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Use of e-Science Environment on CFD Education

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1. Introduction

'e-Science' represents the global collaborations of people and shared resources to solve new and challenging problems in science and engineering (Hey & Trefethen, 2003) on the basis of the IT infrastructure, typically referred to as the Grid (Foster & Kesselman, 1999). As we can easily infer, e-Science initially meant a virtual environment where a new and challengeable research can be accomplished using latest infrastructures. That virtual environment usually has a form of a web portal page or an independent application with a bunch of computer scientific components inside: high-end application researches include large-scale computations for complex multi-physical mechanisms, coupled works of computation and experiments for design-to-development processes, and/or data-intensive researches. The infrastructure consists of computational and experimental facilities, valuable datasets, knowledge, and so on. Researchers can be referred to as a core component of e-Science environment as their discussions and collaborations are promoted by, managed by and integrated to the environment.

Meanwhile, the meaning of 'e-Science' is becoming broader nowadays. Though e-Science first intended to enrich high-end research activities, it is soon proven to be also effective on academic activities as a cyber education system. (On the other hand, use on interdisciplinary collaborative researches is not much vitalized as expected, because of diverse preference on internal workflow, I/O and interface among research domains.) Thus, the term 'e-Science' is rather used to represent 'all scientific activities on high performance computing and experimental facilities with the aid of user-friendly interface and system middleware' these days.

As a virtual academic system for aerospace engineering, 'e-AIRS' (e-Science Aerospace Integrated Research System) has been designed and developed since 2005. After three years' development, e-AIRS educational system is finally open, where non-experts can intuitively conduct the full process of computational and experimental fluid dynamic study. Also, the

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system is currently under improvement to the research system and eventually would include other physical domains for multi-disciplinary researches.

To develop a cyber education system, we have employed/developed a number of computational and experimental components, as well as lots of middleware modules. They include computer scientific modules (monitoring and scheduling, metadata management, plotting), CFD (Computational Fluid Dynamics) computation tools (mesh generator, visualization software, CFD solver), and remote experiment management tool. Computing and experimental facility pool including resources in Korea, Japan, and Germany are/were connected to e-AIRS server by using Globus (<http://www.globus.org>). Access Grid Toolkit (<http://www.accessgrid.org>) is used for open discussion. Services are implemented on a web portal interface, developed by using GridSphere (<http://www.gridisphere.org>).

Current system is used as lecture materials for undergraduate and graduate fluid dynamic classes. Students get offline lecture on the physical basis of their application target, be trained on how to use the system, and their own simulation on representative fluid dynamic phenomenon through the CFD service in e-AIRS portal. Up to now, more than two hundred students in five universities experienced the use of e-AIRS as their lecture materials and they demonstrated more understand on CFD by using this web portal.

The characteristics and features of e-AIRS educational system will be demonstrated in this chapter. We will first describe how we applied the computer scientific concept (e-Science) to the application domain (fluid dynamics) in detail, including our objective and strategy, design of system and troubleshooting between computer scientist and application researcher. Next, our technology implemented/improved/developed are to be mentioned, including what has been done to develop an optimal system for a specific application domain (fluid dynamics), where we had a hard time in applying currently available computer scientific technology. Then, we will demonstrate how much our product influenced on the education of students majoring in this domain, and will briefly introduce our next goal (professional research system) with current technical trouble.

2. Design of a system

2.1 Motivation

For years, a number of researches have been promoted to conduct aerospace engineering researches/educations under the latest cyber infrastructure. As the representative researches on e-Science, a few projects in the UK e-Science program, a workbench by German Aerospace Center (DLR), a research system by NASA are present. The Distributed Aircraft engine Maintenance Environment (DAME: Jackson et al., 2003) is an UK e-Science pilot project, demonstrating the use of the Grid to implement a distributed diagnostic system for deployment in maintenance applications and environments. The main aim of DAME is to construct a distributed aircraft engine maintenance environment, motivated by the needs of Rolls-Royce and its information system partner Data Systems and Solutions. The Grid-Enabled Optimisation and Design Search for Engineering (GEODISE: <http://www.geodise.org>) is also one of the UK e-Science pilot projects. It is intended to enable engineers to carry out engineering design search and optimisation involving fluid dynamics, and is bringing together the collective skills of engineers and computer scientists. The Grid-Enabled Computational Electromagnetics (GECEM: <http://www.wesc.ac.uk>) project aims to use and develop Grid technology to enable large-scale and globally-distributed scientific and engineering research. The focus of GECEM project is collaborative

numerical simulation and visualisation between globally-distributed research groups. The Grid-Enabled Wind Tunnel Test System (GEWiTTS: Crowther et al., 2005) project is concerned with the development of a GRID enabled set of communication protocols that enable scientific test equipment and facilities to be networked with computational resources and data storage/visualisation in a secure yet flexible manner. The TENT (Forkert et al., 2000), a simulation environment for DLR, is a component-based framework for the integration of technical applications. The main goal of TENT is the integration of all tools which belong to the typical workflows in a computer aided engineering (CAE) environment and it allows the engineer to design, automate, control, and steer technical workflows interactively. The DARWIN (Walton et al., 2000) is a distributed analysis tool that was developed at the NASA Ames Research Center to support aeronautics design activities. By providing aircraft manufacturers with faster access to wind-tunnel data, the DARWIN system helps to shorten the aircraft design and test process.

Also, there have been a number of trials on developing a cyber education system for fluid dynamic study. E-Fluids (<http://www.efluids.com>) holds a number of images and videos on various fluid dynamic experiments and computations and it also supports web-based numerical simulation. Java Applets for Engineering Education (<http://www.engapplets.vt.edu>) includes many Java applets related to fluid dynamics, statics and dynamics. Users can get the source code for all applets. In the Java Virtual Wind Tunnel (<http://raphael.mit.edu/Java/>), an interactive two-dimensional inviscid CFD simulation of a channel with a bump can be conducted. Users can experiment how the solution evolves with different boundary conditions and numerical schemes.

Though above projects on developing a professional research environment have opened a new scientific frontier on integration of aerospace engineering divisions with IT technology, they also have some weak points in service environment constitution. For example, they are specified for professional engineers and permit only assigned member, so that many general users can not access or use them. There is no user-friendly interface or portal web site for various classes of user groups. Also, for the cyber education system described above, users can easily learn at anytime and anywhere, but there are limitations that simulation and experiment are separated, and they don't have enough resources to conduct many simulations simultaneously.

In consequence, the e-Science environment for any kind of scientific computing including aerospace engineering should be a users' playground, which encourages pioneering trials on their domain science with maximal degree-of-freedom. In this sense, the environment should possess the latest IT technology for application scientists; help various types of researches by conjugating computation, instrumentation and data-driven approach; gather and open as many knowledge as possible; support and encourage the coupling of multiple disciplines; give a detailed guideline on using this environment. Thus, a new e-Science environment is devised to integrate latest IT technology with aerospace engineering discipline and conjunct computation with experiment and existing datasets, in the form of a web portal.

