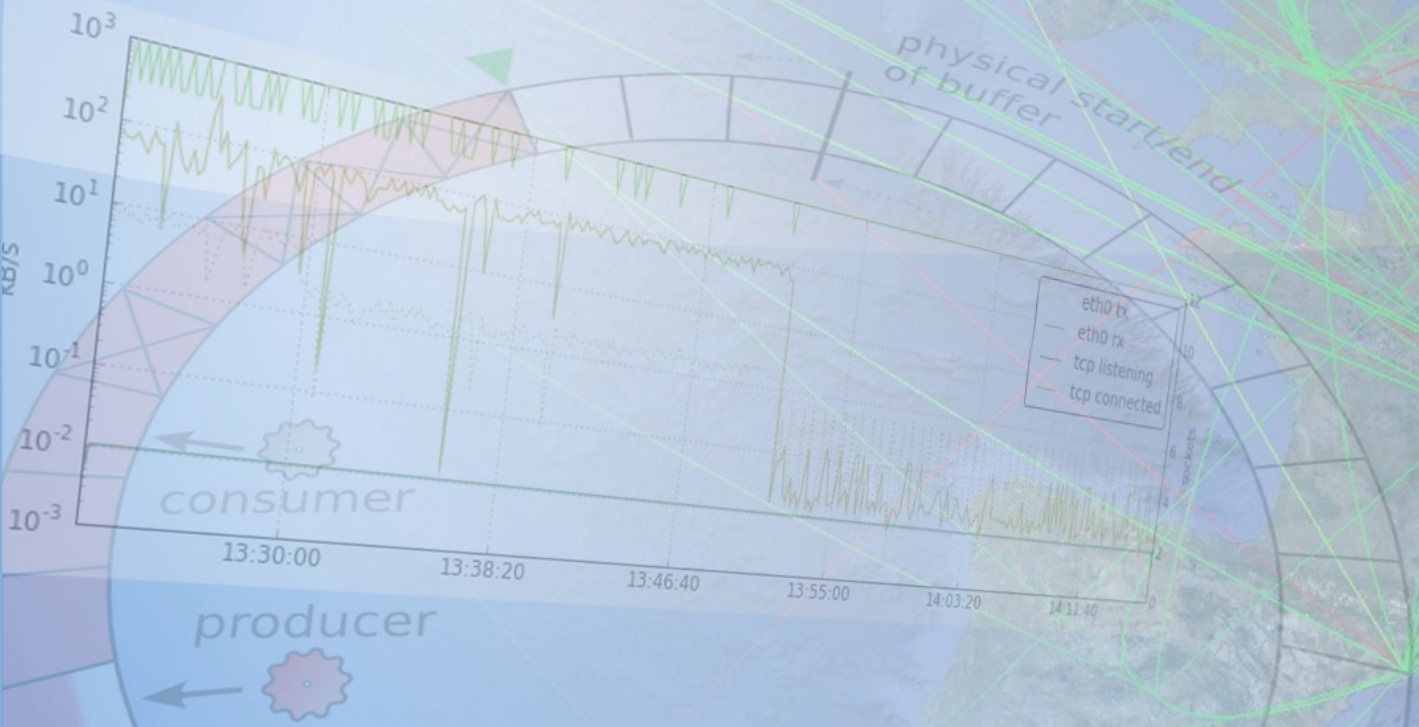
Application of Remote Debugging Techniques in User-Centric Job Monitoring



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Agenda

- Scope & Motivation
  - The WLCG and the PanDA Job Brokerage System
  - Grid Job Lifecycle and Failures
- Definition of terms
  - User-Centric Job Monitoring
  - Remote Debugging
- Realisation
  - Job Execution Monitor
  - Implemented Subset (...of Remote Debugging use cases)
  - Current Development

Scope & Motivation

The WLCG and PanDA

- WLCG: World-Wide LHC Computing Grid
  - 141 sites with currently ~270k cores, ~7,83 Billion GB online storage
  - Avg. ~200k jobs/day, average efficiency >95% (central production jobs) / ~80% (user analysis jobs)
- For the ATLAS Collaboration
  - Job brokerage is implemented in „pull“ semantic
  - → PanDA („Production and Distributed Analysis“)
  - Allows submittage of Grid Jobs in an easy-to-use fashion

