

An Interdisciplinary Practical Course on the Application of Grid Computing

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Abstract—This article gives an overview of the organization and realization of an interdisciplinary practical course on grid computing. Both the lecturers and the attendees came from diverse backgrounds and disciplines including computer science, physics, medicine, and the humanities. We describe the management of the course, the assignments, the infrastructure developed and experienced in this interdisciplinary practical course at the University of Göttingen. The challenges and issues, the benefits, the expectations and their fulfillment are discussed. The experiences of the course show that diverse disciplines can be brought together to convey the benefits of grid technology by experiencing varied grid applications in production-like grid environments.

Keywords—grid computing, interdisciplinary, practical course, D-Grid

I. INTRODUCTION

The idea of an interdisciplinary practical course in grid computing emerged from an overlap of interests in the disciplines computer science, physics, medicine, and the humanities. Grid computing, an important research area in computer science, connects and advances research of disciplines with high computational demands, such as the participating ones.

A grid is a networked system “that coordinates resources that are not subject to centralized control using standard, open, general-purpose protocols and interfaces to deliver nontrivial qualities of service” [1]. It provides a service-oriented environment for collaborative and efficient sharing of computing and storage resources belonging to different organizations to fulfill the demand of distributed, high-performance applications, in our context grid applications. Today, grid applications are commonly used in research, as well as business domains such as financial, automotive, and pharmaceutical domains. However, the requirements of such

applications grow steadily and need to be fulfilled by an appropriate infrastructure such as provided by a grid.

In this practical course, concepts and usage of grid computing in an interdisciplinary manner were taught. The expertise of the German grid initiative D-Grid [2] provided an excellent basis for studying and learning about grid technology. The students experienced and applied production-like grid environments. The D-Grid initiative is a research program initiated and funded by the *German Federal Ministry of Education and Research* (BMBF) to establish a national grid infrastructure for research and industry. The community projects of the D-Grid initiative involved in this course included MediGRID [3], *High Energy Physics* (HEP) Grid [4], and TextGrid [5]. These are all related to the disciplines mentioned above and located in Göttingen within the joint grid resource center GoeGrid [6].

The course took place in the summer term of 2008 at the University of Göttingen. The participants were assigned uniformly to groups according to their field of studies. Each discipline provided a tutor for supervising the students. For the establishment of a local grid environment, several computers located in a local computer network were allocated to each group.

The concepts of grid technologies were explained by practical applications of a grid environment using the grid software Instant-Grid [7]. Instant-Grid contains all necessary software to automatically set-up a pre-configured grid on computers in a local network by booting from CD. Within such an environment, the students were able to start, build, and use an experimental grid system for solving the assignments of the different disciplines.

This article is structured as follows: In Section II, the structure and content of the assignments of the three disci-

plines are explained. Afterwards in Section III, we describe the technical environment that the students used to solve the assignments. In Section IV, we present the evaluation of the described course. In Section V, we consider related work. Finally, we conclude with results and an outlook in Section VI.

II. COURSE DESCRIPTION

The goal of the course was to teach the concepts of grid computing by the application of grid computing independently of the field of study of each participant. In this section, the course and the posed assignments are described.

A. General Structure

The assignments addressed the HEP Grid of physics, the MediGRID of medicine, and the TextGrid of the humanities. All assignments involve inevitable concepts of computer science.

Each discipline developed a track of assignments, where each of the tracks referred to the corresponding D-Grid project. The students worked on the assignments on a rotational basis. The tracks of the assignments were structured in:

- 1) introduction and fundamentals,
- 2) exercises and practice, and
- 3) reflection and further discussions.

In part one of each track, the students prepared a report about the respective discipline that included the applications of grid computing in the fields of the discipline, their requirements, and the status of the related D-Grid project. During the preparation, the students looked into the specifics of the discipline and established connections between the discipline and grid technology. Furthermore, the students made suggestions and developed proposals for an optimization of the project with a focus on the grid perspective.