2.2 Objectives and strategies

E-AIRS has been developed and used since 2005 (Kim et al., 2006; Ko et al., 2007), as a product of the Korean e-Science project. The Korean e-Science project has been promoted since 2005 with support from the Korean Ministry of Science and Technology. On the basis

of the Korean Grid infrastructure, five research topics were selected as main applications. They include the remote imaging service of an electron microscope, climate information system, molecular simulation, bioinformatics, and the current aerodynamic research system. As can be inferred from its name, e-AIRS first aimed to give a full support on aerospace engineering research process including numerical simulations and instrumental experiments. However, it is soon proven to be very hard to establish a professional research environment without breaking our primary propositions. First, in implementing CFD codes, researchers preferred to import their own solvers without having to change their interfaces according to the formula of system, and suggested diverse GUI designs compatible with their tools. Regarding the instrumental experiments, many valuable data were closely related to national defence, so asked to be protected within an organization. However, it was contradictory to our policy, which is 'to open all information to public and give equal opportunity to all users'. Thus, we have turned our direction to develop a web portal for academic use first and migrate to professional research environment which intensify users' controllability on numerical simulations and allow data protection by restricted user group. Thus, we have determined our objective to construct an easy-to-use cyber education system which includes the full procedure of numerical simulation, remote execution of instrumental experiment with a number of referential datasets, valuable knowledge to academic user. Also, considering the enormous time on building a multi-disciplinary scientific research environment, we first focus on supporting fluid dynamic research activity. As the schematic in Fig. 1 shows, non-experts can intuitively conduct the full process of computational and experimental fluid dynamic study in the e-AIRS educational system. Also, professional users can perform their parametric study on representative fluid dynamic applications.

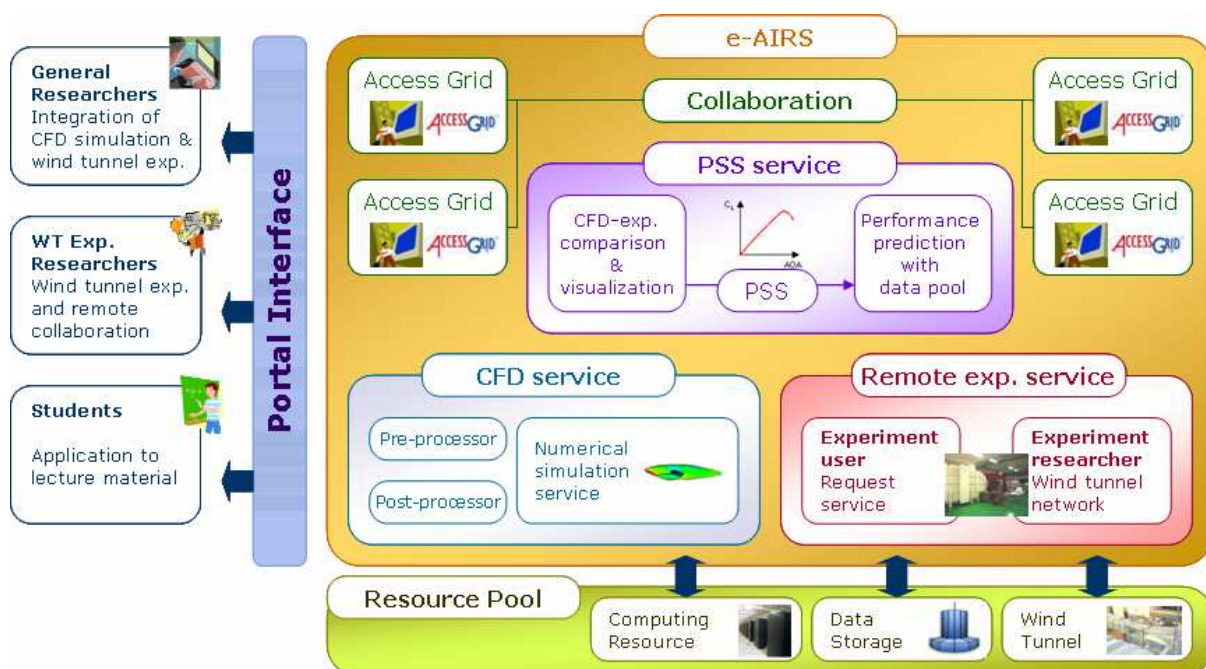


Fig. 1. Schematic of e-AIRS Educational System

The major strategies to establish the above system can be summarized as follows:

- **Open to Public:** The system should be open to anybody who wants help from us. They should be able to request our service anytime, anywhere. In this reason, the system will be built in the form of a web portal.

- **User Interface:** Portal interface will be easy enough for non-experts to use intuitively. So, all simulation toolkits are attached in or linked with portal pages. Also, most controllable variables for numerical and instrumental experiments are set up as default values and hidden inside the system to avoid users' mistake.
- **Middleware and Core Modules:** We focus on integrating application domains and showing our system is running in any cases, not devoting much time on designing and developing new software. We perform a deep survey on available and reliable middleware/application components and minimize the new development.
- **CFD Service:** Required tools for CFD simulations (i.e., mesh generator, flow simulation code, visualization software) are included in the system. Pre- and post-processing tools are developed in the form of a web application, CFD solver support easy control with automatic parallelization.
- **Remote Experiment Service:** Considering impossibility to control wind tunnels electronically, the remote experiment service will be asking the experimental operator to conduct specific experiments for users. For this, e-AIRS will facilitate close connection between end-user and experimental operator.
- **Integrated Research Service:** This service will show the comparison between CFD and experimental results. Furthermore, automated high throughput computing on the selected ranges should be conducted. The system supports automatic parameter sweep and submission of multiple tasks.
- **Collaborative Conference:** Basically depend on functionality in AGTk. Use various shared applications and give a guideline to use them.

2.3 Brainstorming and conceptual design

As mentioned in the above section, our main strategy is to maximize the use of existing software and focus on integrating them to work. So, a lot of time is spent on filling the list of reliable software components and selecting ones for our system construction.

For portal interface, the main focus would be user-friendliness. So, a long time has been spent on designing detailed user interface and lots of toolkits for web portal development were investigated to select which toolkit will satisfy our design needs. We chose GridSphere as a portal construction package. The GridSphere portlet framework provides a solution to construct an open-source web portal which provides with a friendly and easy to use interface by allowing users to interact with Grid services through standards means such as a web browser. It can also enable developers to quickly develop and package third-party portlet web applications that can be run and administered within the GridSphere portlet container. It supports administrators and individual users to dynamically configure the content based on their requirements. One of the reasons we choose GridSphere is that Gridsphere itself provides grid-specific portlets and APIs for grid-enabled portal development.

CFD service should support pre- and post-processing tools as well as CFD solvers for one-stop CFD service. Also, they shall run through portal page. The selection of CFD tools were rather easy because a CFD group participating in this project already possessed their own tools. As we already had an accurate parallel solver for moderate CFD simulations, this in-house code was used as the core of CFD service. Regarding mesh generator and visualization software, these tools we have possessed were programmed with C language. To let them run through the portal page, they have been ported to Java language and serviced in the form of web applications.

On the other hand, designing a remote experiment service was so hard. First, aerospace engineering experiments were closely related to national defence researches. The security requirement makes instruments hard to open to public service. Thus, moderate-sized supersonic and subsonic wind tunnels possessed by current research group are used to public service. Second, the wind tunnel experiment cannot be digitalized and automated. As all experiments should be done manually, the web portal will support users in requesting specific experiments and getting the resultant data conducted at one of the wind tunnel facilities in the resource pool.

Regarding system construction, we could list a number of middleware available for e-AIRS service. To connect computing infrastructure with e-AIRS system, Globus has been used for Grid setup. Monitoring and scheduling tools will follow resource contributors' choices. Metadata management service and database setup are referenced by previous portal setup experiences. Other components like plotting service and parametric study engine are newly developed.