* numbers according to gstat, http://gstat-prod.cern.ch

Grid Job Lifecycle

- Pilot Factories mass-submit small pilot jobs
- Each pilot...
  - Ensures proper health of the worker node it is run on
  - Checks the WN's software environment and resources
  - Pulls a matching user job from a central database
  - Executes it
  - And creates exit summary logs after the job finished and wrote its output
- The Grid Job, in the context of ATLAS, usually performs a „stage-in → init → execute → stage-out“ cycle

Grid Job Failures

- Obvious payload errors (crashes) aside, a Grid job can fail for various reasons
  - Resource excess (wall time, memory, storage, …)
  - Missing or invalid input files (also: version mismatch between chosen input files and processing software)
  - Missing or invalid contextual metadata files
  - Grid proxy certificate time-out
  - Service failure at the Grid site (typically: storage and transfer of input/output data)
- From the user's point of view, there are 3 classes:

Initialisation failure Run-Time failure Time-Outs

Grid Job Failure Classes

- Initialisation failures – „the Job didn't even start“
  - Grid middleware errors
  - Input Data missing / not available on the only sites that provide the needed software (version)
  - Erroneous Job definition
- Run-Time failures
  - Crashes ← in theory, those should all be found locally...
  - Miscalculations ←  this means logical errors in otherwise succeeding jobs! „Not detectable“...?
- Time-Outs
  - Wrong job queue chosen (wrong run time expectation)?
  - Site problems? I/O-problems?
  - Looping job? (← problem in user code / endless loops...)

Definition of Terms

User-Centric Job Monitoring

- = Provision of job-related data describing the progress, health and environment of the job
  - Progress: „How far has my job proceeded?“ „does it even still do something?“ „why is this sub-job so much slower than the rest?“
  - Health: „Will my job make it?“ „Does it produce meaningful output (so far)?“ „Does it efficiently use its resources?“ – or: „Why exactly did it fail?“
  - Env.: „How much CPU/RAM/storage/bandwidth does it use?“ „How much storage/bandwidth/... is available?“
- Distinguished from Site Monitoring by scope
  - Can provide input for Site Monitoring, though

Remote Debugging

- Wikipedia says:

  „Remote debugging is the process of debugging a program running on a system different than the debugger. [...] Once connected [over a network], debugger can control the execution of the program on the remote system and retrieve information about its state.“