In part two, the students realized the ideas suggested in part one and solved practical assignments. This included the establishment of a production-like grid environment based on Instant-Grid and the technical realization of the assignments. Depending on the assignments, the students needed to discover, use, and start appropriate grid services and functionalities provided by *Globus Toolkit 4 (GT4)* [8] or by the respective D-Grid project grid environment. With the help of these services, the students were able to develop efficient solutions for the assignments.

The assets of the solutions, as well as further optimization proposals were discussed and reflected in part three. At the end of each track, the developed grid software was presented and executed. The presentation included the design and challenges of the development, issues, and proposals regarding the existing solutions of the projects. These were then discussed and reconsidered. This also led to an improvement of the solutions presented by the students.

At the end of the course, the students compared the requirements and solutions between the three tracks. They reflected upon similarities and differences, but also expressed specific criticism and their opinions whether they would use grid technology for other areas.

B. Learning Objectives

The goals of the course can be divided into two areas – one related to technical knowledge about grid computing and, the other – to soft skills. The goals related to technical knowledge included understanding, explaining, and applying grid computing technology, in particular:

- concepts of grids,
- requirements of grids especially related to different disciplines,
- application and usage of grid technology on areas in different disciplines based on D-Grid projects,
- migration of legacy applications into a grid environment, and
- experiencing advantages of grid computing.

The goals related to soft skills on the other hand focused on the students' abilities to communicate clearly in the context of a wide range of topics, such as:

- collaboration across disciplines,
- establishment of effective and manageable team work in a heterogeneous environment,
- discussing results in a clear, structured, and concise manner,
- critical thinking,
- gathering and accessing relevant information from a library and other information resources,
- explaining the scientific method including the concepts of hypothesis and experimental controls, and why objectivity is essential, and
- writing effectively in an appropriate style and depth,
- integration and application of knowledge and experiences.

These learning objectives were promoted in several ways. These included team meetings with the instructors of the respective discipline, introductions to the disciplines, grid concepts, and available grid services. Furthermore, weekly assignments and tutorials of the grid used in the respective D-Grid projects were given. These activities were extended by regularly discussions, and final presentations.

C. D-Grid Projects Located in Göttingen

The D-Grid projects located in Göttingen supported by several faculties of the University of Göttingen built the basis for the assignments. The projects are described in the following.

1) *MediGRID*: The MediGRID project uses grid computing systems as an underlying infrastructure for providing services that access distributed applications supporting biomedical research, clinical research, and image processing.

These applications require high-performance computing and may access data from geographically distributed locations. The project represents institutions in the area of medicine, biomedical informatics, and life sciences. The objective was the development of a grid middleware integration platform enabling biomedical life science services. For this, four methodological modules (middleware, ontology, resource fusion, and e-Science) have been developed and served for the establishment of a grid infrastructure implementing the specific requirements of biomedical users [9]. Therefore, the grid middleware has been embedded in a user-friendly environment that allows intuitive access to e-Science services for biomedicine. Applications for image processing, ontology, and biomedical informatics are incorporated in a web based portal [10] that is easily accessible and usable. The services that access these application are based on an enhanced security model with different security levels. This is required because access to specific secured resources which host pseudonymized patient data is needed for the computation of medical data, e.g. for investigations on specific disease patterns [11].

A major requirement in up-to-date biomedical research is the creation, maintenance and usage of data located in shared resources. In MediGRID, this need is fulfilled by grid services provided in the e-Science platform that is continuously available. Within this platform, costs for the usage of resources for necessary tasks are pre-calculated and policies are established to allow a reliable deployment. Data can be stored and processed by using grid services independently of the geographical location. MediGRID demonstrates the feasibility and usefulness of grid services in medicine and life sciences by applying these services in biomedical research with multidimensional data and by correlating genotypic and phenotypic data.

2) *HEP Grid*: The D-Grid initiative supports the world wide *Large Hadron Collider* (LHC) [12] computing grid of the *High Energy Physics* (HEP) community. The LHC is a proton-proton collider at CERN in Geneva, Switzerland, where multi-purpose experiments – *A Toroidal LHC Apparatus* (ATLAS) [13] and *Compact Muon Solenoid* (CMS) [14], – and two specialized experiments – LHCb [15] and Alice [16] – are performed. The computing challenges of these experiments are enormous. For example, the ATLAS experiment produces data in the order of 300 MB/s. This data needs to be reconstructed, i.e., the signals of the various detector components are combined to reconstruct the particles that are produced or scattered in the collision of protons. The demand on storage and computing resources can only be handled with modern grid systems.