For collaborative conference, various shared applications are implemented on AGTk. Of these services, the remote visualization was hardest to refer to: though Shared GNUPlot was the only available one, CFD researchers feel hard and uneasy to control this software. Thus, some example scripts are attached to the system to ease CFD visualization.

Designed architecture of e-AIRS system according to above brainstorming is given in Fig. 2.

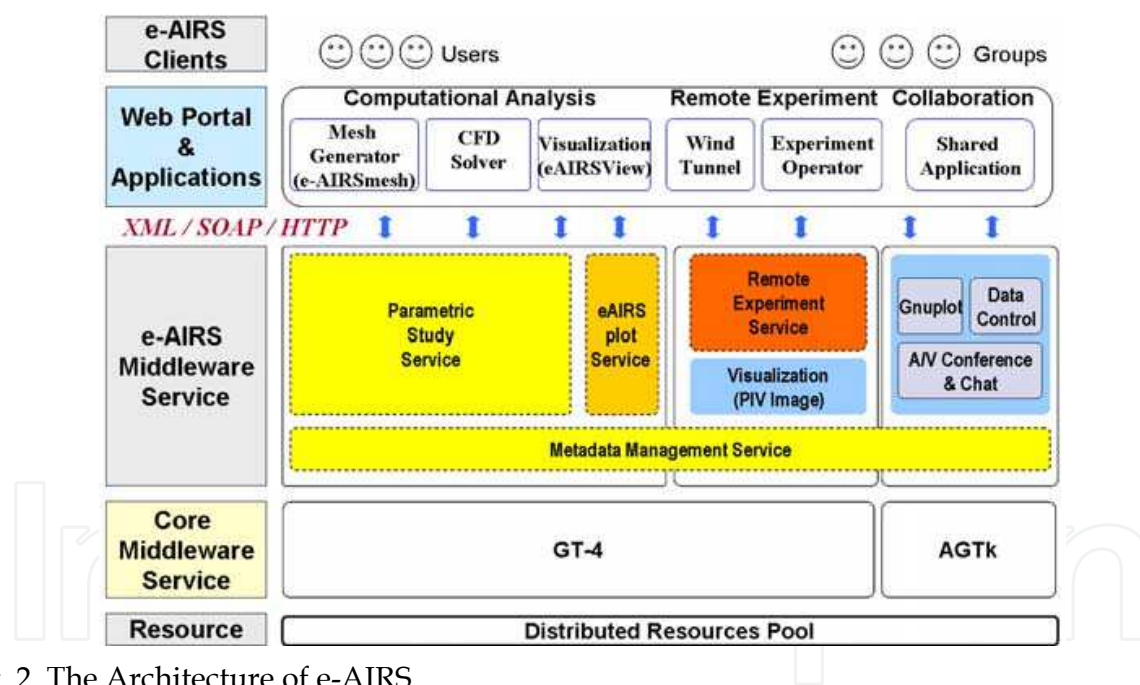


Fig. 2. The Architecture of e-AIRS

3. Development of e-AIRS: infrastructure and general middleware components

3.1 Use of international resource pool

For computing service, e-AIRS first tries to use our own local clusters in KISTI and Seoul National University, Korea, and submits job requests to PRAGMA Grid testbed (<http://www.pragma-grid.net>) when more resources are required. E-AIRS server requests job execution by using Globus and follows PRAGMA's policy when using international

resources. The authors wish to acknowledge the use of the PRAGMA Grid testbed and technical support of many researchers and site administrators at PRAGMA member institutions.

For wind tunnel experiments, e-AIRS utilizes local supersonic and subsonic wind tunnel facilities at Seoul National University. E-AIRS server is connected to control PCs of these equipments to request remote experiments and get resultant data from experimental operators.

3.2 Implementation of core middleware service

3.2.1 Globus

We use the Globus Toolkit to establish cyber environment for CFD simulation because the Globus Toolkit – the de facto standard for open source grid computing infrastructure – is the world’s most widely-used set of services and software libraries to support Grids and Grid applications. This Toolkit is freely available in open source format on the Web with applications for security, information infrastructure, resource management, data management, communication, fault detection, portability and more. In many ways, the Globus Toolkit defines Grid computing which enables users to solve a technical or scientific problem that requires a great number of computer processing cycles or access to large amount of data.

We installed Globus Toolkit 4 on our local server to access and submit jobs to computing resources based on Grid. The computing resources are distributed geographically and installed Globus Toolkit 2 or 4. Actually this version of e-AIRS only supports for resources with Globus Toolkit 4 to submit jobs. We are developing an adapter module for Globus Toolkit 2 and 4 so that users can submit jobs to computing resources with different version of Globus Toolkit. e-AIRS uses some Globus components such as WS GRAM for resource management, GridFTP for transferring files, and GSI for security.

A user can log into web portal to solve problems by using Grid environment. Actually, all users should have to get a grid account and proxy to submit a job on Grid environment. However, it is hard to add and manage lots of grid account on each site. So we only use one grid account for all portal users, which means all portal users are mapped into one grid account in e-AIRS system and are sharing one proxy certificate. Even though users share one proxy certificate, it is not much of a problem. Because e-AIRS is a web portal environment and does not support shell environment such as remote terminal using telnet or ssh, so users can’t directly access and modify any files.

3.2.2 AGTk (Access Grid Toolkit)

Remote conferencing on e-AIRS is managed by the AGTk (Access Grid Toolkit), and the concept is shown in Fig. 3. When a user needs a remote discussion with other researchers, the user can create a new AG session, and see the session information on the e-AIRS portal. The host can also include participants from the user list on the portal, and the portal server will automatically send e-mail notices to the requested participants. Then, they can participate in the remote conference either by directly accessing the session or by following the link to the session, which is presented on the portal. Fig. 4 shows the interface of the e-AIRS collaboration service.

The AGTk is a powerful system for both remote communication and research data sharing. Detailed AGTk specifications will be omitted in this paper because the AGTk is popular and

