M:FR/E

Final Report of Project	Project No. : 2007/0294

Part A

Project Title: Internet-based Education for Design and Innovation

Name of Organization/School: Department of Mechanical and Automation Engineering,

The Chinese University of Hong Kong

Project Period: From   April, 2009   to   September, 2011

Part B

Please read the Guidelines to Completion of Final Report of Quality Education Fund Projects before completing this part of the report.

Please use separate A4-size sheets to provide an overall report with regard to the following aspects:

1. Attainment of objectives
2. Project impact on learning effectiveness, professional development and school development
3. Cost-effectiveness – a self-evaluation against clear indicators and measures
4. Deliverables and modes of dissemination; responses to dissemination
5. Activity list
6. Difficulties encountered and solutions adopted

The report should be signed by the supervisor of the school/the head of the organization or the one who signed the Quality Education Fund Agreement for allocation of grant on behalf of the organization.

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Annex

Table 1: Attainment of Objectives

Objective statement	Activities related to the objective	Extent of attainment of the objective	Evidence or indicators of having achieved the objective	Reasons for not being able to achieve the objective, if applicable
To motivate senior primary students and secondary students to learn independently advanced technologies using on-line design education resources.	Development of the Internet education resources for design and innovation.	Fully achieved	(1) Developed a design curriculum, which is published online (http://137.189.100.118/course/), for online learning. This design curriculum is tailor-made for Junior forms and Senior forms Design and Technology subject. (2) Developed an online design platform that not only supports 3D interactive design but also transfers initial designs in 2D drawings to 3D designs.	
To develop students' learning capability and sense of creativity by stimulating their initiatives to learn and providing on-line problem-based learning environment and materials to design and innovation.	Development of the Internet education resources for design and innovation.	Fully achieved	(1) The curriculum was implemented in 8 schools and over 200 students took part in the curriculum in the academic year 2010-2011. (2) Developed the on-line design platform.	
To promote technology education in Hong Kong by appraising students' innovation and	Organization of design and innovation competitions using the on-line design	Fully achieved	Organized or participated in a number of activities using the deliverables of this	

efforts demonstrated in design competitions.	tools.		project, including the IRIS 2009 Final competition; the IT Winter Camp 2010; the QEF Roving Exhibition 2011 and Robocup Junior 2011 competition exhibition. The details will be provided in later part of the report.	

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Table 2: Budget Checklist

Budget Items (Based on Schedule II of Agreement)	Approved Budget (a)	Actual Expense (b)	Change [(b)-(a)]/(a) +/- %
Staff Cost	$1,212,120	$1,144,129.00	-5.61%
Equipment	$318,000	$374,009.37	17.61%
General Expenses	$100,000	$60,403.99	-39.60%
Contingency	$12,540	$0.0	-100%
University Overhead	$114,140	$114,140.00	0.0%

Table 3: Dissemination Value of Project Deliverables

Item description (e.g. type, title, quantity, etc.)	Evaluation of the quality and dissemination value of the item	Dissemination activities conducted (e.g. mode, date, etc.) and responses	Is it worthwhile and feasible for the item to be widely disseminated by the QEF? If yes, please suggest the mode(s) of dissemination.
One online design platform(Appendix 1), including the online design tool for converting 2D design to 3D designs (Appendix 2)	An online design platform hosted in CUHK is developed by the research team.	A pilot teaching was launched in 8 schools in academic year of 2010-2011. IRIS 2009 has used the platform as one of the competition (IRIS-X). The Winter Camp 2010 (December 28-30, 2010) has adapted the online design platform as main teaching tool. In the QEF Roving Exhibition, the platform was exhibited to collect the feedbacks and modify the platform. The project outcome was exhibited in Robocup Junior 2011.	With a better performance computer, the schools can set up their own server in schools. Meanwhile, a number of schools can set up the server to share the students' work in their district. QEF can setup a server for all schools in Hong Kong. So the cost of dissemination is not high.
Online learning platform (Appendix 3)	An online learning platform "Moodle" is established and the server is host by CUHK.		Moodle is a freeware which can be used free of charge. And the requirement of the computer to setup the server is not demanding. Just a PC can do. So the schools can set up their own server for their own use or for their partnering schools. QEF can also set up one for schools in Hong Kong.
One set of design curriculum (Appendix 5)	A set of curriculum which is suitable for all levels in secondary schools.	A pilot teaching was launched in 8 schools in academic year of 2010-2011. The VEX projects were exhibited in Robocup Junior 2011.	The software of the curriculum can be distributed as a book or CD-Rom in a low cost. While schools can choose the hardware of the curriculum, i.e. robots can be chosen based on the resources in their own schools.

Table 4: Activity List

Types of activities *(e.g. seminar, performance, etc.)*	Brief description *(e.g. date, theme, venue, etc.)*	No. of participants				Feedback from participants
		schools	teachers	students	others (Please specify)	
Curriculum implementation	Academic year 2010-2011 in supporting schools	8	8	200		Positive feedback from the students, the teachers and the school.
IRIS 2009	Final competition held on February 4, 2010 in TY Wong Hall, The Chinese University of Hong Kong	100	110	1,500	Teams 300	The ideas of the platform are good for students to learn robotics, however, the stability of the platform to be improved to guarantee the performance.
IT Winter Camp 2010	December 28-30, 2010 in The Chinese University of Hong Kong			200		Students found the sharing function and design interface very interesting.
QEF Roving Exhibition	January 21-23, 2011 in Kwai Chung Estate				>3000	Public found the outcomes are interesting. Some asked us the information about the website and would like to take part in the curriculum if resources allowed.
Robocup Junior 2011 – Technology Exhibition	Hong Kong district competition was held on June 4, 2011 in Sir Run Run Shaw Hall, The Chinese University of Hong Kong		102	408	>300	They are interested in the curriculum and show their interest in implementing the curriculum.

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Guidelines to Completion of Final Report of Quality Education Fund Projects

Please elaborate the following items in your evaluation of the project. It is expected that the guide would provide a reference to the project leader/team in reflecting on the effectiveness of the project.

1. Attainment of Objectives

Objective statement	Activities related to the objective	Extent of attainment of the objective	Evidence or indicators of having achieved the objective	Reasons for not being able to achieve the objective, if applicable
To motivate senior primary students and secondary students to learn independently advanced technologies using on-line design education resources.	Development of the Internet education resources for design and innovation.	Fully achieved	(1) Developed a design curriculum, which is published online (http://137.189.100.1 18/course/), for online learning. This design curriculum is tailor-made for Junior forms and Senior forms Design and Technology subject. (2) Developed an online design platform that not only supports 3D interactive design but also transfers initial designs in 2D drawings to 3D designs.	N/A
To develop students' learning capability and sense of creativity by stimulating their initiatives to learn and providing on-line problem-based learning environment and materials to design and innovation.	Development of the Internet education resources for design and innovation.	Fully achieved	(1) The curriculum was implemented in 8 schools and over 200 students took part in the curriculum in the academic year 2010-2011. (2) Developed the on-line design platform.	N/A
To promote technology education in Hong Kong by appraising students'	Organization of design and innovation competitions using the	Fully achieved	Organized or participated in a number of activities	N/A

innovation and efforts demonstrated in design competitions.	on-line design tools.		using the deliverables of this project, including the IRIS 2009 Final competition; the IT Winter Camp 2010; the QEF Roving Exhibition 2011 and Robocup Junior 2011 competition exhibition. The details will be provided in later part of the report.	

2. Project Impact on

(a) Learning Effectiveness

The project was carried out with an aim at broadening students' horizons and enabling students to develop: (i) the basic knowledge in design, robotics, mechanical engineering, computer engineering, and Internet technology in the on-line project-based learning environment; (ii) the capability of applying their knowledge in design, robotics and programming to specific design tasks by utilizing the on-line design tools; (iii) the nine generic skills, as stipulated in EDB's document, through students' active participation in the on-line learning process and in the competitions; (iv) the understanding of impacts of technology to the local and global societies. The project impact on the learning effectiveness can be interpreted as follows:

- An effective and low-cost platform for teaching and learning the Design and Technology subject: We are currently living in a technology world and rapid development of technology has greatly improved our living standard and environment. It is requested that secondary students grasp fundamentals of technology so as to face challenges in the high-technology society, which is the objective of the subject Design and Technology. However, not all schools are able to offer this subject due to tight course schedule and limited resources. Many schools integrate part of the materials in the Design and Technology subject in other subjects such as Computer, General Education or extra-curriculum activities (ECA). The developed on-line curriculum and design platform will provide those schools additional resources for teaching and learning the Design and Technology subject and other related subjects.

- Flexible design curriculum catering different needs: The design curriculum is so designed that it covers the content from fundamental concepts to daily applications of technology. To cater for different needs at different school, we designed the curriculum at four different levels. Schools can choose the appropriate level(s) according to their students' ability and their resources. The materials at the entry and basic levels are mainly for junior form students to grasp the basic knowledge and overall picture of the subject, while the curriculum at the essential and advanced levels are more suitable for senior students who have some prior knowledge and need more in-depth or professional training.

- Enhancing students' learning attitude and problem-solving skill by project-based learning: Project-based learning is adopted as the major learning method in this project and the developed design curriculum because it is one of the most effective learning modes, allowing students to apply the knowledge learnt to the real life examples. The projects in the developed curriculum

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require students not only to learn the basic theories but also to undergo information researches and a series of trail-error processes. As a result, the learning attitude and problem solving skills of the students can be improved. The realized projects' outcomes can also increase students' satisfaction of learning. Furthermore, the developed curriculum considers team work and creativity important elements. The technique of team work and creativity are diminishing when students are more engaged in virtual Internet world. Through the collaborative design projects in the curriculum, the students' creativity and team work spirit will be improved. As a result, they can be better prepared for the future working environment.

- Enriching e-learning materials for learning fundamental knowledge and conducting projects in Design and Technology: Online learning (or namely "e-learning") is prevalence in the technology world. Nearly all students in Hong Kong are doing some homework or learning via the Internet. As the world is ever-changing, printed materials like textbook, magazines can no longer satisfy the rapid information changes. Our online curriculum and online learning platform will allow students to carry out design projects and obtain the relevant knowledge in a low-cost and effective way. The online platform also allows students to exchange ideas and share the design works, and hence fosters their self-learning initiatives and learning efficiency.