Different kind of grid applications exists in the HEP community. Scientists all over the world access the experiment-data to perform a variety of physics analyses. This data is replicated to grid sites all over the world to avoid data loss. However, individual analysis jobs can also be very data or

computing intensive. Thus they may need to be switched to another data location. In addition, detector components need to be calibrated regularly. The calibration jobs take detailed measured data as input and are performed on remote grid sites.

A large fraction of the grid jobs calculate simulated collision events, so-called Monte Carlo events. For a physics analysis, simulated and measured data of roughly the same size are required. Monte Carlo events are continuously produced to increase the available statistics. Similar to the measured data, the calculated Monte Carlo event-results are distributed on the grid for world wide access.

3) *TextGrid*: TextGrid is the humanities project in the D-Grid initiative. It establishes a trusted repository (TextGridRep) that ensures the long-term availability, interoperability and re-usability of research data in the humanities. Furthermore, TextGrid provides a platform for the co-development and sharing of dedicated services.

The humanities are a large and diverse discipline. TextGrid's first dedicated target group within the humanities are philologists, linguists, musicologists, and art historians. For these scholarly fields, TextGrid provides a virtual research environment (TextGridLab) that offers a single point of entry to specialized tools, content, and collaborative spaces.

The TextGrid infrastructure is based on the grid middleware GT4 with extensions along several lines to meet the requirements of research areas in arts and humanities. First of all, TextGrid developed a gateway between *Grid Security Infrastructure* (GSI)-based security – which is prevalent in grid environments – and Shibboleth [17] – prevalent in higher education. Another major effort was the integration of repository technologies for data and metadata management [18] solving problems of long term data preservation. On higher architectural layers, TextGrid creates an open service environment and provides a grid-based, interactive client based on the Eclipse Rich Client Platform [19].

D. Assignments of the Disciplines

In the following, the tracks according to the D-Grid project are described corresponding to the structure presented previously.

1) *MediGRID track*: Within this track taught by the biomedical informatics group, a brief and practical introduction to different biomedical applications in the MediGRID web portal was given. The participants used and experienced applications for medical image processing, bioinformatics, and clinical research in the MediGRID portal. Before using these applications, the students needed to be authenticated. For this purpose, they acquired X.509 certificates belonging to the *Virtual Organization* (VO) “Education” from the German D-Grid Initiative that was established especially for this course and for later teaching purposes. After applying this certificate to the MediGRID portal, the participants

were authorized to use protected medical grid resources and to execute selected grid applications of the MediGRID portlets [11].

In part two of the MediGRID track, application programs from the production grid portal, such as image processing (3D ultra sound), bioinformatics (gene prediction) and clinical research (biosignal processing), as well as an identification portlet (as a Java deployment service) were gridified and added to the Instant-Grid environment. The distribution into the grid was carried out by command-line instructions. These commands were transferred into a shell script and started on available computing resources. The sequence of commands in this script corresponds to a grid workflow. A workflow is an abstraction of complex processes in the grid software stack. This script was exemplified by gridifying a gene prediction algorithm for the comparison of two species. The developed workflow was applied in the Instant-Grid environment and reflected the same operations that would have been stated on resources in the grid offered by MediGRID. The results of solutions and adjustments developed by the participants were taken into consideration in ongoing MediGRID developments.

In the third part, the discussions and reflections focused on issues about ensuring privacy of hardware and software resources. These included topic such as security requirements in application classes related to privacy levels compared to existing security measurements. Specific aspects as the need of certificates, and the procedure of applicable and operable security levels (security vs. usability) were considered. Finally, it was discussed which requirements future medical grid applications need to fulfill, and how ethical aspects and the acceptance of the end user need to be considered. The result was a report that has been presented for discussion in the MediGRID community at the university.