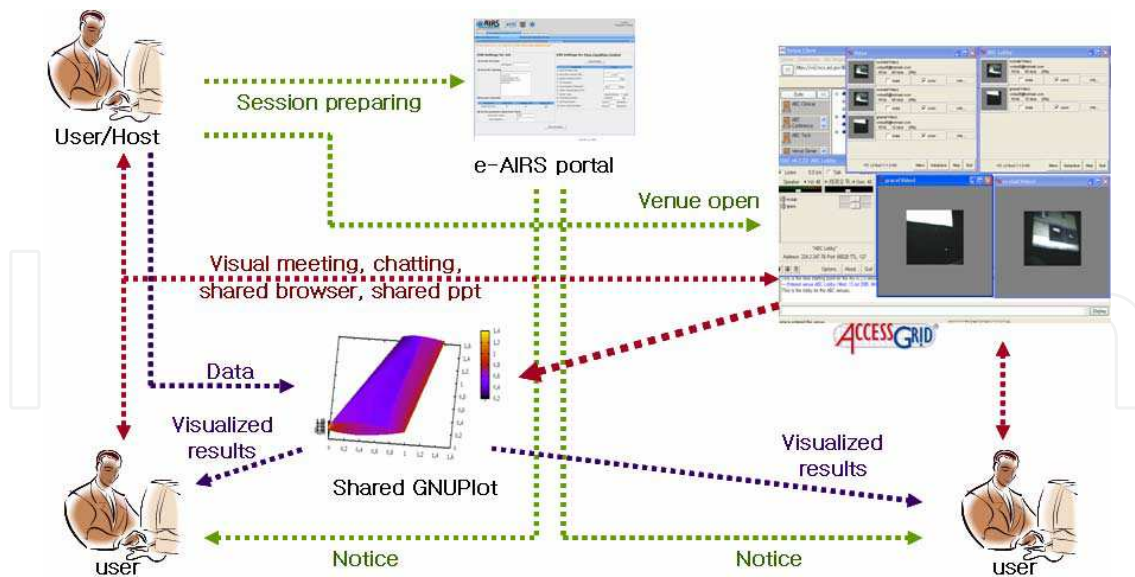


Fig. 3. Overview of the e-AIRS collaboration service

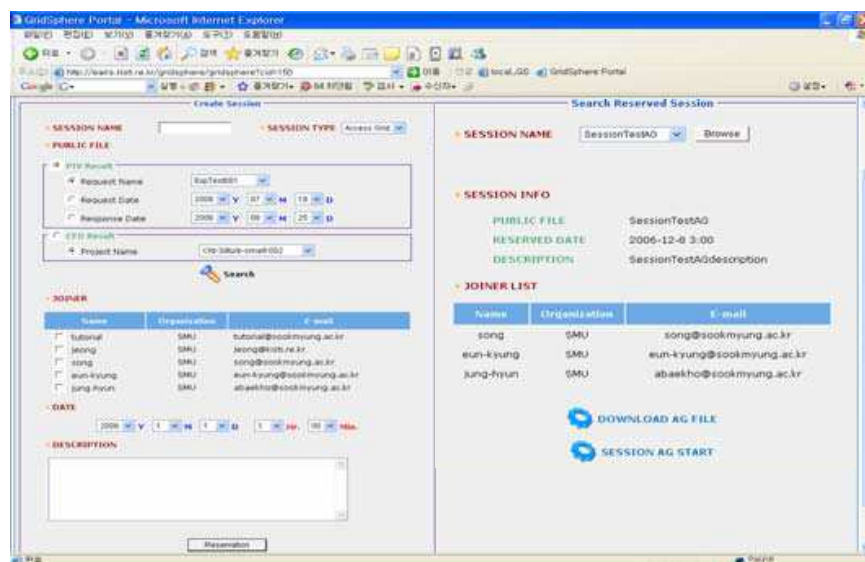


Fig. 4. Interface of the e-AIRS collaboration service

broadly used. Apart from the virtual face-to-face conference and chatting functions, participants in remote conferencing can exploit other shared applications to exchange their ideas and data through AGTk environment. The shared applications include shared PPT, shared browser, shared desktop, shared PDF, and so on. Furthermore, to share research data, the shared GNUPlot software is installed. PIG(Personal Interface to AccessGrid) nodes have been established at Seoul National University, KISTI(Korea Institute of Science and Technology Information), and Sookmyung University.

Because shared desktop on AGTk only supports full screen mode, we developed a module for integrating AGTk and TightVNC which is a free remote control software package. Using TightVNC, Users can see the desktop of a remote machine and control it with your local mouse and keyboard, just like you would do it sitting in front of that computer. Using this module, users can also view the remote desktop in whole on a screen of smaller size, or users can zoom in the picture to see the remote screen in more detail.

3.3 Formulation of e-AIRS middleware service

3.3.1 MMS (Metadata Management Service)

Because of large amount of numerical data in CFD simulations, the massive data storage should be established separately from the portal server. If the data is saved in the separated storage, it has to be described where certain data is stored. The metadata contains size and type information of the real data, storage server information, and so on. The MMS(Metadata Management System) is integrated management service for this 'metadata and real data' hierarchy. The main roles of MMS can be summarized as follows:

- Creation of metadata
- Storing of metadata onto the meta-DB
- Browsing of metadata when there is a reuse query
- Transfer of real data from the separated server to the portal server

MMS is integrated management service about various data; input data, computational result data, experiment data, and sharing data for collaboration. When user operates his job, his data are accumulated, but user wants to reuse used data and search his data easily. We provide that user only uses projects/cases and system connect selected project/case, DB and real data in remote storage through MMS. User can reuse and analysis whole data easily. If user selects a project, MMS matches cases to the project and connects parameter value of case. Also, since MMS entirely manages data, if user can select a project, user can get computational data and experiment data about the project. e-AIRS service modules call MMS to access the data. MMS is developed as internal web service for security.

Data Storage having real data and DB server are Resource Layer. Portal service, job submission, job monitoring, user management service, e-AIRS internal services are Service Layer. MMS are in Middleware Layer for such services can access and use data in Resource Layer MMS use DB value using wrapper classes which are matching to DB table, and the value of wrapper classes are got/set/updated/deleted by specific web services.

3.3.2 PSS (Parametric Study Service)

Job submission system takes the role of assigning available computing resources to every job when multiple simulations with various input conditions are requested. In e-AIRS, the PSS(Parametric Study Service) supplies not only the assignment of massive computation jobs to resources but also the control of running simulations, using the job scheduling technique. Completed simulation results on various input conditions are then aggregated in a graph by the PSS in order to plot the change of flow characteristics(i.e., lift and drag coefficient profiles) with variation of input parameters(i.e., flow angle of attack, Mach number, Reynolds number).

The PSS is composed of several internal and three external modules. These modules are connected on the Grid services. The EDL(Experiment Description Language) possesses simulation information and it is extended with the reference of RSL(Resource Specification Language) and JSDL(Job Submission Description Language). The EPP(Experiment Parametric Parser) understands the EDL, and effectively creates task units. The ETS(Experiment Task Scheduler) assigns available resources for tasks. An aim of the ETS is to flexibly control tasks according to performance and state of resources and to provide executive environments. The ETD(Experiment Task Dispatchers) bids available resources execute defined tasks.

The Grid information service gives resource information to the PSS internal modules. The experiment information service acquires the metadata from tasks and provides task information to users.

The PSS helps clients acquire additional flow data by simulation. The missing-data-acquisition process proceeds along the following sequence:

1. Choice of the end-cases of data-missing region
2. Generation of the number of sub-cases
3. Automatic submission of additional calculations
4. Final graph-drawing using the validation service.

The PSS consists of four components: a parameter parser, a task generator, a task scheduler, and a task allocator. The parameter parser confirms the user input, and obtains suitable parameter information from the database. The task generator produces sub-cases under the parameter information, and writes sub-case information on the database. The task scheduler checks the status of the computing resources, and the task allocator distributes calculation jobs to the resources of the HTC environment. Fig. 5 shows the overview of the PSS process.