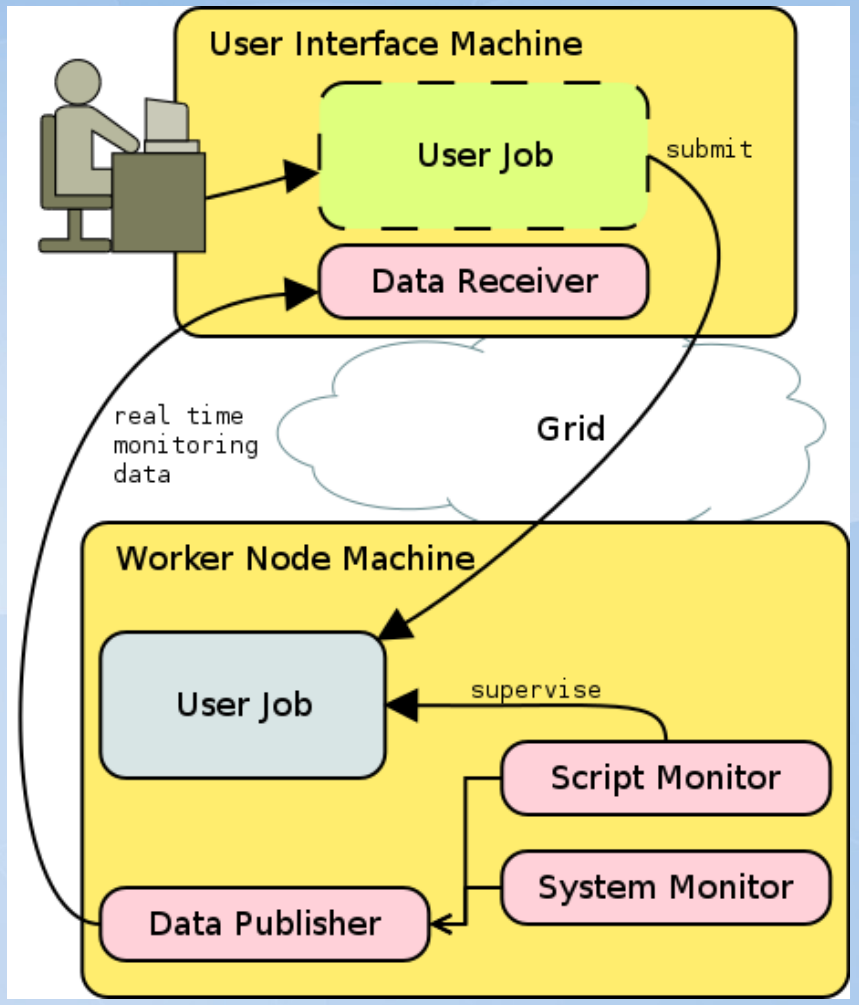
- Main points: One needs to be able to...
  - Control the execution.
    - Granularity: Job, Module/Script, Function, Line
    - Interactively? (breaking, stepping) – useful on the Grid...?
    - Semi-Interactively? (break, get debugging data, continue)
  - Retrieve Information.
    - Environment, Current execution state, (temporary) data, memory contents, …

      if retrieved automatically → Non-Interactive rem. debugging

Realisation of a Remote Debugger for the Grid

Job Execution Monitor

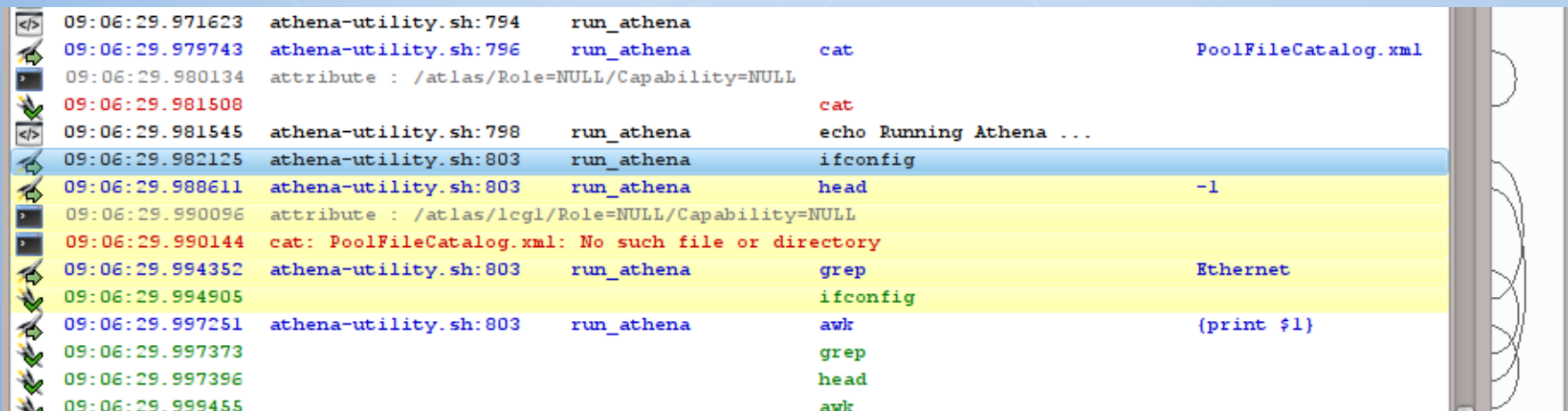
- Small & lightweight user space tool
- Submitted and run alongside the job on the worker node
- Gathers monitoring data, stores them in log files and can transmit them in real time
  - To the user, if he/she wants
  - To a central instance that generates statistics