- Appraising the students' creation via competitions: Through participating in the Internet-based Robotics Inter-Schools competition, the students learned how to apply the knowledge learnt to build functional robots and improved their problem-solving skill.

(b) Professional Development

This project also helped develop the professional skills of teachers. The details are as follows:

- To design the curriculum and implement the project in schools, a committee was set up. Apart from the teachers, the committee is composed of professors from University in robotics and design. The committee held meeting regularly to discuss the curriculum, the on-line platform, implementation, etc. During the process, the secondary teachers shared their experiences in teaching the Design and Technology subject, and the professional staff from the university also gave their inputs to the teachers. These helped the teachers learn from the other teachers in designing and teaching the course and obtain the updated information on the technology development from the staff in the university. During the project period, the teachers also had opportunities to communication with other professional bodies and outside companies.

- In this project, the teachers participated in organization of the competitions and exhibitions in the expos. Organizing the competitions in the inter-school level helped the teachers learn event organization, etc. And in the competitions, a number of student helpers from schools were recruited. Participate in the large scale events as helpers are good experiences for the students.

- To implement the designed curriculum, we had a number of meetings, sharings and workshops, which helped train teachers' teaching skills, like how to deliver the knowledge, how to arouse the students' interest, how to manage time, how to manage classroom discipline and how to round-up. Practices make perfect, and hence it was a good learning process for teachers through the project implementation. The "training the trainer" method used in this project is an effective learning mode not only applied to teaching students, but also to training teachers. 10 pilot schools implemented the curriculum in the first phase, and the curriculum was fine-tuned based on their teaching experiences and feedbacks. And they are expected to share their teaching experiences with other teachers who would like to implement the curriculum as well.

(c) School Development

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With the implementation of the curriculum, the schools gained more experiences in teaching and learning of the Design and Technology course and received additional resources. The on-line projects and multiple-choices quesionts (MCQ) enriched the teaching materials. By participating in this project, the school also learnt from the other participating schools. Through organizing various activities and competitions for primary schools, the schools also promoted their images and had positive impact in student intake. Collaboration with University and various professional bodies can enhance the overall image of the schools. It's usual for a school to have limit chance to collaborate with other professional bodies due to limited resrouces. Following is the press release from SKW East Government School regarding the issue:

3. Cost-effectiveness

Budget Items *(Based on Schedule II of Agreement)*	Approved Budget (a)	Actual Expense (b)	Change [(b)-(a)]/(a) +/- %
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The project's cost-effectiveness should be evaluated with regard to:

- utilization of available resources (e.g. equipment, human resources of applicant school/ participating school(s)) :
- unit cost for the direct beneficiaries
- sustainability of the learning programme and materials developed – publsihed online
- expenditure items which require no injection of resources when the project is replicated by other schools (including setup cost of the project, deliverables ready for use)
- alternative approaches for equivalent benefits at less cost

- Utilization of available resources: We fully made use of the available resources such as manpower and equipment at The Chinese University of Hong Kong and the participating schools. For example, a PhD student supported by the university was responsible for developing the algorithms for 2D sketch recognition, database searching, etc.; The participating schools sent their D&T teachers to help design of the curriculum and the on-line platform. The students helped organization of the competitions and the other events as student helpers; CUHK provides design software and computers for staff and competitions, and the participating schools provide equipment support for implementing the curriculum.
- Unit cost for direct beneficiaries: The number of students taking the curriculum in the implementation stage is 200. The number of students participating in the competitions is over 400 schools and the number of students was over 3000. It is important to note that the developed curriculum and on-line platform can be used by all the secondary students. Therefore, the number of direct beneficiaries is large and the unit cost is low.
- Sustainability of the learning programme and materials developed: The curriculum and on-line platform are available via the Internet. As long as we maintain the server, students can access them anytime and anywhere.
- Expenditure items which require no injection of resources when the project is replicated by other schools: Since the design curriculum and design platform are available on-line, no additional cost is needed when they are used by other schools. It is important to note that the robot kit needs to be purchased if they want to assemble the real robots, not the robots in the simulated environment.
- Alternative approaches for equivalent benefits at less cost: We do not know an alternative approaches.

4. Deliverables and Modes of Dissemination

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5. Activity List

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Robocup Junior 2011 – Technology Exhibition	Hong Kong district competition was held on June 4, 2011 in Sir Run Run Shaw Hall, The Chinese University of Hong Kong		102	408	>300	They are interested in the curriculum and show their interest in implementing the curriculum.

Some of the photos taken in those activities are shown in Appendix 4.

6. Difficulties Encountered and Solutions Adopted

It took longer time to develop the curriculum and online design platform than scheduled because we would like to incorporate the NSSDAT framework into the curriculum and design platform. It was also necessary to have more time to develop the software. As a result, the overall project time frame has been extended for 6 months.

Appendix 1 The Online Design Platform

1. Introduction

The on-line design platform aims to facilitate the design and technology education for secondary students using the Internet. It is built in the browser-server structure with advantages of being easy to maintain and upgrade. The following features are included:

- Design from components: There is a library which stores a large number of components including mechanical "bricks", sensors, actuators, micro processors, electronic components, etc, which can be purchased from industry. The students will design their products using the components provided. The component library can be customized as personalized ones based on interests of individual students. Students can also add components to their personalized library by themselves.

- 3-D interactive design: Unlike 2-D approaches adopted by design engineers, students can design their products in 3-D directly using the powerful graphics engine provided by the software. With 3-D design, the students can really build their product from components like what children build their LEGO toys from "bricks".

- Initial design input from 2-D drawings: The software allows students to input their 2-D drawings as initial designs by incorporating image processing and recognition technology with the system. The on-line system can recognize 2-D drawings of students and automatically map them to 3-D products or robots that can be built from the components library. Then, the students can use the interactive design tool to modify their designs. This function can significantly shorten the design process and is particularly useful for junior students.

- Components search function: Optimization and search technique has been developed so that the students can search components by inputting abstract meanings such as "small legs", "fat body", "small head", etc. Furthermore, with this function, during a design process a list of candidate components are also generated from the huge database so as to reduce the designer's workload and speed up the process.

- 3-D simulation: The 3-D simulation tool enables the students to view the 3-D motion of their products after they complete the design.

- Prototyping and production: Once the students are satisfied with their design, they can request the collaborating manufacturers to prototype or fabricate the product with fee. → VEX

- Design sharing and competition: The on-line software platform also allows the students to share their design with their peers and participate in the on-line design competitions.

Figure 1 shows the overview of the platform. The left side is the client side where users visit the platform on web browsers with Flash Player plug-in (currently Flash Player has been installed over 98 percent web browsers in the world); in the center of the image, how to store and access data is shown----users can visit the data in their own space, private database and common database; in the right side, we can see the role of system manager and the server's framework (Apache + PHP + MySql).

Currently, the online share and interaction modules are still under construction. Now users can visit files in the database and download existed parts to assemble some toys and simulate their motion.
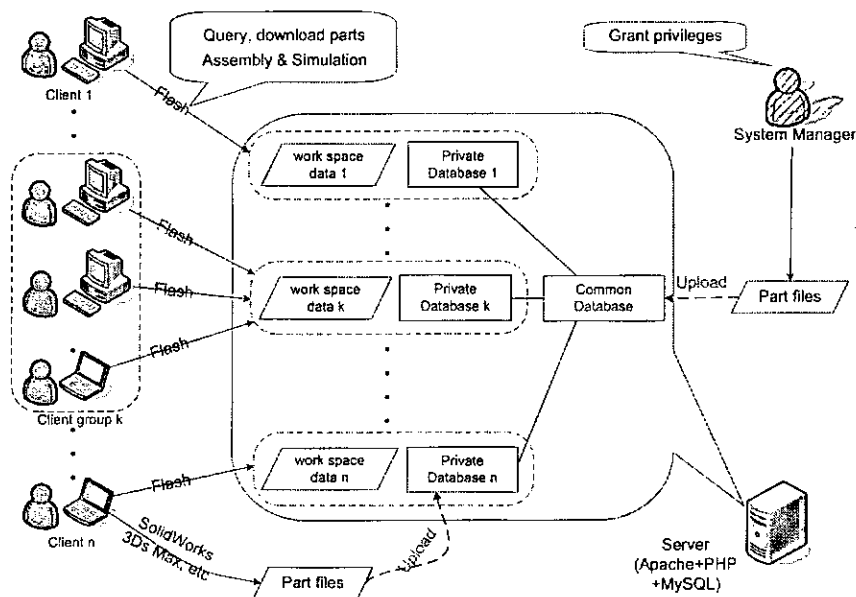
Fig. 1 Overview of the platform

2. User manual

2.1 Access of the platform

In the platform, users can construct assembly of parts provided by the system and simulate the motion of assembled components. The user interface of the platform is integrated in a flash file and can be run in any web browser. In our tests up to now, :   ' and :·-.. ·   faster than ˉ .. ˉˉ ·ˉ·· ˉ. So we suggest users to adopt the former two web browsers, and please remember to update the .   _ ˉ ˉ ˉ·which is integrated in your web browser. The rendering speed of the platform is mostly determined by the configuration of user's computer and the version of   , ˉ ˉ   . ˉ; the speed of downloading process of parts from the database is determined by the internet.