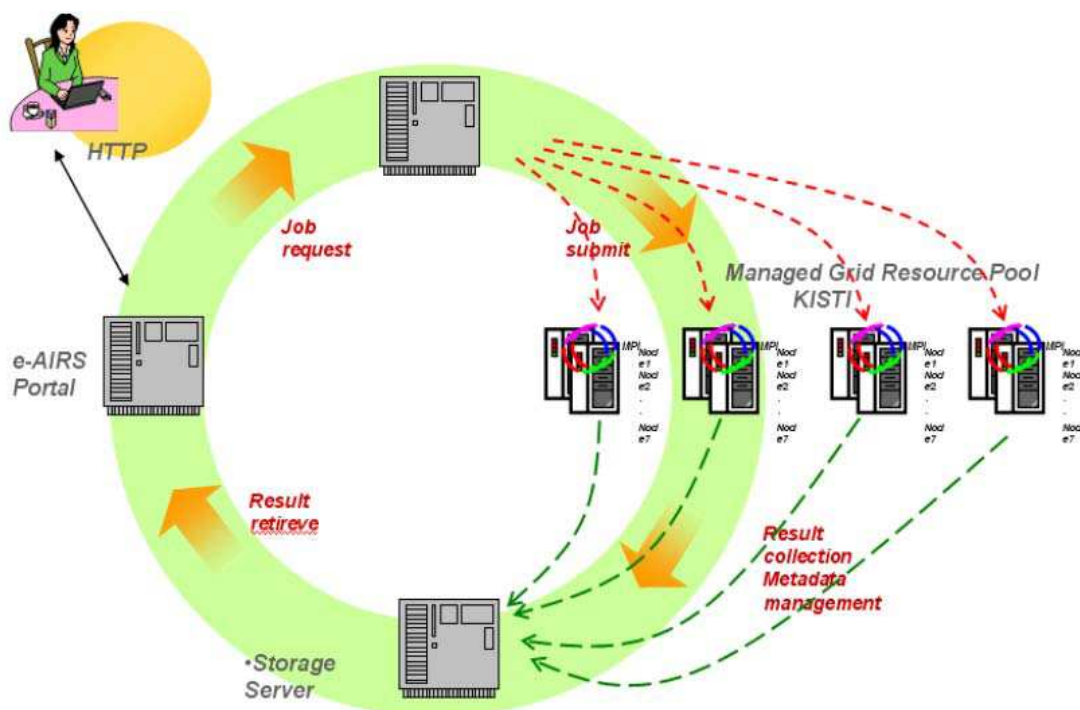


Fig. 5. Overview of automatic job execution of the PSS

3.3.3 Monitoring service

A submitted job is identified by a unique job ID, which can be used for enquiry about the job status. Seven different job states can be presented depending on the current status: queued, stage-in, ready, active, stage-out, done, and failed. Fig. 6 shows the interface of the monitoring service.

With the monitoring service, a user can monitor the latest status of the simulation. The user also can see the convergence history graph for error checking. We developed an error history data module which show error history data that is output of solvers on graph. The convergence history and intermediate results enable the user to judge whether the computational procedure is correct. The user can interrupt the job if it turns out to be wrong. e-AIRS periodically gathers intermediate result files from computing resources by using GridFTP.

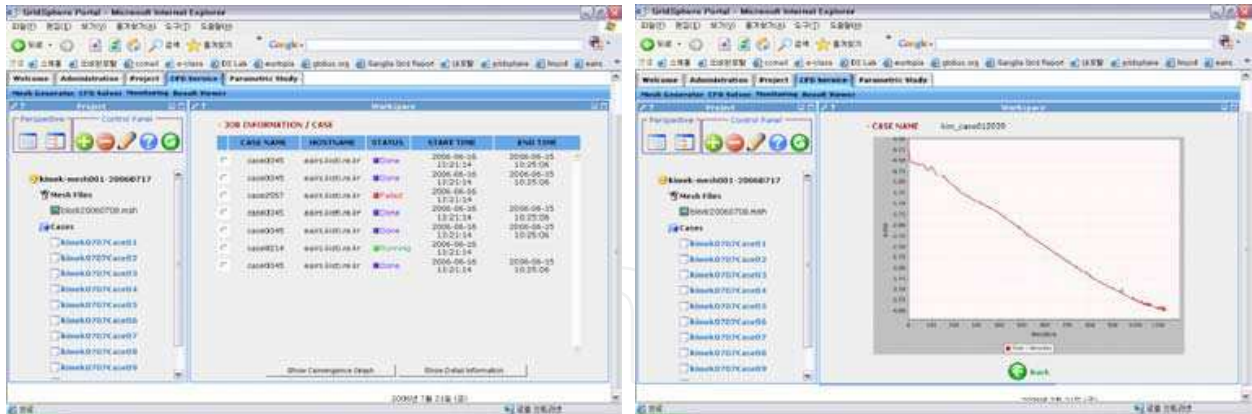


Fig. 6. The monitoring service of e-AIRS

3.3.4 Scheduler

Actually, a scheduler is implemented as a part of PSS. The scheduler fetches a queued job from Database; when a user submits a job, the job is just inserted into a Database and set the field to 'Queued'. And then, the scheduler checks available resource by retrieving RESOURCEINFO table in the Database. The RESOURCEINFO table keeps available queues and status. We should keep dynamic information about available queues, but now set the values manually; we use PRAGMA grid, but there is no global resource broker and scheduler. After the scheduler selects one of resources, it assigns the job into the selected resource. The scheduler assigns queued jobs into first selected resource until the queue is full. If the queue is full, remaining jobs are assigned to the next selected resource.

4. Development of e-AIRS: e-AIRS service components

4.1 CFD software

As application tools, a simple mesh generator and a visualization tool for CFD are developed and attached to a portal in the form of Java applets, and compiled CFD solvers within computing pool are executed using input flow parameters through user interface. They cover the full CFD simulation procedure, seen in Fig. 7.

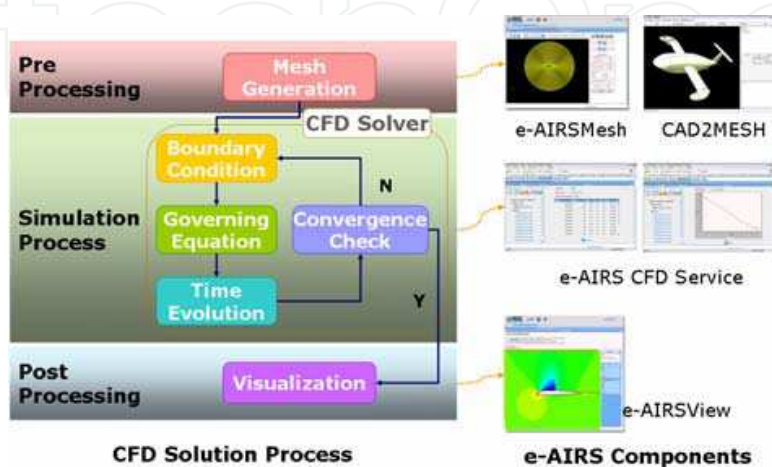


Fig. 7. CFD Service Flow

4.1.1 A mesh generator

The mesh system means the set of discrete cells around the target geometry. CFD simulation tool can obtain the physical values of gas or air on this divided zone, by calculating the numerical fluxes between neighboring spatial cells. Currently, the e-AIRS users can either use their existing mesh system or generate a new mesh on the portal.

To generate the mesh system on the e-AIRS, users need to use two softwares of 'CAD2MESH' and 'e-AIRSmesh'. At first, CAD2MESH captures major line and surface components from CAD data file. CAD2MESH can read CAD files with VRML format and returns those components to e-AIRSmesh input format. Then, e-AIRSmesh generates the mesh system around the body. To construct the mesh system, an algebraic method by a transfinite interpolation technique is used. Also, exponential, hyperbolic tangent, and hyperbolic sine functions are used to distribute grid points.

e-AIRSmesh has a convenient interface to create the model geometry, to make a mesh system, and to specify boundary conditions. Additionally, for easier mesh generation of simple shapes, e-AIRSmesh supports some default mesh templates for standard geometries such as cubical or spherical shape and NACA 4-digit airfoils. CAD2MESH and e-AIRSmesh softwares are shown in Fig. 8.