2) *HEP Grid track*: The goal of this track was to give insights on typical demands of computing required by modern particle physics experiments and to study the various challenges posed. The DØ experiment [20] at the Tevatron, a proton-antiproton collider at the Fermi National Accelerator Laboratory [21] in the USA was taken as an example. At the Tevatron, packets of protons and anti-protons collide at their highest possible energy at a rate of 2.5 MHz. After an online event pre-selection, the signals of the scattered and newly produced particles are recorded by the DØ detector at a rate of 50 Hz. The average size raw data of a single event is 250 KB. The experiment runs since 2001 so that already an enormous amount of data has been stored. From the raw data, physic objects are reconstructed and stored to further process them in various analyses.

In the first part of this track, the simulation of DØ events was performed step by step. The workflow of the simulation chain and the workflow scripting system were investigated in detail. From the duration of the simulation of single events and the file size of the different output data, the

demand on computing and storage resources of the whole experiment was extrapolated. As an example, in 2005 the DØ experiment reprocessed 250 TB of raw data. Such enormous challenges for computing can only be handled with grid clusters distributed world-wide.

In the second part of the HEP Grid track, the interactive simulation of Monte Carlo data was adopted in such a grid environment. This has been accomplished by the use of Instant-Grid, similar to other tracks of the lab course. The students submitted simulation jobs to the Instant-Grid environment via commands provided by GT4. The use of a command line interface and scripts or macros is the typical way of applying grid computing in high energy physics. In addition, an supplementary introduction to gLite was given. GLite is the grid middleware of choice in the HEP Grid.

The third part included reflections and discussions of various grid applications addressed in HEP. Aspects like data archiving, data security and safety, data management, the structure of a grid system, demands on the middleware, and possible future developments were discussed. The students' conclusions were that grid computing has permanently been used for the production and storing of physic experiments and Monte Carlo data. For the calculation and analyses of the data, a stable, standardized, and tested grid environment is more important than the application of the latest features of grid technologies.

The computing challenges of experiments at the LHC at CERN in Switzerland increase the need of grid computing in high energy physics even more. As an outlook, the requirements of the Fermilab and the CERN experiments were compared.

3) *TextGrid track*: Building on the experiences of the D-Grid humanities project TextGrid, this track provided students with an overview of the opportunities of the e-Infrastructure used in the humanities. The first part of the track introduced exemplary research activities in the humanities including research on languages, literature, and art history, covering their diverse scholarly workflows [22]. Building on these information, the students derived requirements for grid technologies posed by the humanities. Amongst the scenarios mentioned by students were collaborative and interactive workflows, as well as data curation – the preservation, interoperability, and re-usability of digital objects. Particularly, the replication of data across multiple grid nodes potentially raises the stability and availability of data over long periods of time.

In the second part, students practiced how grid technologies support data curation. For an assignment, students replicated digitizations of ancient texts to distributed grid nodes using standard grid protocols. Further extending this exercise, the replicated data were processed at the distributed nodes with a typical function of data curation: the migration of digital objects between formats of varying quality or stability, e.g. proprietary formats versus standard formats

with public format specifications. In particular, students were asked to take the digitize high-quality preservation formats (100 megabyte TIFF images without compression) and convert them into a scaled-down copy for presentation purposes (1 megabyte JPEG2000 format) making best use of distributed processing in the storage grid.

The discussions in the third part of the track reflected the opportunities of grid technologies for the arts and humanities. During the discussions, the perspective reverted, and students highlighted possible contributions of the humanities to current e-Infrastructure technologies. This includes existing mechanisms for data curation such as repository technologies that establish reference networks of data (cf. data-centric science [23]), as well as virtual research environments that foster collaboration through exchange of data and methodologies. Discussions about the integration of such systems into existing e-Infrastructure environments helped students to understand the opportunities and limitations in both worlds.

III. TECHNICAL CONFIGURATION

The practical realization of the course assignments required grid software. We chose Instant-Grid since it offers simplified possibilities for starting local computer grids and its software components are compatible with the ones utilized by D-Grid. Instant-Grid employs the open source grid middleware GT4 and is based on a Knoppix-Linux [24] environment. With the GT4, Instant-Grid provides a pre-configured security infrastructure and services for job management, data handling, and information delivery. With the Instant-Grid Live-CD, a computer grid can be started without a complex installation. This environment allowed the students to study and use a grid on their own computers without the restrictions that are associated with a remote production grid environment. However, starting many Instant-Grids on the same local computer network requires specific adjustments, as described in this section.