- Can be activated by PanDA users with just one parameter
- Will be limited by a central instance (in development) to prevent misuse/excess monitoring/flooding

Implemented Remote Debugging

- The Job Execution Monitor today provides non-interactive remote debugging functionality
  - Bash Scripts and Python Code
    - Works out-of-the-box, enabled via submit-time configuration
    - At a moderate performance penalty in such scripts
    - Gives data about script execution progress and exceptions
  - Output streams (stdout/-err) and watched log files
    - Content can be streamed in real time, if desired
    - Time-stamped – allows correlation to rest of mon. data



Implemented Remote Debugging

- The Job Execution Monitor today provides non-interactive remote debugging functionality
  - For C/C++/Fortran-based ELF binaries
    - Needs to be prepared by compiling the user code with debug symbols and hook-instrumentation (GNU gcc specific)
    - At moderate performance penalty when idle and high overhead when active (white-listed functions/methods, …)
    - Gives data about execution progress and memory contents (variable values, object instances, function arguments)
    - Uses a trigger-system to e.g. create in-depth stack traces on user code failures
    - Is guarded against user code crashes (detect and report) and against internal errors (e.g. due to corrupt pointers/mem)

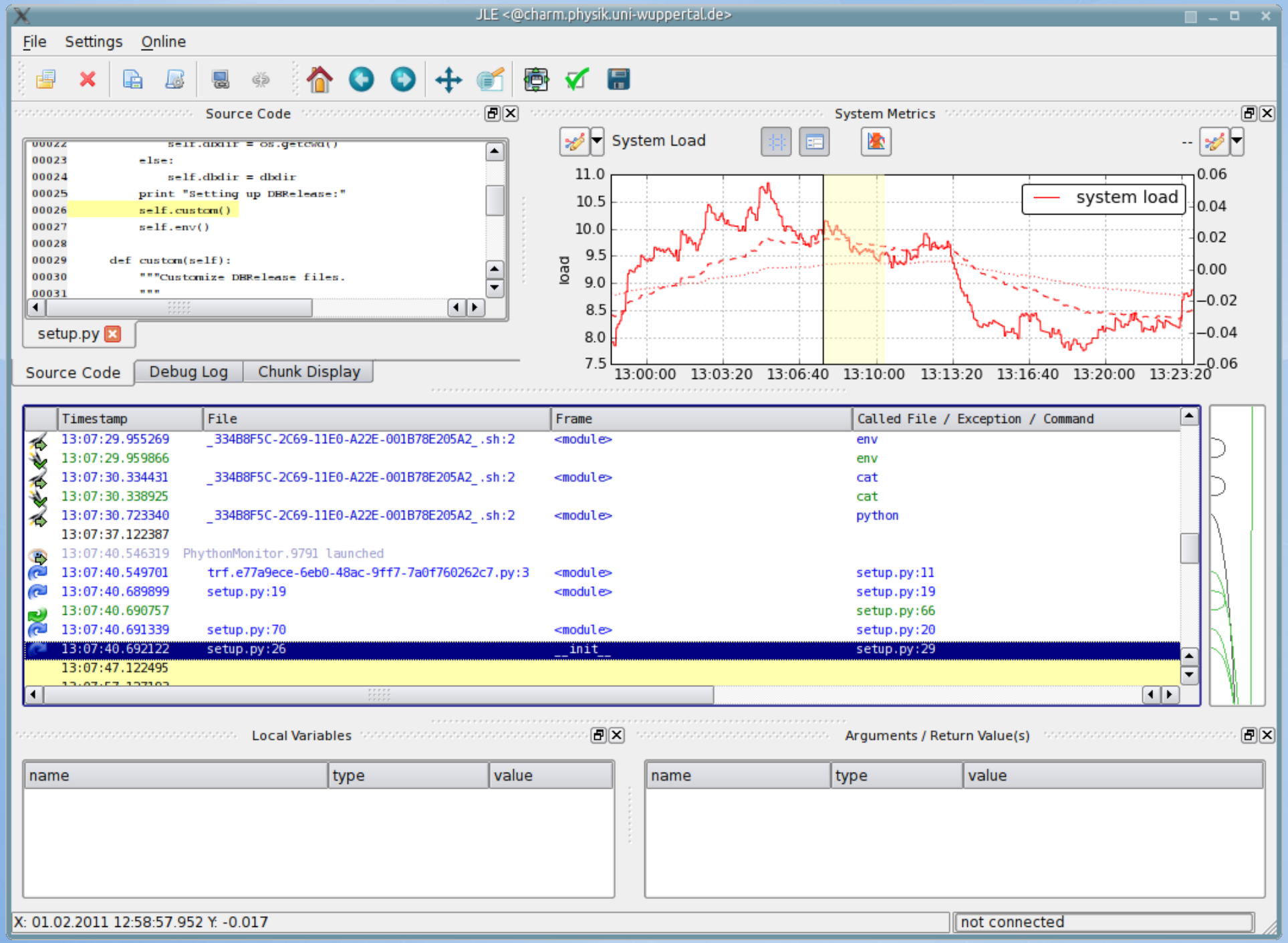
Example real time data

.	Timestamp	File	Frame	Called File / Exception	Called Frame / Exception Reason	Code / Command	Arguments / Return Value
	10:51:13.887	GaudiHandle.h:194	void StatusCode::StatusCode				
	10:51:13.888	ToolHandle.h:121	StatusCode GaudiHandle<IHelloT...				