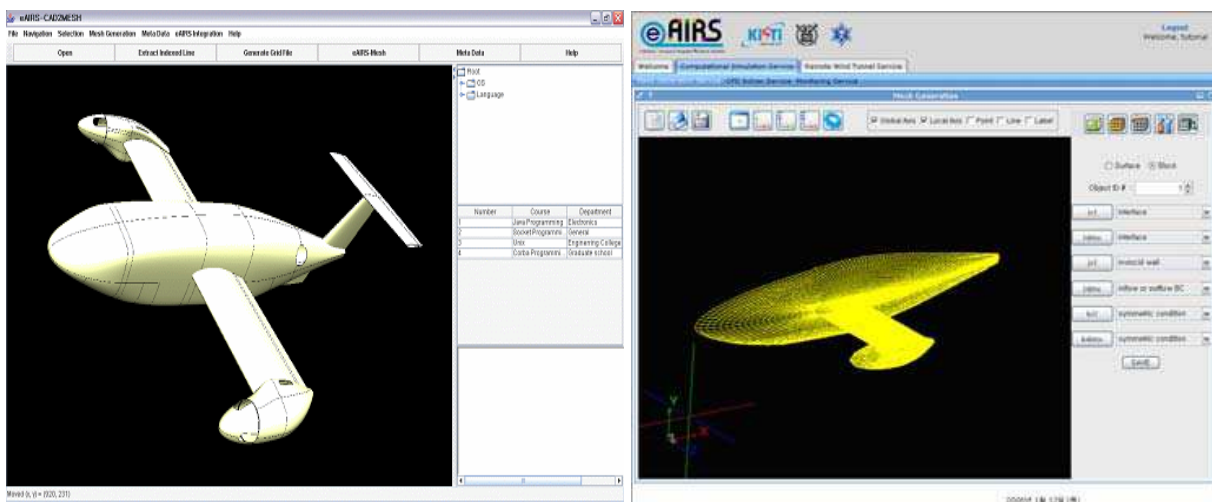


Fig. 8. CAD2MESH and e-AIRSMesh applications

4.1.2 CFD simulation codes

Accurate CFD solver is the core of fluid dynamic simulations. Two in-house CFD solvers for incompressible and compressible flow simulation (Lee et al., 2006; Kim et al., 2003) are imported on e-AIRS. Basically, included CFD codes can conduct parallel simulation and they solve three-dimensional fluid dynamic problems from subsonic to supersonic flow ranges. But, for e-AIRS service, solvers need to be light to enable a number of students to run multiple simulations at the same time within restricted resources. Thus, in e-AIRS, solvers are fixed to solve two dimensional problems by serial processing. Details on solvers are described on above references.

4.1.3 CFD visualization

During and after the computation, all output data in result directory of each case are transferred to a storage server. And, saved resultant data can either be downloaded to users'

local machine or visualized through the portal. e-AIRS supports the JAVA-based, free visualization software. As seen in Fig. 9, e-AIRS can visualize the resultant pressure data of the CFD computations with various visualization functions, such as displaying mesh, contour, vector, and boundary plot attributes.

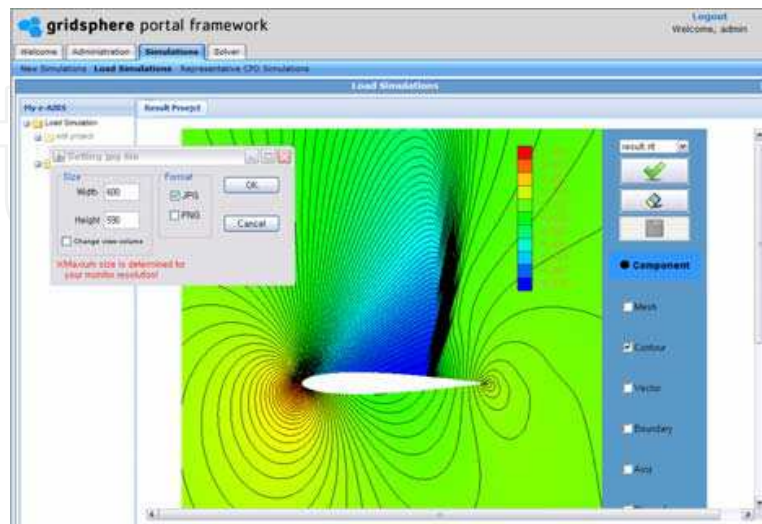


Fig. 9. A data visualization software on the e-AIRS portal

4.2 Components for remote experiment

The remote experiment service consists of three services: the experiment request service, the experiment management service, and the experiment information service. A client can request an experiment through the experiment request service. Then the wind tunnel operator checks newly requested experiments on the experiment management service. This management service offers the detailed information of requested experiment to the operator such as the Reynolds number, the angle of attack, the data form, the test area on the aerodynamic model, and so on. Then the operator can carry out adequate experiments and upload result data files including particle image through web UI. Finally, a client user can browse and check the status of the experiment through the experiment information service. The states are classified as <NEW>, <ON-GOING>, and <FINISHED>. This information service also shows various images with which a user is able to see the result image files conveniently. The figure 9 shows the remote experiment procedures.

The interface of the remote experimental service is composed of various portlets which are developed within the framework of GridSphere. The GridSphere portlet framework provides a solution to construct an open-source web portal. The GridSphere supports standard portlets, and these can be extended to the new portlets. The portlets are implemented in Java and can be modified easily. Regarding experimental service, portal pages cover remote experiment request and information on the result, and Access Grid Toolkit allows the open discussion to that experiment, as in Fig. 10. The AGTk is a powerful system for both remote communication and research data sharing. Apart from the basic face-to-face conference and chatting functions, the participants of remote conferencing can use other shared applications to share their ideas and data. The shared applications are the shared PPT, shared browser, shared desktop, shared PDF, and so on. Furthermore, for sharing of the research data, the shared GNUPlot software is installed. PIG(Personal Interface to AccessGrid) nodes are established in Seoul National University, KISTI(Korea

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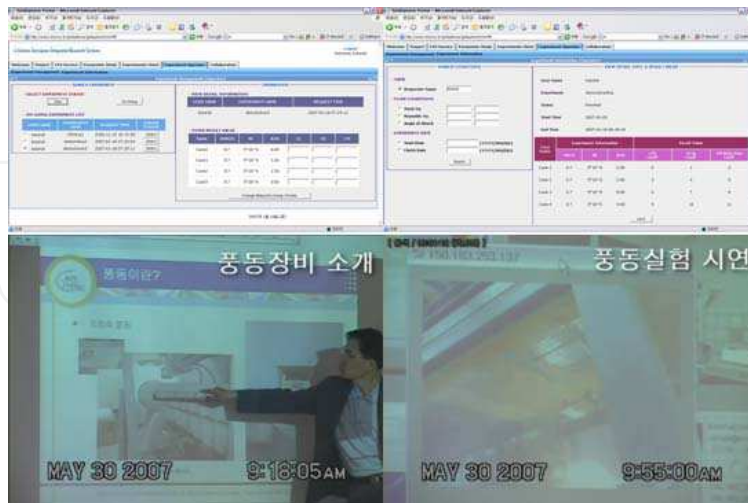


Fig. 10. Remote Experiment Service

5. Use of e-AIRS on academic activities

5.1 Additional support for academic activities

Developed e-AIRS web portal is utilized as lecture materials of undergraduate and graduate classes. Usually, students first learn the basic physics of their application problems in the offline class and get trained on how to use the system. After then, they conduct their numerical simulations through e-AIRS web portal.