In the web browser, after input the following address http://137.189.100.85 or http://137.189.100.50:88, you will be directed to a webpage as shown in Figure 2.
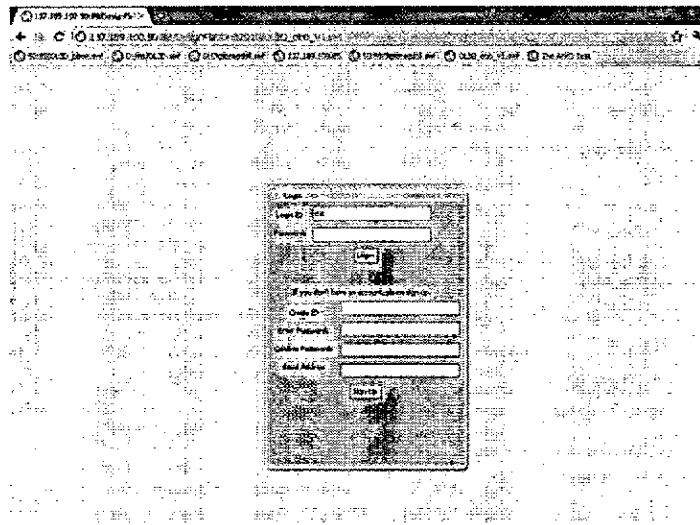
Fig. 2 User login interface

If you have already registered in the system, then you just need to input your ID and password to access your own space. Otherwise, you have to create a new account then log in.
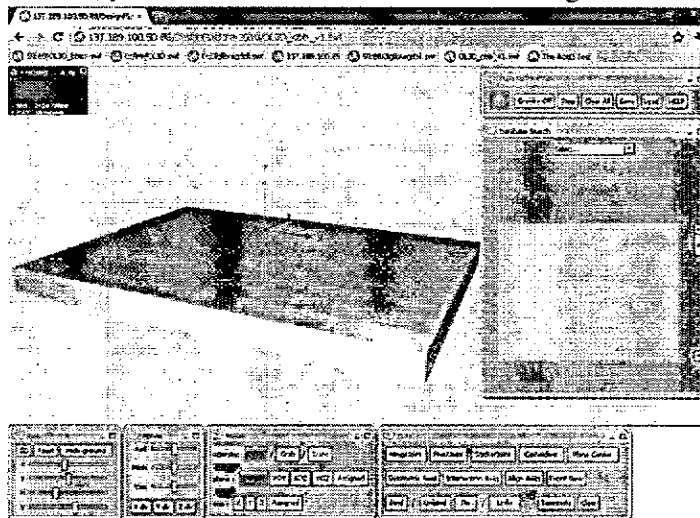
Fig. 3 Interface of the system

2.2 Functions in main menu

In the center of the screen there are three axes to show the coordinate system used by the space. Y axis is upwards, and a board is set perpendicular to Y axis in the screen. Gravity is along negative direction of Y axis, so when gravity force is introduced in, loaded objects will drop on the board. The main function of the board is to act like a table where objects are put on. The right-top panel is the main menu as show in Figure 3.

Fig. 4 Main menu

The first button is to delete loaded part into litter bin. Before you click the delete button, please use mouse to click the object that you want to delete. The second button "Gravity Off" is to control gravity on/off in the system. Its default setting is "Gravity Off". Once you click the button, it will change into "Gravity On". If currently some objects hang in the space, they will drop onto the board. As the example shown in Figure 4, (a) one airplane is hanging in the space when "Gravity Off", (b) the airplane drops on the board when "Gravity On". If clicked again, the button will change back to "Gravity Off".

(a) gravity off   (b) gravity on
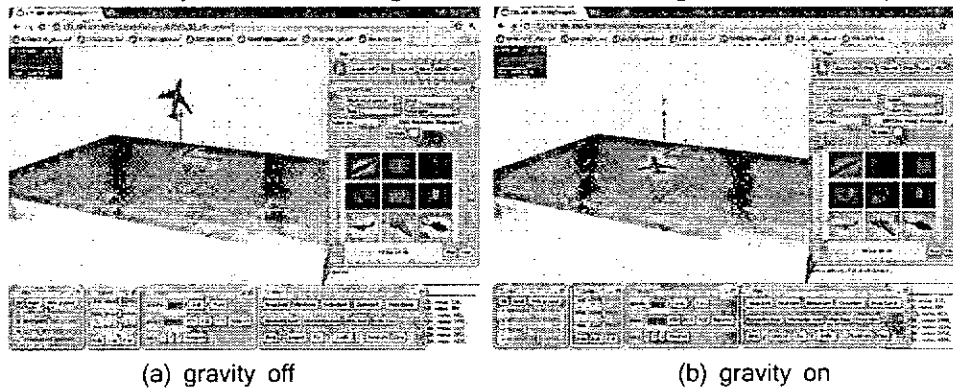
Fig. 5 Effect of gravity on/off

Sometimes you want all objects to stop quickly other than experience a long period of vibration and damping, then you can click button "Stop". The speeds of all objects are set as zero instantly by clicking this button. But obviously, if the system is now in "Gravity On" status, the hanging objects will just experience a braking process then start to move again. So, generally if you want to stop all objects, you need to switch off gravity at the same time.

At the right of the panel, there is a help button "Help". Click it, you can read the help documents of the system.

2.3 Help documents

In the first page of the help document as shown in Figure 6, we mainly show how to use mouse or hot keys on the keyboard to control the view point of the work space. The user can use "left" and "right" direction keys to rotate the view point in horizontal plane, and use "up" and "down" direction keys to rotate the view point in vertical plane. These two kinds of rotations can also be realized by moving knobs of "H" and "V" slider bars in the "View" panel. In the "View" panel, "X" and "Y" slider bars provide controlling on the location of view center. The zoom in / out functions can be performed by mouse wheel

or "Page Up" / "Page Down" or "+" / "-" keys in the numpad on the keyboard. "Reset" button will restore all settings to their default values. "Hide ground" button can hide the board in the system (but it still exists physically) to help user to grab objects behind the board.
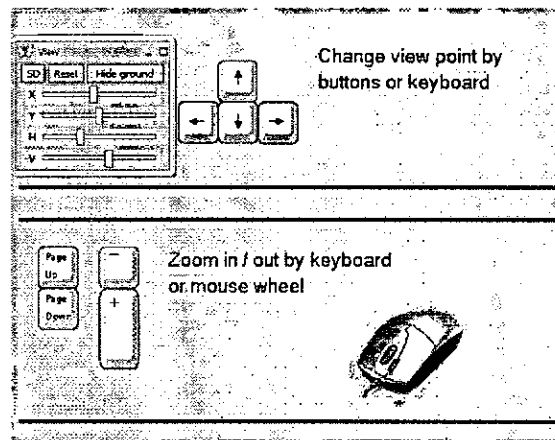

Fig. 6 First page of help file

The "SD" button is used to switch between Standard Definition with High Definition for the rendering mode. In the later mode, the button will show "HD". In Figure 7, we show the different effects under the two modes. The rendering result under SD mode is with some error on showing depth information. The reason is due to the coarse calculation method on judging triangle depth in the view space. On the contrast, the HD mode can provide correct rendering on all details, however, it is much slower than SD mode. So, in general, the system works under SD mode. If users want to show a definitely correctly rendered result, they'd better choose a desired view angle and scale, then switch to "HD" mode.
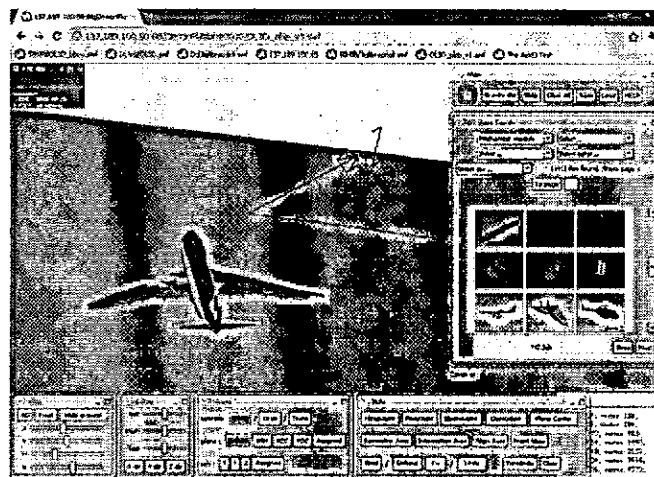
(a) SD (standard definition)
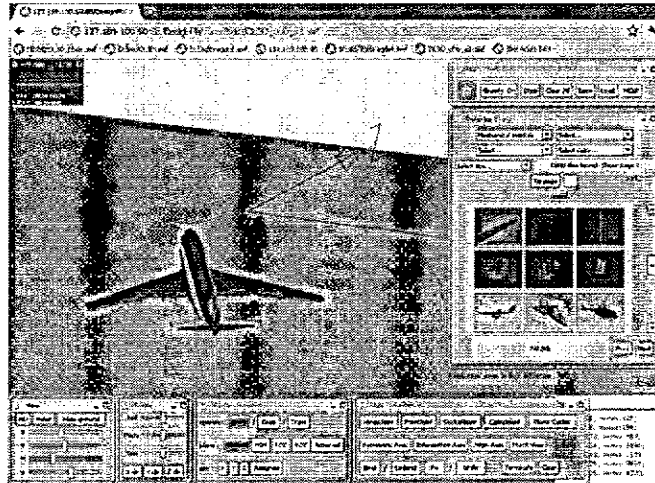
(b) HD (High Definition)

Fig. 7 Different rendering effect between SD with HD modes

In the next four pages in the help document as shown in Figure 8, we show how to select objects (parts) from the database in the server and download them to user's work space.