	10:51:13.898	HelloAlg.cxx:103	StatusCode ToolHandle<IHelloToo...			if (m_myPublicHelloTool.retrie...	
	10:51:13.981	HelloAlg.cxx:103	StatusCode HelloAlg::initialize	StatusCode.h:131	bool StatusCode::isFailure	if (m_myPublicHelloTool.retrie...	{'this':('const const Status(
	10:51:13.982	HelloAlg.cxx:103	bool StatusCode::isFailure			if (m_myPublicHelloTool.retrie...	
	10:51:14.048	HelloAlg.cxx:107	StatusCode HelloAlg::initialize	GaudiHandle.h:38	const string (= basic_string<ch...	log << MSG::INFO << m_myP...	{'this':('const const GaudiH
	10:51:14.049	HelloAlg.cxx:107	const string (= basic_string<cha...			log << MSG::INFO << m_myP...	
	10:51:14.134	HelloAlg.cxx:110	StatusCode HelloAlg::initialize	StatusCode.h:104	void StatusCode::StatusCode	return StatusCode::SUCCESS;	{'this':('const StatusCode*'
	10:51:14.135	HelloAlg.cxx:110	void StatusCode::StatusCode			return StatusCode::SUCCESS;	
	10:51:14.181	???:-2	StatusCode HelloAlg::initialize				
	10:51:16.333	???	???	HelloAlg.cxx:162	StatusCode HelloAlg::beginRun	StatusCode HelloAlg::beginRu...	{'this':('const HelloAlg*','0x
	10:51:16.373	HelloAlg.cxx:167	StatusCode HelloAlg::beginRun	StatusCode.h:104	void StatusCode::StatusCode	return StatusCode::SUCCESS;	{'this':('const StatusCode*'
	10:51:16.373	HelloAlg.cxx:167	void StatusCode::StatusCode			return StatusCode::SUCCESS;	
	10:51:16.374	???:-2	StatusCode HelloAlg::beginRun				
	10:51:16.493	???	???	HelloAlg.cxx:115	StatusCode HelloAlg::execute	StatusCode HelloAlg::execute(...	{'this':('const HelloAlg*','0x
	10:51:16.534	HelloAlg.cxx:146	StatusCode HelloAlg::execute	StatusCode.h:104	void StatusCode::StatusCode	return StatusCode::SUCCESS;	{'this':('const StatusCode*'