A. Configuration in an Existing Local Network

Instant-Grid was originally designed for closed *Local Area Networks* (LANs) in order to avoid conflicts with services, such as *Dynamic Host Configuration Protocol* (DHCP) services that run in the existing network. Thus, starting many Instant-Grids on the same local computer network is not possible without further adjustments. Therefore, the computers used for the course and required to boot Instant-Grid had to be separated from the lab network. For this purpose, we established layer three networks on a layer two switch to which the computers were connected. We grouped the computers of one Instant-Grid into different *Virtual Local Area Networks* (VLANs) on the switch-level and separated them from the local computer network (lab network).

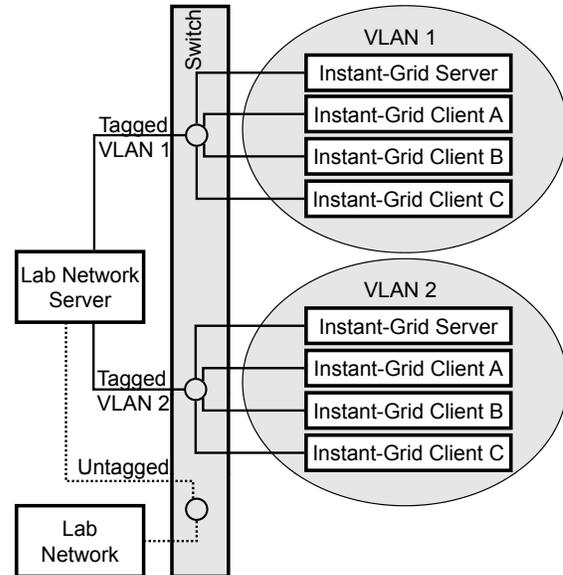


Figure 1: VLAN configuration

Figure 1 illustrates two project groups, VLAN 1 and VLAN 2, in which each starts an Instant-Grid server with up to three clients independently from the other project group. The packages sent out from the Instant-Grid networks were labeled (“tagged”) with the identifier of the VLAN, and filtered by a firewall to provide protection for the existing networks, and to route between the different virtual networks. The packages sent from the other networks, such as the lab network, did not have any labels (“untagged”), and thus were not filtered.

In our configuration, four computers from the lab network were configured and then assigned to each group. The students were able to start and configure their own grid on these computers. However, this was only possible at predetermined times, since the particular network configuration of VLANs had to be enabled by a course mentor. After the students finished their activities in their local grid, the network switch needed to be reset to the original configuration. This was necessary because of security reasons that require that only the standard operating system is started.

To access the Internet from the Instant-Grid network, *Network Address Translation* (NAT) had to be set up on the Instant-Grid server as well as on the router of lab network, i.e., on the lab network server. Figure 2 illustrates the NAT-gateways of our configuration.

B. Technical Challenges of Instant-Grid

Instant-Grid is based on Knoppix-Linux. Because of its Live-CD design, neither a component for the management of user accounts was provided, nor a configuration could be written permanently. Therefore, it was not feasible to create permanent grid user accounts. Grid user accounts have additional but very specific requirements according to

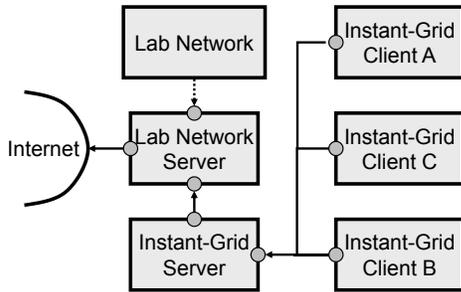


Figure 2: NAT configuration

TABLE I. FIELD OF STUDY OF THE PARTICIPANT

Computer Science	Physics	Medicine	Humanities
5	4	5	2

the grid environment compared with a usual Linux user account. The students were only able to work locally and, in addition, they needed to be supervised by a mentor, since misconfiguration of the network had to be avoided.