(a) connect to database

(b) search files in database

(c) select file in searched result

(d) download file through internet
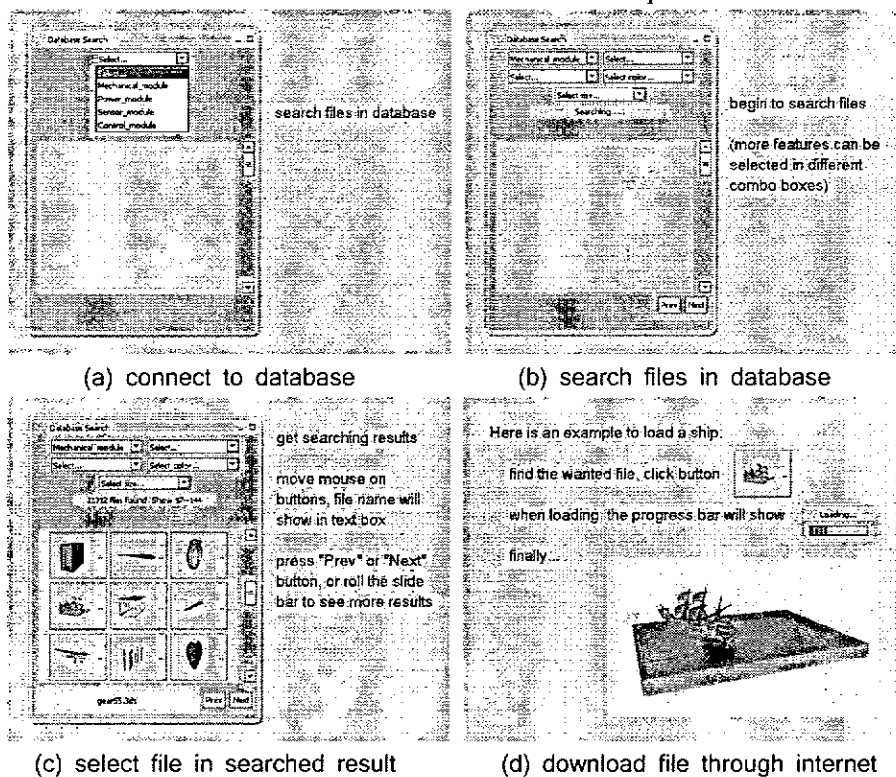
Fig. 8 Select and load objects from database (help document)

As shown in Figure 8(a), if when you click the "Select..." item in the "Database Search" panel, a list with four items can be shown, it means the database is connected and can be visited. In Figure 8(b), we show an example of searching process. Hint of searching will be shown in the panel. In Figure 8(c), the icons of searched results are shown in tile form. When user moves mouse on each icon, the file's name will be shown in the text box at the bottom of the panel. If results can not be shown in the limited space in the panel, the system automatically adopt slider bar and multiple-page functions. Figure 8(d) shows the downloading process and final effect of one example. In the downloading process, a progress bar

 will pop up. After downloading, the platform's speed is totally dependent on local computer's performance, and now even internet connection breaks, the objects in the platform will not be influenced.

In the last two pages of the help document shown in Figure 9, we deliver some settings on grabbing objects, loading files, handling gravity, multiple object loading and suggested configuration on hardware and software.
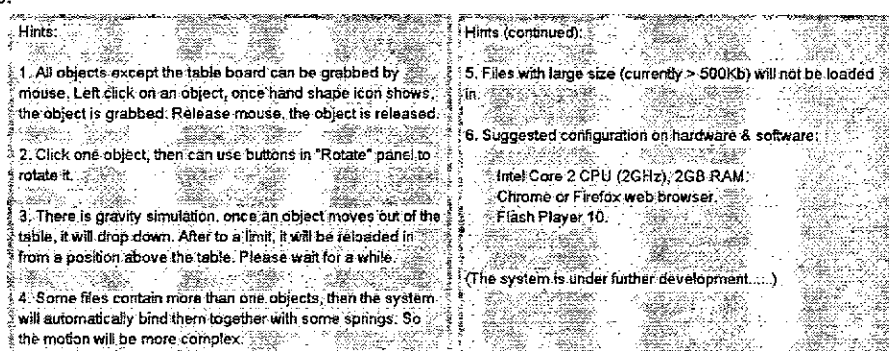
Fig. 9 Last two pages of the help document

2.4 Rotation panel

In the rotate panel as shown in Figure 10(a), there are three slider bars and three buttons. Moving knobs of three slider bars will rotate the selected object a degree referring to the sliding distance; clicking "X dir", "Y dir" and "Z dir" buttons will rotate the clicked face of the object to face the selected direction. The rotation is performed in a dynamic method, so it will take several seconds to finish the process. In the rotation process, if there is any collision with other objects, the rotating process will last for a longer time which depends on how the object responds in the collision process. In order to let users know whether the rotation process finishes, a hint blinks under the database searching panel as shown in Figure 10(b). Once the process finishes, it will show "DONE!" as shown in Figure 10(c). In Figure 10(d)~(g), we give an example of one object experiencing rolling, pitching and yawing sequentially.
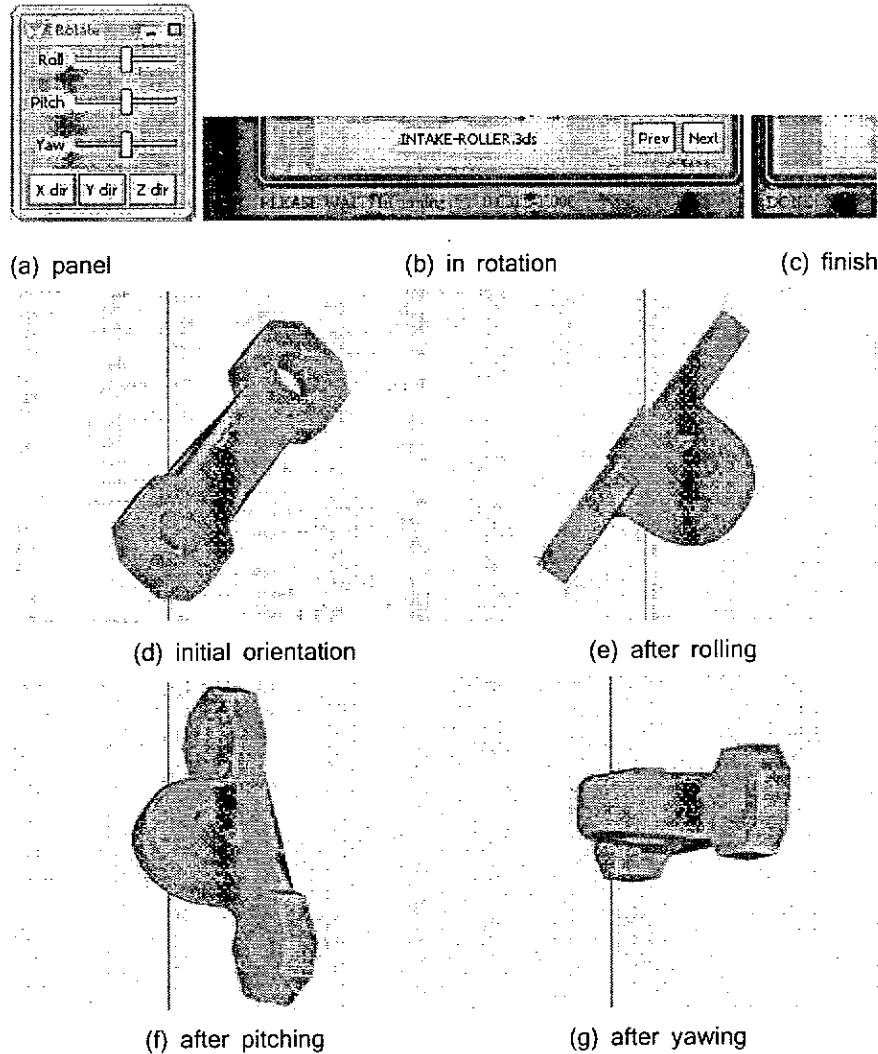
(a) panel	(b) in rotation	(c) finish

(d) initial orientation	(e) after rolling

(f) after pitching	(g) after yawing

Fig. 10 Rotate panel

2.5 Mouse panel

In the mouse panel as shown in Figure 11, there are three rows of buttons.

In the first row, three buttons correspond to three different styles of moving objects. In "Drag" mode, mouse will drag the clicked object by holding the clicked point. In moving process, the object will rotate under physical rules. In "Grab" mode, the clicked object will keep its orientation in moving process. The mouse acts like a hand grabbing the whole object. Once collision happens in the moving process, the orientation of the object will be changed. However, the orientation can be resumed if mouse is not released. In "Trans" mode, the object is moved by grabbing its center. So, if no collision happens, it looks same as "Grab" mode, however, once collision happens, the orientation of the object can not be resumed. "Grab" mode is often used to assemble one object into a hole.

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In the second row, five buttons correspond to five different styles of projection method of mouse coordinate from 2D to 3D. Since we all know, the mouse is moved on the 2D screen. How to project its coordinate into 3D space needs to know its projection method. "Default" button will let the mouse be projected on a plane perpendicular to the optical line of sight; "XOY" button will utilize the XOY plane in the 3D coordinate system, similarly, "XOZ" and "YOZ" will utilize XOZ and YOZ plane separately; "Assigned" button will let the mouse be projected on an assigned plane which is defined in assembly process.

In the third row, four buttons also correspond to four different styles of projection method of mouse coordinate from 2D to 3D. The difference with the buttons in second row is that now projections are onto an axis other than on a plane.
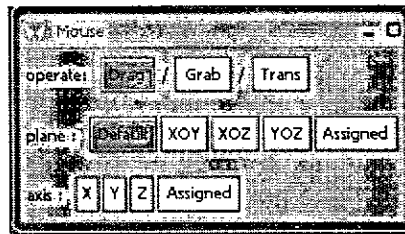
Fig. 11 Mouse panel

2.6 Mate panel

In the mate panel as shown in Figure 12, there are a number of buttons which provide assistant functions in assembly process.
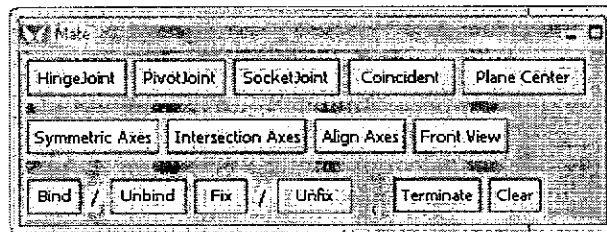
Fig. 12 Mate panel

Firstly, we give an example on assembling a hinge joint. In the first step, users need to download two objects into the space. As the example shown in Figure 13, two Y-shaped bars are imported in. In the second step, after clicking "HingeJoint" button, users need to define two points on each object to define joint's location as shown in Figure 13 (b). The system will give the first instruction *"Build hinge joint. Select hinge position on first object:"* below the database searching panel. After user clicking a point on one object, the second instruction *"Select second point to define hinge axis on this body:"* will be shown. If the user correctly selects a point on the same object, the third instruction *"Set hinge joint position on another object"* will be printed. Otherwise, the system will give error message *"not on the same object, select again please:"*. After clicking one point on another object, the fourth instruction *"Select second*

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point to define hinge axis on this body" will be shown. Once four points are selected successfully, the system will show "*Done!*" and the joint can be automatically formed as shown in Figure 13(c). The two objects generally will experience a period of vibration and damping process. Users can click "Stop" button in the main panel to shorten the process. Sometimes, an unsuitable setting of the joint will induce a quite long period of motion. Then the user knows that the setting should be modified. By clicking "Unbind" button in the third row of mate panel, the recently completed joint or binding constraint can be released.