Arguments

Type	Name	Value
const HelloAlg*	this	0x09b06220 [= <HelloAlg instance
bool	m_myBool	1
double	m_myDouble	3.14159
int	m_myInt	42
int	m_runCount	0
map<std::basic_string<char, ...	m_myDict	<map<std::basic_string<char, std::
ToolHandle<IHelloTool>	m_myPrivateHelloTool	<ToolHandle<IHelloTool> instance @
ServiceHandle<IToolSvc>	m_pToolSvc	<ServiceHandle<IToolSvc> instance
IMessageSvc*	m_pMessageSvc	0x0b03771c [= <IMessageSvc insta
ISvcLocator*	m_pSvcLocator	0x0ad798b4 [= <ISvcLocator instar
ToolHandle<IHelloTool>	m_myPublicHelloTool	<ToolHandle<IHelloTool> instance @
vector<std::basic_string<char...	m_myStringVec	<vector<std::basic_string<char, std
vector<std::pair<double, dou...	m_myTable	<vector<std::pair<double, double>
vector<std::vector<double, st...	m_myMatrix	<vector<std::vector<double, std::al

User Interface (prototype)

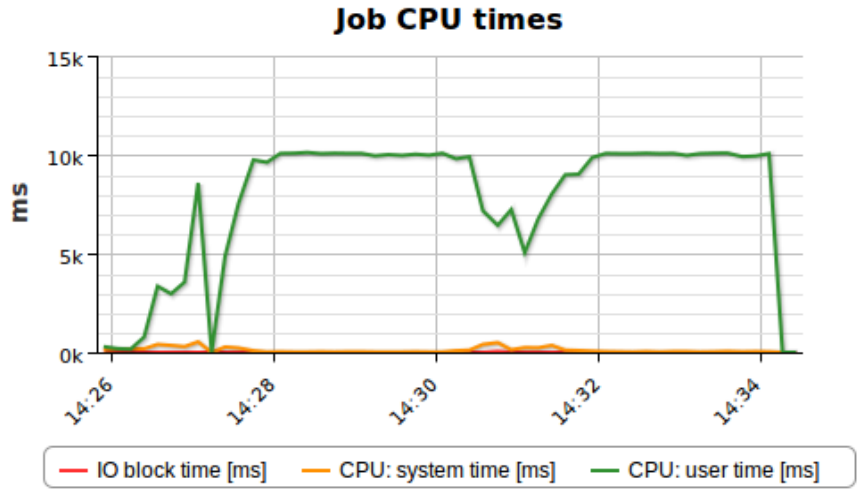


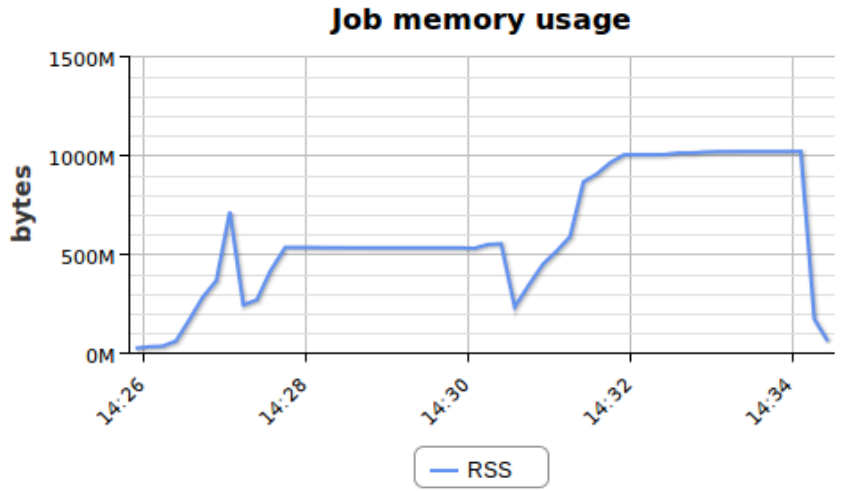
Web-Based UI

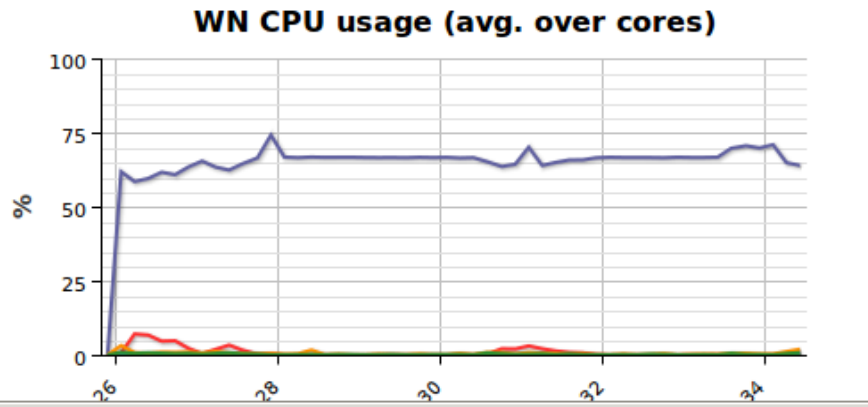
Job Execution Monitor

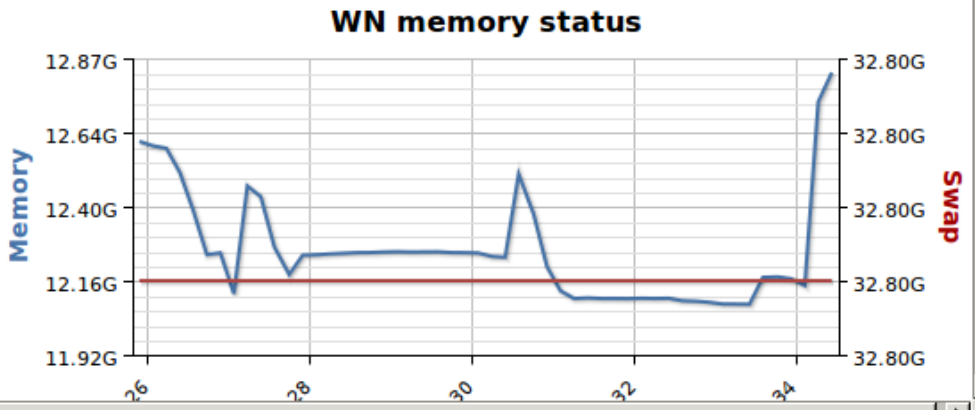
detailed system metrics for job PanDA.1300623467

jobId	started	finished	last seen	cloudName	siteName	userName	exitcode	wall time [s]	#events
PanDA.1300623467	29. August 2011 16:25:54	29. August 2011 16:34:27	29. August 2011 16:34:27	CERN	CERN-PROD	Johannes Elmsheuser	0	513	None









Current Development

- One major topic is extension to semi interactive remote debugging
  - Obviously, single-stepping through instructions in a Grid job makes not too much sense
  - But: Being able to halt, inspect and then (optionally) continue a Job may be useful
  - This also encompasses download of intermediate output files during run time, the change of monitoring verbosity level on demand, etc.
  - Most important aspect in this project is security: authentication / authorization, data integrity, et al.

Current Development

- Approach: Web-based UI and a messaging channel to the Job (encrypted MQ messaging)
  - For authorized users (Job author? Production role? Site admin?)
  - Providing semi interactive debug actions, for example:
    - „halt the Job, take data / inspect memory, continue the Job“
    - „kill the Job“
    - „add watch for variable X, value Y“
    - …

Current Development

- Further Work-in-progress Projects
  - Central controlling instance that can veto (or enforce) monitoring, deciding on a per-job level
  - Aggregated, projected and derived monitoring data (e.g. trend analysis hinting at imminent job failure, daily averaged job performance stats per site, …)
  - Sophisticated automatic triggers on the Worker Node, providing real time functionality like for example:
    - Adaptive monitoring verbosity
    - Exception tracking (discard „expected exceptions“, caught ones, …)
    - Reaction on user-defined job milestones / conditions
    - … and more!

Thank you