Though the tutorial on system usage is given to students, it is insufficient for students to understand the procedure of CFD and fully utilize the whole service within e-AIRS system. Thus, an e-AIRS web page is also developed to let students to review the physics and portal usage by their own. A number of valuable materials on fluid dynamics are stored in the web page. Also, this site provides video tutorials which contain the way of using e-AIRS portal and solving representative fluid dynamic problems, which will be explained in the next section. Features of e-AIRS web pages are given in Fig. 11.

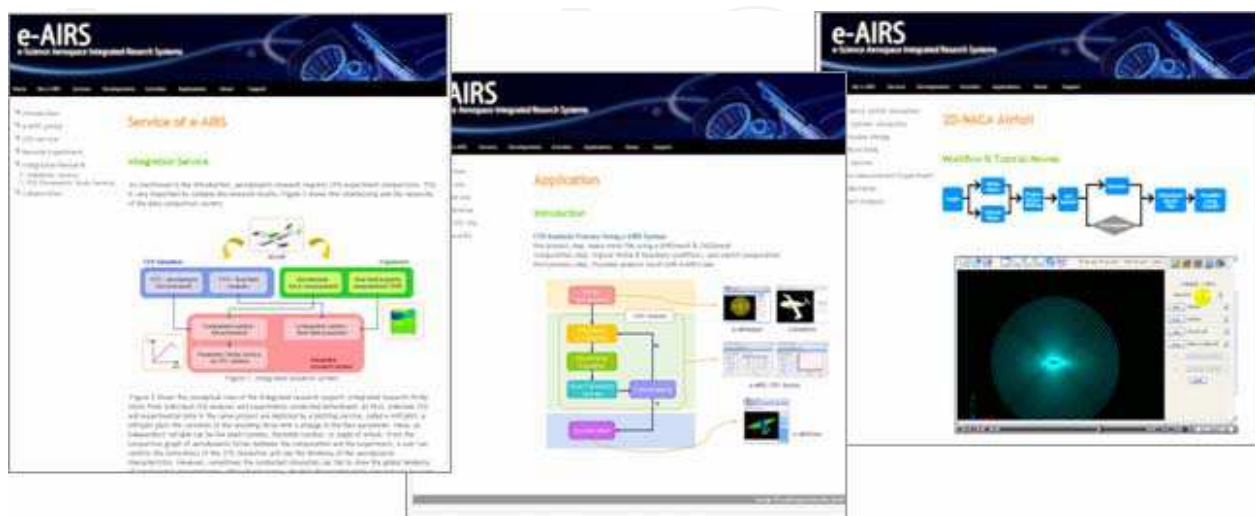


Fig. 11. e-AIRS Web Page (<http://eairs.kisti.re.kr/eairs>)

5.2 Use of the system on classes

5.2.1 Fluid dynamic applications for students

For the education of students, application problems need to contain various physics of fluids. And, the flow solver is recommended to be light and efficient to reduce total computing time. Thus, two-dimensional compressible and incompressible CFD examples are selected and CFD service on the e-AIRS utilized for the education of undergraduate and graduate students.

For compressible flow analysis, flowfield around NACA0012 airfoil (Fig. 12) is selected as examples. Flow analysis over a NACA0012 airfoil is a conventional example of aerodynamics. In this problem, Mach number and angle of attack are set to be 0.73 and 6 degree. By using 'mesh template' function in e-AIRSmesh, users can make NACA airfoil mesh and impose boundary condition easily. As the flow is in transonic range, a shock wave is formed on upper surface and flow properties change abruptly through the shock.

Likely, the unsteady flow analysis over a cylinder has been selected for the understanding of incompressible flow characteristics. The results (Fig. 13) show the difference of pressure contour and streamlines by the viscous effect. In viscous flows at specific Reynolds numbers, vortices are shed alternatively from the upper and lower surfaces of the cylinder, creating the periodic flow pattern.

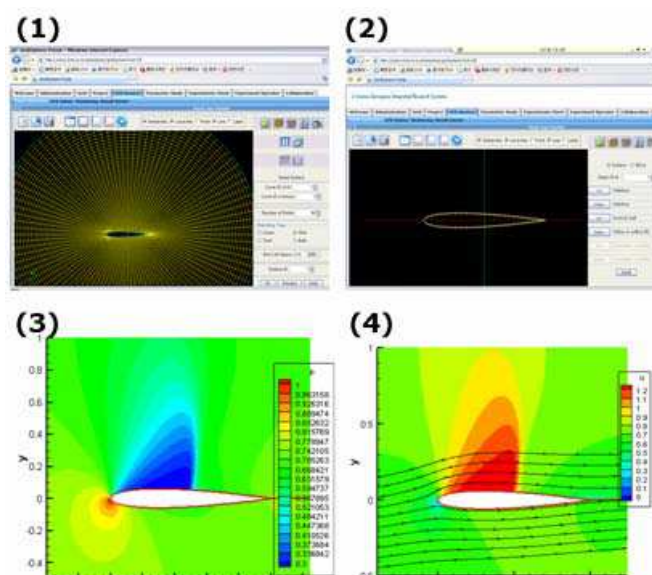


Fig. 12. NACA0012 Airfoil Analyses; (1) Airfoil Mesh System (2) Surface Mesh Points of NACA0012 Airfoil Geometry (3) Pressure Contour around an Airfoil with Transonic Speed (4) Mach Number Contour with Streamline

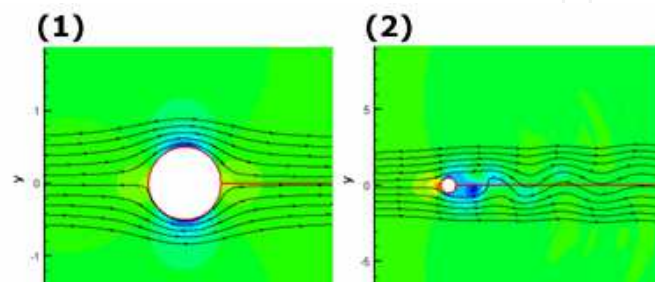


Fig. 13. Vortex Generation on a Cylinder; (1) Inviscid Simulation, $Re=140$ (2) Viscous Simulation, $Re=140$

5.2.2 Survey results

Hundreds of students on 6 universities in Korea have experienced this remote lecture on fluid dynamic simulation since 2007. We conducted a survey to 230 students from seven different classes in five universities, about the usefulness of e-AIRS system. Fig. 14 shows the result of the survey. The point 10 is the best and 0 is the worst score. Etc indicates scores lower than six point. We assume that students were satisfied with e-AIRS service if they give more than seven point on each question.