(a) download two objects   (b) select reference points for hinge joint

(c) final assembly
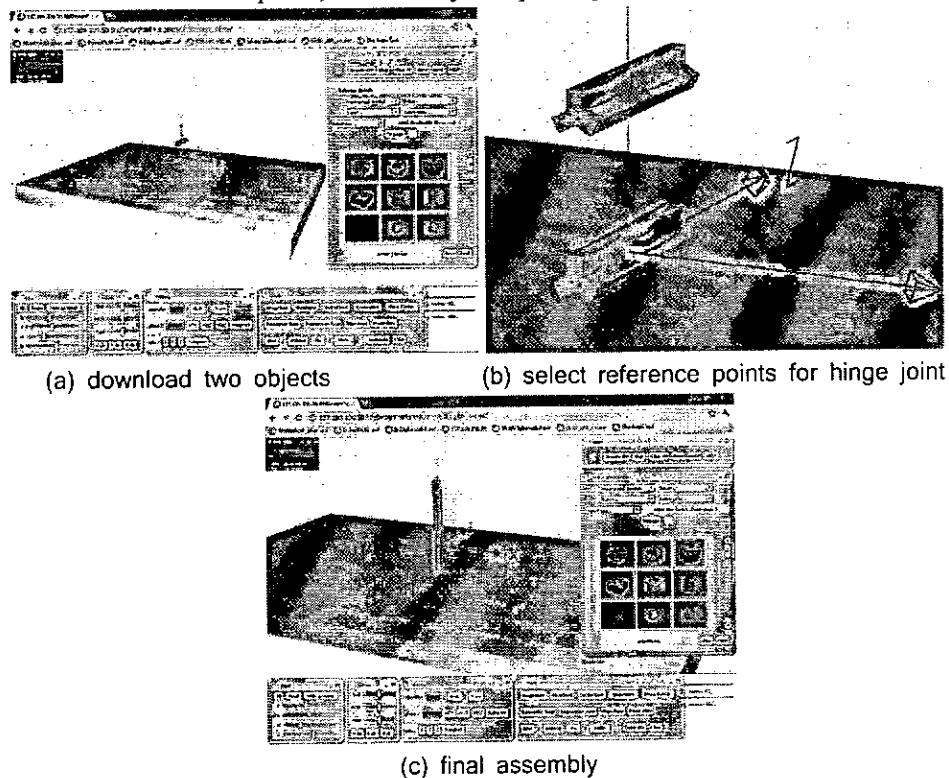
Fig. 13 Assembly process of hinge joint

The assembly processes of other joints, "PivotJoint" and "SocketJoint", are similar with the above one. In each step, the platform will give an instruction or an error message, so users can follow the instructions to finish related operations.

The "Bind" button can bind two objects with a rigid connection, while "Unbind" button will release the selected object from binds. The "Fix" button is used to fix the selected object in 3D space, while "Unfix" button will resume its free status. The "Terminate" button is used to terminate an unfinished mating process, such as rotation. The "Clear" button can clear all data related to a mating process.

The "Plane Center" button can provide assistant operations to assemble axles in caves. As the example shown in Figure 14, in step (a), one axle and a wheel are loaded in the work space; in step (b), we suitably zoom in and rotate the view point for easier observation on the objects; in step (c), we click button "Plane Center", a hint "*Click on a plane, system will calculate its center*" will show below the database searching panel, then, click in the top plane of the axle, and then it can be seen that the color of the plane changes into

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orange; in step (d), click on the wheel's side plane where the hole pass through, and we can see the axle begins to rotate with hint information shown below the database searching panel; in step (e), we can see the rotation is finished and the axle is moved to the front of the hole of the wheel; in step (f), we use mouse to click the wheel (carefully, do not move it), then click "Fix" button to fix it (change into gray color), and then in the mouse panel, select "Grab" mode and "Assigned" axis method; in step (g), use mouse to grab the axle (mouse icon changes into a hand), and move it into the hole (sometimes the axle will vibrate due to calculation precision of the collision detection), and click "Bind" to fix the connections between the two objects; in step (h), now we click the wheel and click "Unfix" (its color will resume), and change the mouse mode back to "Drag" and "Default", and then we can drag the objects to check the assembly.

Since the collision detection is highly sensitive when objects contact each other, sometimes the assembly runs not smoothly and vibrations will destroy the relative position between objects. Then, we need to click "Unbind" button to release the two objects from binding relationship, and perform above procedure again.
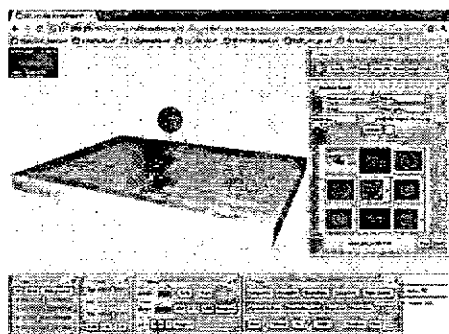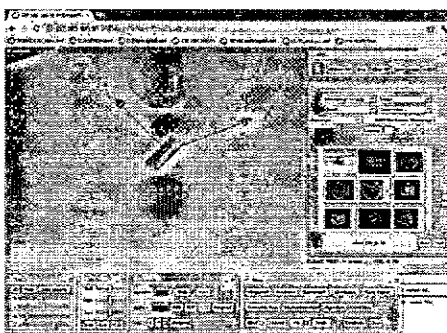

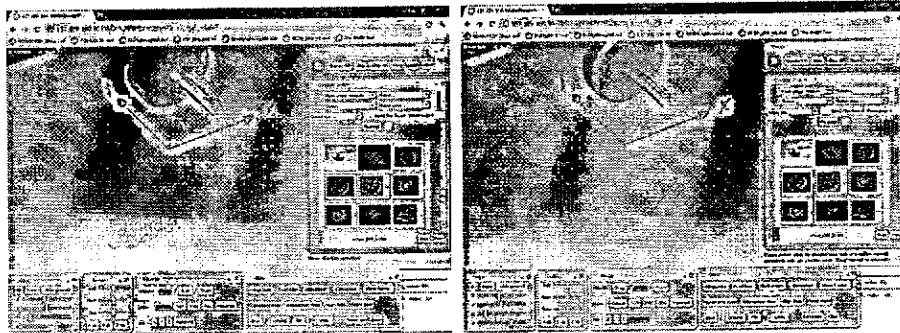(a) load in an axle and a wheel

(b) modulate the view point and zoom scale
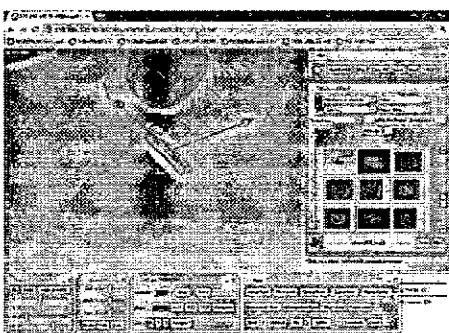
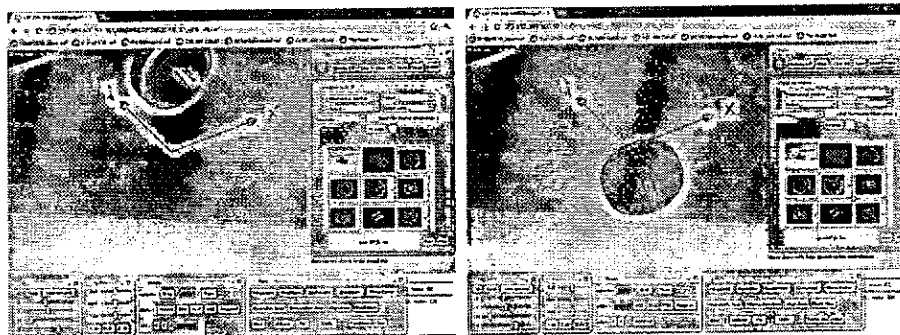(c) clicked axle plane changes its color

(d) clicked wheel plane changes its color and the axle begins to rotate

(e) axle is moved to the front of the hole   (f) fix wheel and select mouse modes

(g) move in the axle and bind it with the wheel (h) resume mouse modes and unfix the wheel to check the

assembly in different view angle

Fig. 14 Steps of assembling an axle in a wheel

2.7 Status panel

At the left-top of the screen, there is a status panel as shown in Figure 15. Users can get information on the frame rate of rendering and the usage of RAM space.
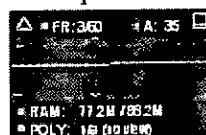

Fig. 15 Status panel

3. Reference material

3D graphic engine and tutorials: http://www.away3d.com

PHP documentation: http://php.net/docs.php

MySql documentation: http://dev.mysql.com/doc/

3D Studio Max tutorials: http://www.3dstudiomaxtutorials.com/

Appendix 2 3D Design Using 2D Sketches

1. Introduction

Over the last few decades, the number of 3D models available on the Internet grows rapidly. People need not design 3D models from the ground up now, they can pick the components from the Internet to simplify the designing process. As Thomas Funkhouser says "The primary challenge in computer graphics will shift from 'how do we construct them?' to 'how do we find them?'". For example, if you want to build a 3D virtual world representing a room. You can download a bed, a desk, a sofa, etc. from the Internet, and then position them in the right places to construct a 3D room model. So the key question is how to find the desired 3D components. 3D model retrieval has been a topic of interest to researchers for a long time, the query methods are simply classified as text keywords, 2D sketching, 3D sketching, model matching and iterative refinement. Designers usually use sketches to present a brief idea in the early phase of designing. By the aid of computers, designers can interact with drawings in ways that are impossible with physical papers. We have developed a platform to design 3D models from components using 2D sketches, aiming to facilitate the education, idea sharing and cooperation on designing.

Why use sketches? The strength of sketches is that it quickly represents human ideas and offers an inexpensive but effective way to transfer ideas to others. When computers understand the drawings, they can do lots of things that human cannot do. For example, it can provide a simulation to make the drawing alive. Designers usually use sketches to present brief ideas in the early phase of designing. Sketches is ambiguous, it helps people express, interpret, and modify shapes and relationships among the drawn elements with no need of details such as an alignment or a precise measurement. This strength, however, is a barrier for machines to understand sketches.