Instant-Grid requires a closed local network. Therefore, as described in the previous section, the integration of Instant-Grid into an existing network setup is a laborious task.

Students should not be able to make changes in the network configuration of a lab network server or set up the VLANs. In our setup, a script was started by a mentor, which then activated or deactivated the VLANs. If Instant-Grid had been started without configuring the VLAN, it could have caused serious conflicts within the lab network.

IV. EMPIRICAL COURSE EVALUATION

A. Course Workload

Due to organizational reasons, this practical course has been restricted to 16 participants. 16 students with heterogeneous backgrounds and training attended the course. The distribution of the fields of study of the participants is shown in Table I. The number of participants studying in the humanities was adequate. While the “digital humanities” are gaining speed in applying computer science technologies in their research, awareness about digital infrastructures such as grid technologies, as well as the adaptation of infrastructure technologies to the requirements of the humanities still remains to be increased.

B. Student Perceptions

Overall, the course has been evaluated as “good”. The results of an anonymous feedback survey are summarized in Table II. They reflect the differences in the knowledge and the background of the participants. While students of technical studies missed details about programming, other students were overwhelmed by the technical detail. At the end of the survey, the students were able to make comments. One student mentioned that “it is preferable to work on the

TABLE II. PARTICIPANTS FEEDBACK SUMMARY

Assertion	Average	Median	Standard deviation
The course was excellent	3,43	4	0,73
The requirements of the course were too high	2,14	2	0,83
The dimension of the course was too big	2,57	2	1,29
At any time, I fulfilled the required premises of the course	3,71	4	0,77
Relevant content could be differentiated from irrelevant content	2,57	2	1,06
The contents of teaching were demonstrated by examples and viewings	3,57	4	0,72
Difficult terms have been clarified during the course	3,29	3	0,6
The used media (blackboard, beamer, etc) were appropriate for the course	4,14	4	0,61
The assignments were structured in an excellent manner	2,43	2	1,18
The speed of the course was too slow	2,57	3	0,73
The noise level during the course was very distracting	1,43	1	0,73
Questions were answered during the course.	4,86	5	0,33
Before the course, my interest of the topic was very high	4,14	5	0,92
After the course, my interest of the topic was very high	3,71	4	1,08
Cross-references to other lectures were recognizable	2,86	2	0,78
The benefit for a later employment is very high	2,57	2	1,06
The lecturers showed high professional competence	4,43	4	0,33
The lecturers presented the content of teaching in an excellent manner	3,29	3	0,7
I would recommend the lecturers to fellow students	3,57	4	0,72

Legend:

1 to 5 scale: 1 - "strongly disagree", 5 - "strongly agree"

assignments individually”, and that “the assignments could include complex programming”. Another student wrote that “it was interesting to know about financial and legal issues of grids”. However, others mentioned the opposite. The foundations need to be taught at once and not repeatedly in the beginning of each track. Afterwards, the individual requirements of each discipline for grid and their differences can be imparted so that the student can learn to apply similar methods in different areas.

C. Tutor Perceptions

In this practical course, each of the three disciplines provided tutors for supervising the students. However, the interdisciplinary manner of the course required more collaboration between colleagues and students than in other usual courses of the disciplines. The preparation of the course

took longer, because the different teaching methods and expectations of the different disciplines had to be evaluated, understood, and synchronized first. The tutors as well as the students had varying knowledge of the other disciplines and thus required proper introductions to the disciplines. Even technical terms for the same concepts of grid computing may vary. Also, it was necessary to get familiar with the technical environment chosen for the course so that the right tasks could be defined for the students.

Overall, the feedback given by the involved tutors showed that they had to dedicate more resources for preparing and supervising the course, but they also earned special competence for later teaching purposes.

V. RELATED WORK

Several courses about grid computing have been taught at other universities. The courses focus mainly advanced computer science students. These include courses described in [25], or [26]. In contrast, Mache and Apon describe a course for undergraduate students only focusing on the computer science course of study [27]. They present five knowledge areas that should be covered by a grid computing course. This includes appropriate topics and exercises. Similar approaches of courses for undergraduate computer science students can be found in [28], or [29]. A top-down teaching approach is described in [30]. This means that the students begin with job submissions using a grid portal and, afterwards, they experience step-by-step the details of a grid computing infrastructure and its architecture.