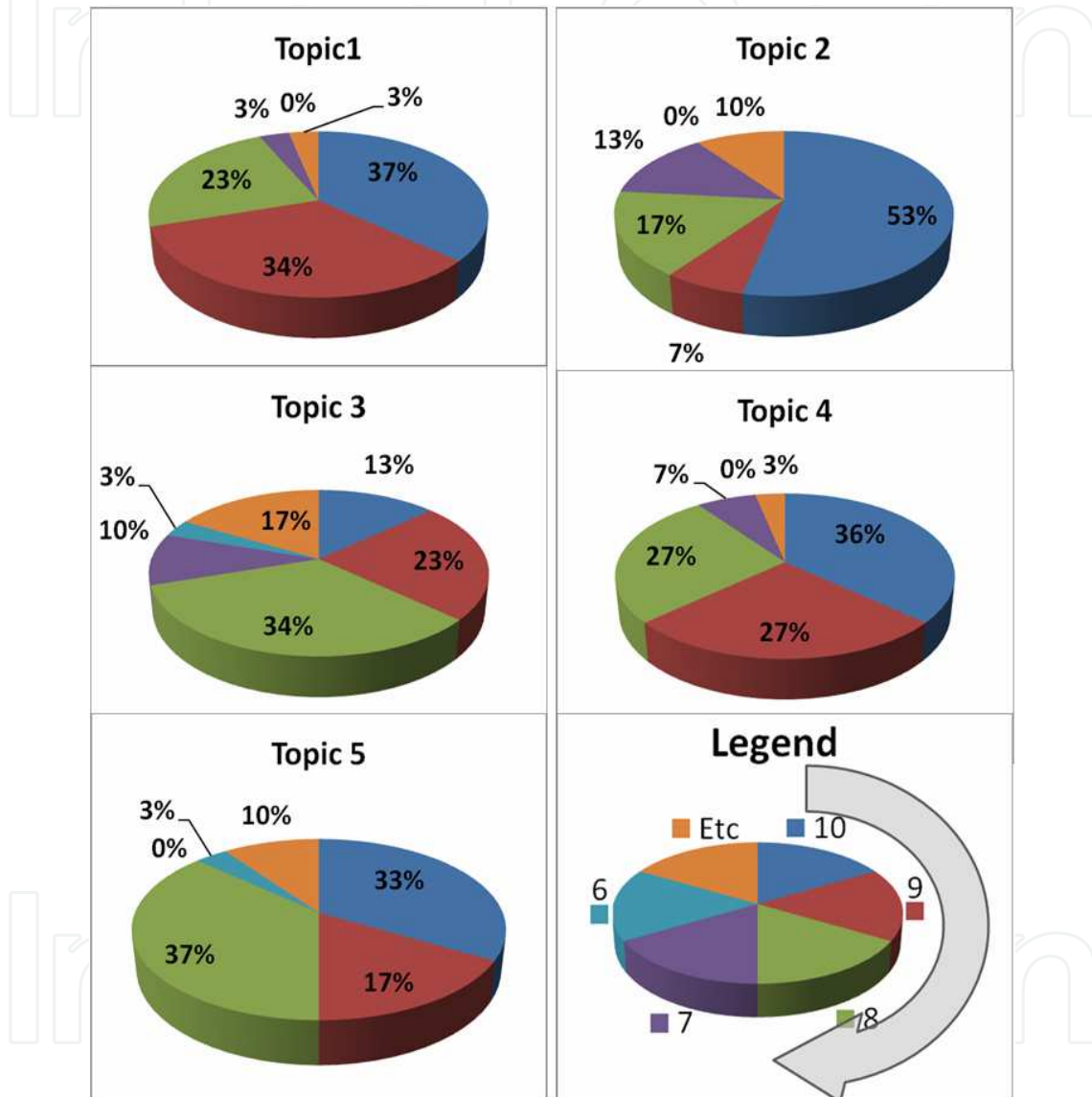


Fig. 14. Graphs of Survey Result;

Topic 1: Increasing the Understanding of CFD Simulation Process

Topic 2: Convenience of Using the Portlet-based Web Portal

Topic 3: Functionality and Convenience of the Mesh Generation

Topic 4: Functionality and Convenience of the CFD Simulation

Topic 5: Functionality and Convenience of the Visualization

As the pie chart illustrates, 94 percent of students said the system helped them to understand the whole process of CFD. Because CFD simulation processes include complex

governing equation and CFD techniques, theoretical lectures have a limit to make students understand CFD simulation process. On the other hand, students could easily practice CFD simulation using e-AIRS system, because e-AIRS system provides all components of CFD simulation process.

As indicated in the pie chart, more than 80 percent of the students said that portlet based web portal is convenient. From the survey result, most of students gave high marks for functionality and convenience for mesh generation, CFD simulation, and result data visualization. However, some students required to improve some applet bugs and requested more various CFD solvers and CFD template meshes. Now, Requested opinion was reflected to e-AIRS portal.

6. Ongoing work

Currently, the system is under improvement to the research system by allowing more controllability of advanced users, such as use of users' own application tools within e-AIRS infrastructure. After then, the system will evolve to be the virtual multi-disciplinary research laboratory by implementing more application toolkits in various application domains such as structural dynamics and propulsion.

In the aspect of educational activities, additional various numerical solvers will be adopted. To increase the user pool of e-AIRS, more practical and useful examples should be provided. While e-AIRS has been used for the educational activities of aerospace field only, however, new e-AIRS solvers are planed to launch e-AIRS into the students studying mechanical engineering. In detail, 2-dimensional internal flow solver, 2-dimensional unstructured mesh system will be adopted for the students of the mechanical field.

Moreover, more improvement of e-AIRS performance is promoted including more powerful pre- and postprocessor, 3-dimensional general parallel solver and overset mesh system.

7. Conclusion

E-AIRS components have been investigated and its usefulness has been discussed in this paper. At the early stage, e-AIRS was first designed to support professional aerospace engineering researches through the portal: soon, the system turned the direction to serve as a web portal for academic studies, considering many hardships in developing a professional research system. For convenient use on fluid dynamic study, e-AIRS web portal is designed to give four main services of CFD, remote experiment, parametric study and collaborative conferencing.

In the design of infrastructure and middleware, e-AIRS have focused on rather integrating many available and valuable computer scientific components, than developing modules by our own. Thus, a number of tools such as Globus, Access Grid Toolkit, GridSphere, etc., are used without modification, and middleware developers have invested much endeavour on developing a PSS toolkit.

On the other hand, based on former experiences by CFD component developers, all CFD components are developed by our own. A simple mesh generator and a light visualization software are developed by using Java applet and validated CFD codes are included in the e-AIRS service. For wind tunnel experiment, there has not been any trial on automated experiments. Thus, we have also adopted a conventional manual operation and the portal agents the automatic request by users to a manual instrumental experiment.

Developed system has been used to a number of fluid dynamic classes in undergraduate and graduate schools. To maximize users' conveniences, we have also opened an e-AIRS web page, where a number of valuable knowledge as well as the usage of e-AIRS portal are provided. In the class, students are trained to use e-AIRS system and they conduct representative fluid dynamic simulations. The use of current system made students to understand fluid dynamics more and get motivated on fluid dynamic study.

Now, e-AIRS system goes through a new evolution to the professional fluid dynamic research system, as well as giving more conveniences on educational system. For professional researches, we are allowing more controllability by advanced users, such as use of users' own application tools within e-AIRS infrastructure. After then, the system will evolve to be the virtual multi-disciplinary research laboratory by implementing more application toolkits in various application domains.

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Starting a journey on the new path of converging information technologies is the aim of the present book. Extended on 27 chapters, the book provides the reader with some leading-edge research results regarding algorithms and information models, software frameworks, multimedia, information security, communication networks, and applications. Information technologies are only at the dawn of a massive transformation and adaptation to the complex demands of the new upcoming information society. It is not possible to achieve a thorough view of the field in one book. Nonetheless, the editor hopes that the book can at least offer the first step into the convergence domain of information technologies, and the reader will find it instructive and stimulating.

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