The challenge in designing 3D models via sketches arises from matching 2D sketches to 3D models. This challenge can be divided into two parts: (1) Making the computer understand the 2D queries, it is known as the sketch recognition problem; (2) Extracting features of the 3D model, and matching them with the 2D sketch queries, it is well known as the 3D model retrieval problem.

To solve the first problem, we present a system for recognizing the 2D sketches. Our system has two advantages comparing to conventional freehand design systems.

(1) The system can recognize complex sketches from the tablet PC and the physical papers;

(2) Our method significantly reduces the searching time and improves the accuracy by using the Fourier Descriptor and the Gaussian-means clustering.

We also developed a Web-based system running in browsers, which enables people from different places and different operation systems to share and cooperate with each other' work easily. Feedbacks from users indicate that our system is quite interesting, and the system encourages them to create various 3D designs.

2. System Overview

Our system supports both online and off-line recognition. To use the online recognition, user can draw on the

blank area of the window, as illustrated in Fig. 1, the results will be presented when the user clicks the button "Recognize". When users draw something in the freehand design window, the system recognizes the drawings and presents the corresponding 3D models. The black ink in Fig. 1 displays the user drawing, and the blue 3D cow model is the corresponding model.
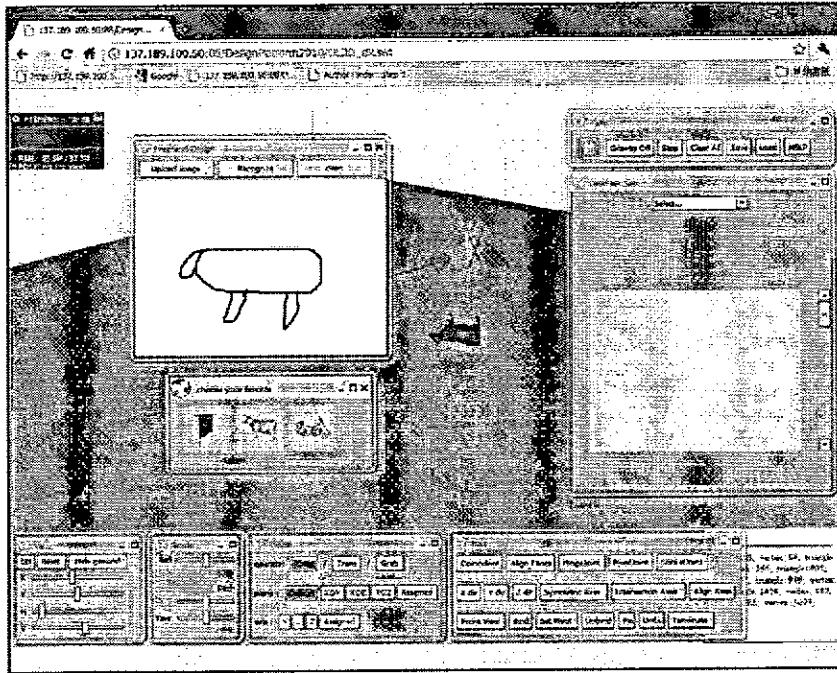

Fig. 1. An example of freehand design. The user draws a 2D sketch query (Blank area), the system returns a corresponding 3D model.

To use the offline recognition, the user can upload his or her work by clicking the button "Upload image". Fig. 2(b-d) introduces the general model construction process using the offline recognition. The user begins with sketching a car on a sheet of paper. The paper is scanned and uploaded to server, as soon as the server receives the image, the system analyzes the sketches and automatically presents a set of possible results (Fig. 2(c)) to the user. When the user clicks the first thumbnail in upper left of Fig. 2(c), the most possible 3D model appears into the platform (see Fig. 2(d)).
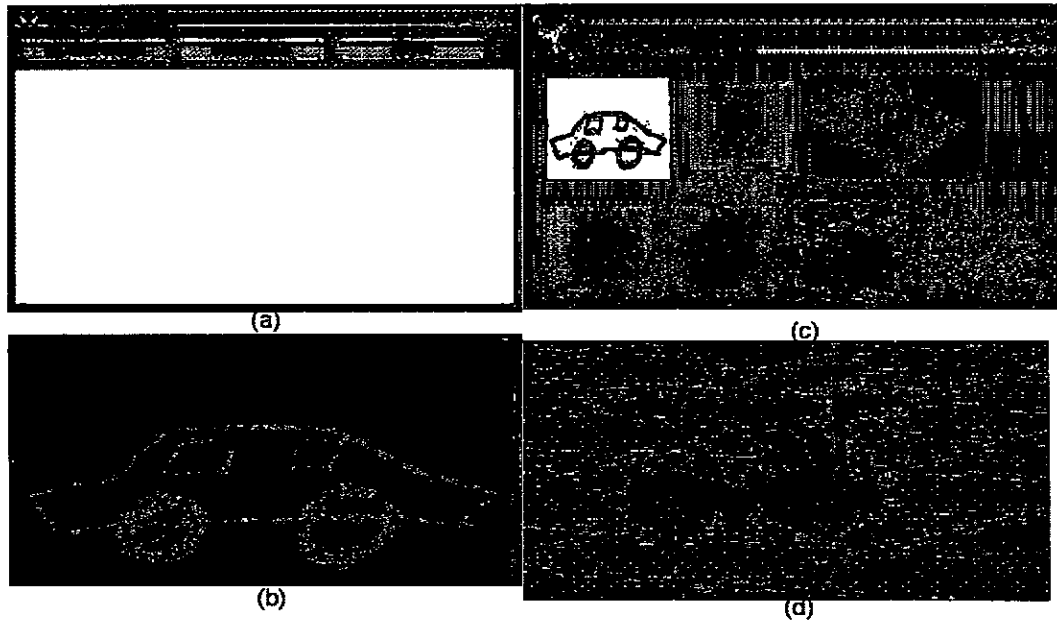
Fig. 2.
Overview of the design operation. (a) Freehand design interface. (b) User sketches a car on a sheet of paper. (c) A set of thumbnail images representing the most likely 3D components. (d) The most likely 3D model when the user chooses the upper left thumbnail.

Technique

The process of our system can be described in Fig.3. The user creates a query, and sends the query to the system via browsers. The system performs the sketch recognition process and then generates a set to 2D descriptors for the later matching. Each 3D model in database is described by a set of light field views, which are quantified by the Fourier descriptors. The process of sketch recognition and 3D model description are discussed in detail.
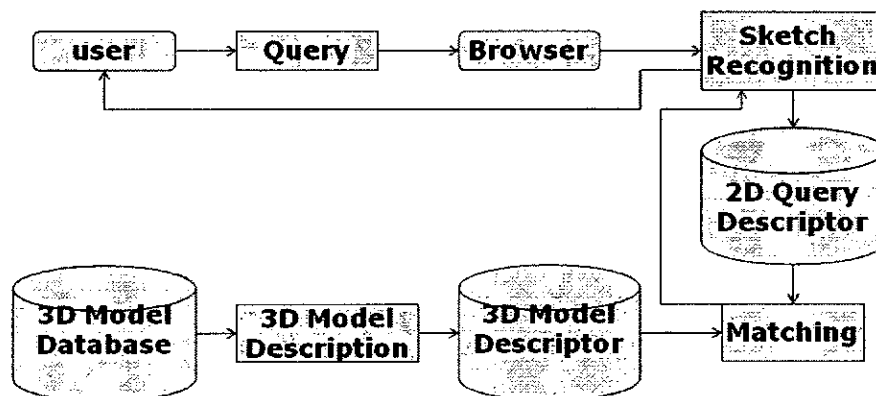

Fig.3. The process of our 3D design platform.

3. Sketch Recognition

Our system searches 3D models based on information related to the shape features. Due to the inaccuracy of the freehand drawing, features such as color and texture are not considered in order to provide more possible results to users. The recognition algorithm works by matching the input against 3D models descriptors in the database.

For geometry matching, we present a novel recognition algorithm to understand hand-drawn sketches. Our algorithm compares the geometry similarity of each component with the classes in database. Compared to other systems requiring devices to capture stroke information of users on sketching the design, our system also can index by using scanned images of sketches.

(1) Smoothing and Segmentation

Sketches may contain many details which are not necessary for recognition. Such as small polygons, lines and colors. Additionally, image acquisition devices introduce some noise into the scanned images, and these features are eliminated by grayscale conversion, median filter, edge detection, dilate and erosion. Fig. 4 shows the process of this smoothing and segmentation.
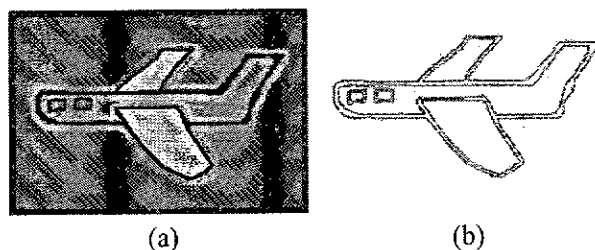

(a)   (b)

Fig. 4. Remove unexpected features of an image. (a) Original input   (b)Image without unexpected features.

(2) Feature Extraction

To extract the subfigures of an image, we need to break the image into different parts at first. In Fig. 5, the plane is divided into 6 parts.