The research projects and disciplines mentioned in this article offer in addition to the practical grid course an interdisciplinary seminary about grid computing in the winter term at the University of Göttingen. This lays the foundations for the students that attend the practical course about grid computing.

Our practical course aimed at students from diverse fields of study including physics, medicine and the humanities. They had to learn best practices from each field and its relation to grid computing. To our knowledge, this interdisciplinary approach of teaching grid computing is unique.

VI. CONCLUSION

The interdisciplinary practical course on the application of grid computing has been evaluated as “good” by the students and thus can be considered a success. Overall, the course provided students with diverse perspectives on grid computing from the various disciplines involved – physics, medicine, computer science, as well as the humanities. From scholarly requirements to hands-on experiences, as well as discussions about the current state and the possible future of e-Infrastructure research. The distinct perspectives contributed to the precipitous learning curve of the students during the practical course.

For solving the assignments, the students had to learn to apply their knowledge on other disciplines, but also to explain their field of study to students of other fields of study, for example, for the realization of inter-domain software. Grid computing builds a bridge between different backgrounds offering innovative opportunities and promising ideas in each discipline. The students had to solve the assignments by combining advantages of each discipline through developing, applying, and experiencing different solutions. The students learned to propagate their ideas and to communicate problems as it was best for the interdisciplinary solution and furthermore, to realize their ideas in a grid computing environment using available resources most efficiently.

In the final discussion and post-processing of this interdisciplinary course, the interactions and teamwork between the students of the different fields of study were considered. The goal of the course was not that the humanities students have to program or that the computer scientist learns the processes of the genetic prediction, but that they work in a complementary manner and solve the assignments together in a team. Ideally, the physicist, for example, would ask the correct questions, the humanities student would introduce methods for answering the questions, the physician would contribute with background knowledge, and the computer scientist would develop a technical solution. In each track, the adequate roles were taken by the students and, therefore, the tracks could be solved in an complementary manner.

From the technical side, Instant-Grid has been proven as an ideal tool for the realization of the course. Instant-Grid is an adjustable and scalable instrument for ad-hoc grid applications. For short-term development, extensions such as specific portals and even complete development environments can be included.

Following the character of this practical course, solutions have been elicited to solve the assignments of the disciplines. For imparting knowledge of grid programming expertise, especially for computer science students, Instant-Grid is the tool of choice. We experienced that there is a great demand for grid-developers in the IT sector, but also in other sectors. However, conveying techniques of grid programming to students in an interdisciplinary course is not feasible, because students who do not study computer science get lost in the technical details. The computer science students were responsible for technical requests of the fellow students and for the realization of their solutions. However, a practical course about programming in a grid has been offered in addition in rotation with the course on the application of grid computing.

At the University of Göttingen, the grid computing teaching track is well established. Good evaluation results and several successful applications for future grants underpin the stability of Göttingen’s grid infrastructure and emphasize the need for substantial grid teaching to educate junior

assistants.

For the interdisciplinary course described in this article, we plan to extend or exchange assignment tracks. For example, other fields of research that are active in Göttingen can be considered. This could include a track about quality assurance in grid computing [31], a track about numerical simulations in a grid environment, cf. OptiNum-Grid [32], or a track about legal issues [33]. Ideally, a training framework for the application of grid computing technology, as well as for programming grid services should be developed.

The skills that were taught in this course went far beyond the technical ones of applying grid computing. It was about collaboration with colleagues, who introduced different knowledge and who may solve tasks in a different way. It was about communication, in which requirements and proposals are not explained only with technical terms and concepts that are only understandable for people of the same discipline. The participants got deep insights in each discipline and learned to develop solutions in cooperation with students from other disciplines as it is often the case in the professional world, where the disciplines often melt. Acquiring such skills is a life-time experience for the students, as it can only be conveyed in an interdisciplinary course.

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