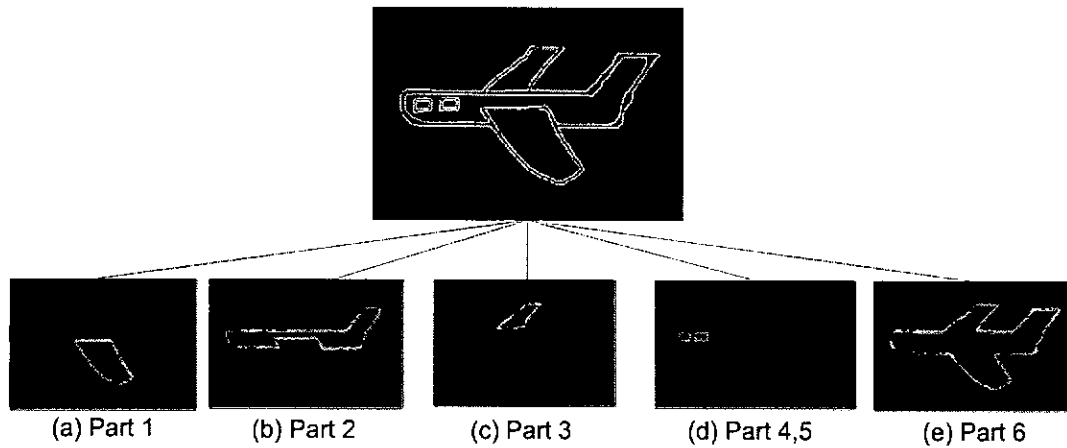(a) Part 1 (b) Part 2 (c) Part 3 (d) Part 4,5 (e) Part 6

Fig. 5. Feature extraction

In our implementation, we apply the Fourier descriptor to represent each subfigure. In general, a Fourier descriptor is obtained by applying Fourier transform on a shape feature. The coefficients of the Fourier series are called the Fourier descriptor of the shape. One big advantage of the Fourier descriptor is it is invariant to translation, rotation and scaling, and the noise only affects the high elements of the coefficients. Fourier descriptor can be derived by different patterns, people often use the curvature function, cumulative angular function, centroid distance is commonly used as the shape feature. In our implementation, we apply the Fourier descriptor derived from centroid distance.

3D Model Description

This section presents our algorithm for object detection. To detect an object, we first generate a set of views by using light field descriptor, then these views are quantified by the Fourier descriptors, finally a set of optimal views are extracted by using Gaussian means (G-means) Clustering. Fig.6 shows the process of our algorithm.

3D object   Extracted Views   Fourier   G-means
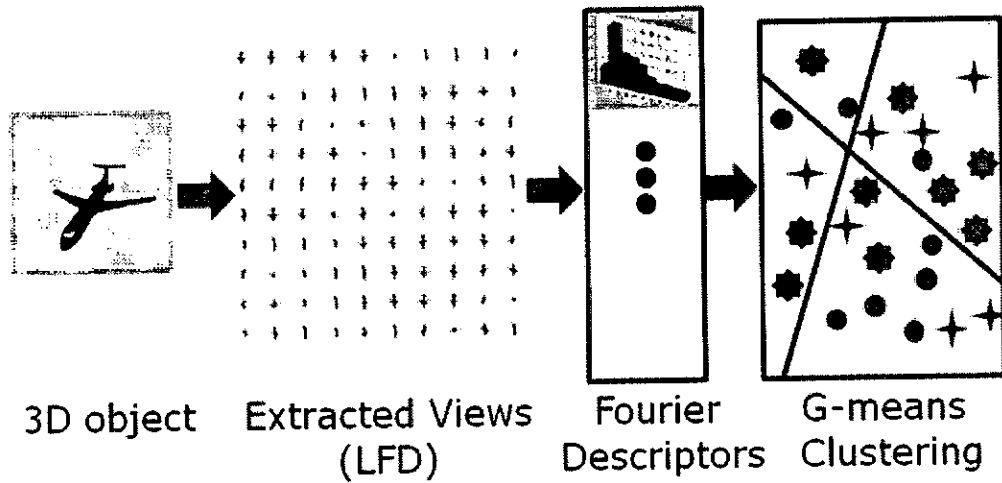(LFD)   Descriptors   Clustering

Fig.6. The process of 3D model description

The most intuitive way to describe an object is its views. For one object, the views can be very different from different viewing angles, thus one view is not sufficient to describe an object. In our algorithm, we extract a number of views from different viewing angles to represent an object. Then the problem comes to how many views are enough for an object. In order to ensure the extracted views are sufficient for representing one object, we presented an algorithm base on the light field. In our implementation, we extract features from the light fields rendered from cameras on a view sphere; the cameras of the light fields are distributed uniformly and positioned on vertices of a sphere. To reduce size of the features and speed up the matching process, we take 100 images for each object in our current implementation, all these views are projected views, and we only consider the contours of the objects. Fig.7 shows 100 views are extracted for a 3D plane model.
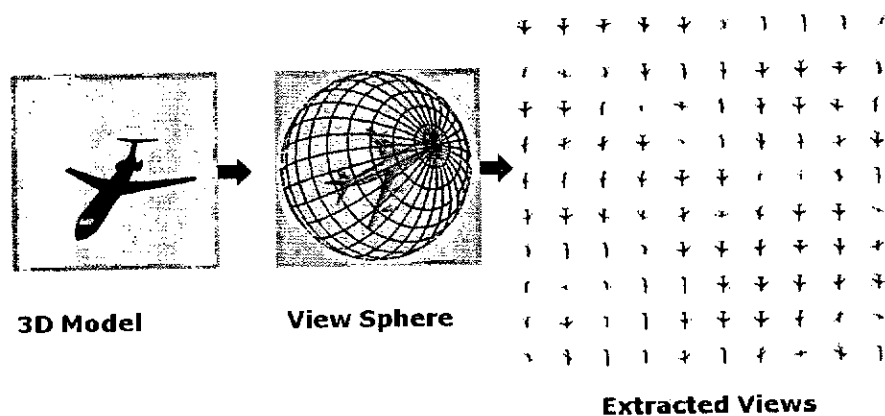

3D Model   View Sphere   Extracted Views

Fig. 7 shows 100 projected views for a plane.

The process for constructing a light field descriptor is listed in the following:

(1) Translating and scaling to make sure the model is contained in the view sphere.

(2) Rendering images of the object. Here we use 100 vertices on a view sphere, as such we got 100 views for one object. The number of views could be larger, but it will result in high redundancy and impractical to an object detection system using current hardware.

(3) Extracting the contours of the object. For each contour, translation and scaling are applied to the similar size and positions. In our implementation, we only consider the contour of the object, which enhance the efficiency and the robustness of the image processing.

(4) Applying the Fourier descriptor to represent the contour, after this step, each contour can be described by a vector.

(5) Measuring the similarity between images.

By using the G-means clustering, 100 viewpoints are divided into several clusters. For the 3D plane model, 17 view clusters are generated to represent it. As the Fig. 8 shows, different color and shapes represent different view clusters.

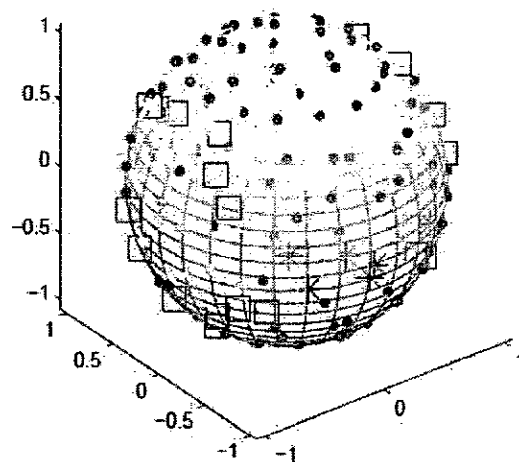Fig.8. View sphere.

The 3D model descriptor is saved in an Xml file. The structure of the 3D model descriptor is described as Fig.9.

```
<?xml version="1.0" ?>
- <opencv_storage>
  - <model2>
      <ID>2</ID>
      <objNm>Y1_barrique</objNm>
    - <FDs type_id="opencv-matrix">
        <rows>100</rows>
        <cols>10</cols>
        <dt>f</dt>
        <data>0.07534 0.038222 0.019553 0.07805 0
          0.022903 0.010879 0.005838 0.010708 0.0
          0.076957 0.023438 0.031146 0.025863 0.0
          0.009086 0.013043 0.004636 0.010546 0.0
          0.04497 0.070434 0.056422 ...</data>
      </FDs>
    - <FD_Clusters type_id="opencv-matrix">
        <rows>4</rows>
        <cols>10</cols>
        <dt>f</dt>
        <data>0.088754 0.027024 0.037146 0.073931
          0.013728 0.015046 0.007389 0.0055056 0.
          0.032703 0.074621 0.030992 0.021897 0.0
        </data>
      </FD_Clusters>
    - <FD_histogram type_id="opencv-matrix">
        <rows>4</rows>
        <cols>1</cols>
        <dt>i</dt>
        <data>33 27 20 20</data>
      </FD_histogram>
  </model2>
</opencv_storage>
```

Fig.9. The data structure of 3D model descriptor

4. Demonstrations

We implemented the algorithms by using the C++ and the OpenCV library. We built two databases to test our algorithm, the first database is consisted of 70 VEX models; the other database contains 11,973 3D models in computer, these models are from the National Taiwan University, Currently this database of the system contains 11,973 3D models.

To improve the retrieval interface, the results can be displayed in several pages. Also, we have implemented a "Find Similar" function, which enables the user search similar 3D models by using the 3D models in result window.
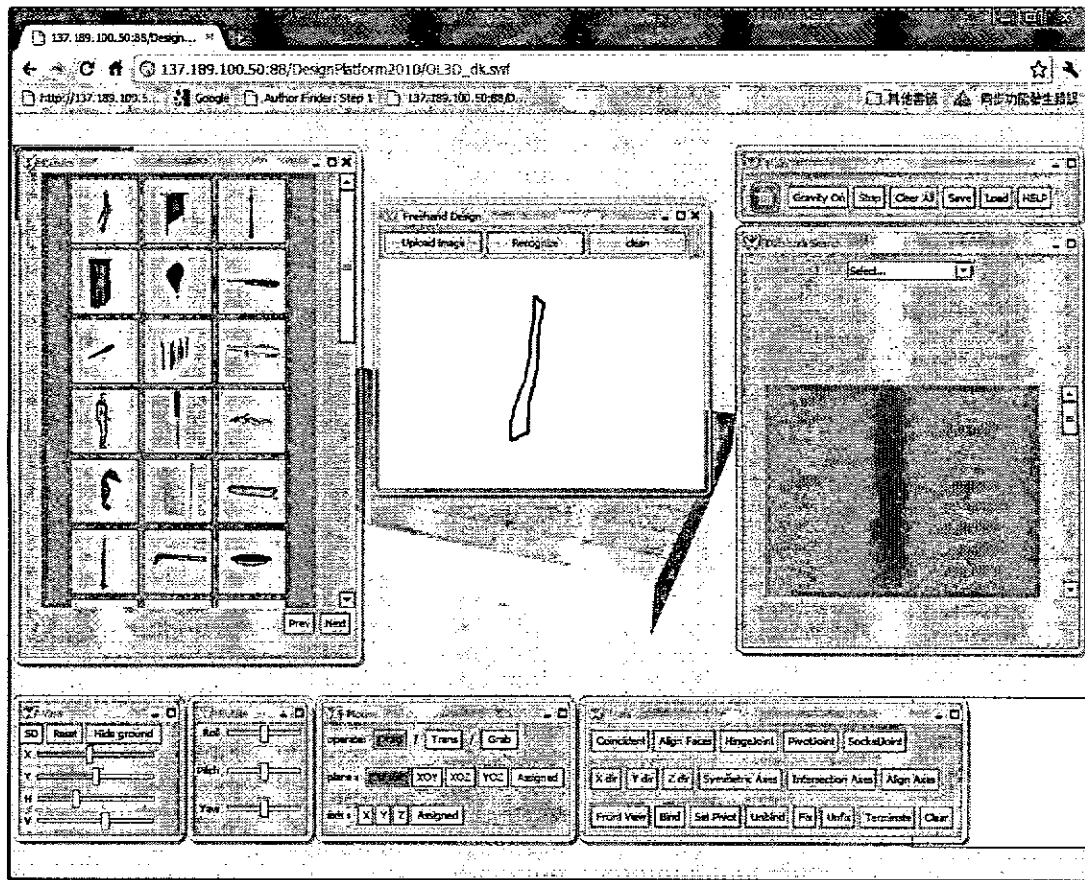
Fig.10. The user draw a slim bar. All the possible results are presented in the left window.
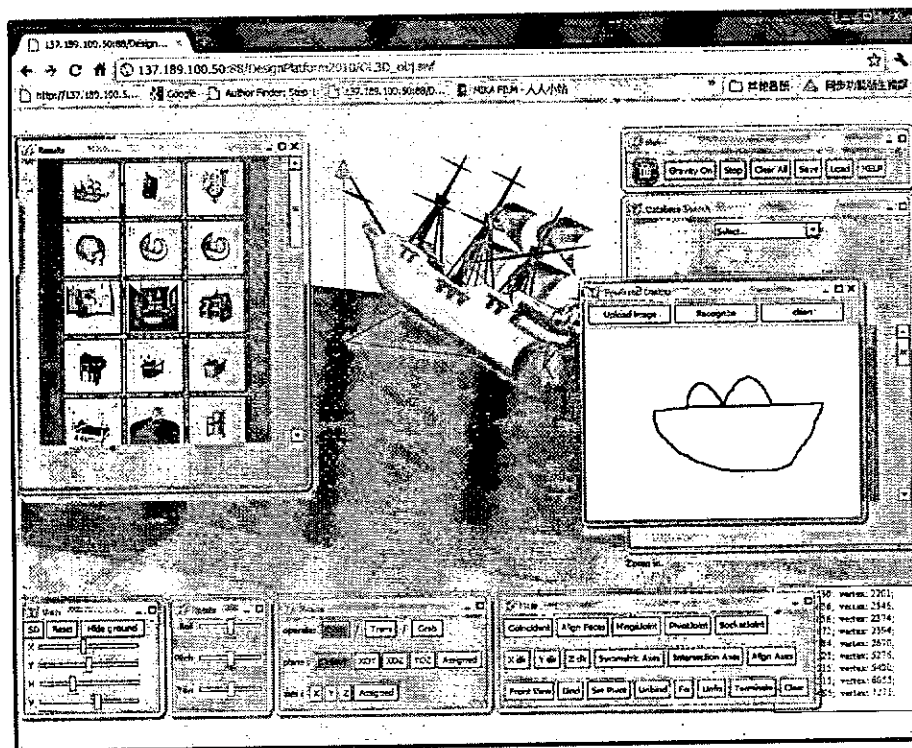
Fig.11. The user draw a ship in the "Free design window". Then the system presents some possible results in the left window, when the thumbnail "ship" is clicked, a 3D ship model will be presented to the platform.
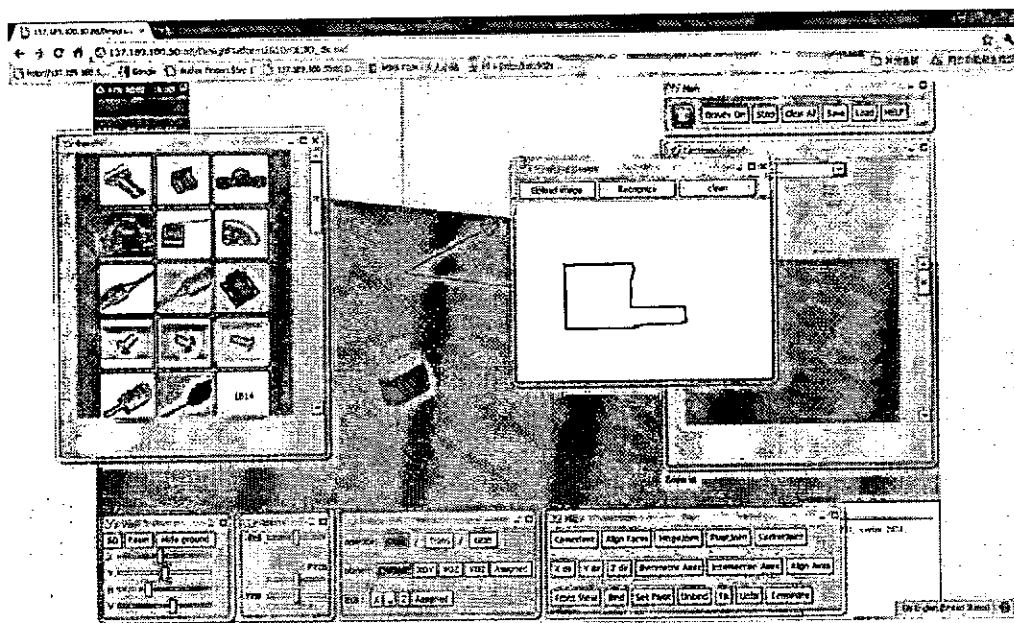

Fig.12. The Demo is based on the VEX database. All the possible for the input drawing are presented in the left window.
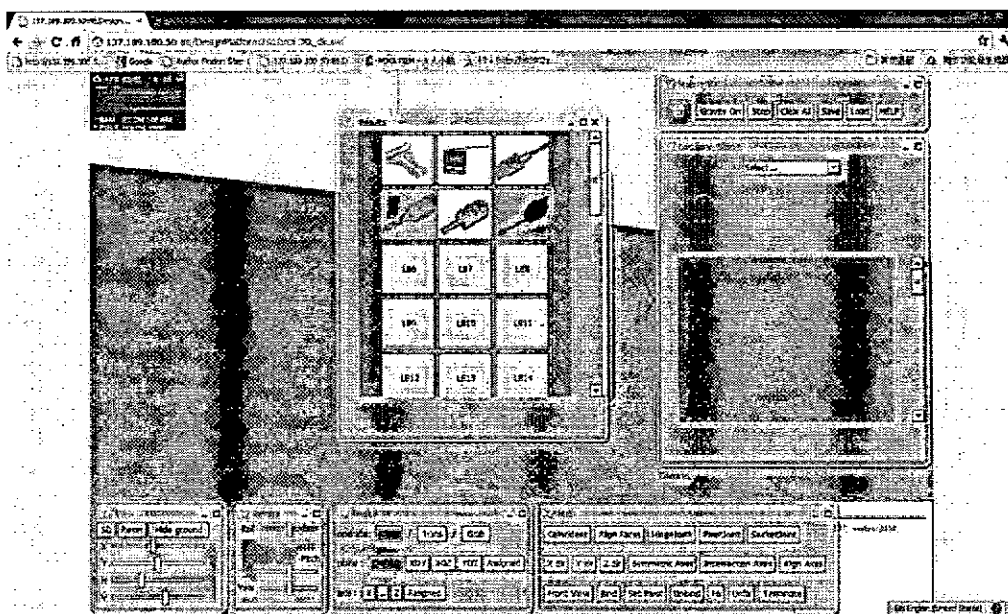
Fig.13. If the user holds the "Ctrl " and then click the thumbnail of 3D model, all the similar 3D models are presented.

Appendix 3　Online Learning Platform

We have hosted an online learning platform "Moodle" to facilitate the teaching and teachers to monitor the learning. On the platform, all the learning materials were uploaded. Students can perform self-learning while teachers can assign homework and assessments.

All the pilot schools are enrolled to the platform, while the teachers can enroll their students which level(s) they are studying. As an integration of online learning resources, users can access the "Online Design Platform" directly in Moodle. Students may also export the CAD model of their designed robot from the online design platform and submit it as assignment via Moodle.

Moodle was built to provide an interactive learning environment. Teachers can also organize their own activities such as discussion forums, learning resources, homework assignments, quizzes, etc. We also encourage self-learning, so students can attempt quizzes composed of MCQs via Moodle. For quizzes, teachers may use the questions provided in our database or create and upload their own questions. After quizzes, teachers can view the performance of the students, statistics analyses are provided.

A user guide has been prepared to the teachers, which will be included in the curriculum package.

**Appendix 4 Competitions and Promotion Activities**

We promoted the deliverables of this project by organizing the 2009 Internet-based Robotics Inter-School competition (IRIS 2009), the 2010 Robotics Winter Camp and participating in exhibitions at the 2010 QEF Roving Exhibition and the Robocup Junior 2010.

The IRIS 2009 was held successfully on February 4, 2010. IRIS is on-line competition for students to participate in robotics competitions including robot design. Some snapshots of the events:

In the 2010 Robotics Winter Camp, one of the four projects requires the student to design robots using the on-line platform first and then use the real parts to build the robot design.

QEF Roving Exhibition:

It was organized by QEF and held during January 21-23, 2011 in Kwai Chung Estate. We displayed the deliverables of this project, which attracted a few thousand people to view and try the on-line design platform. Very position feedback was received. Following is the poster:

優 質 教 育 基 金
Quality Education Fund
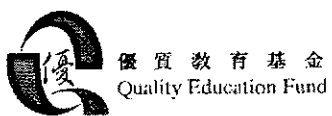
Robocup Junior 2011 Technology Exhibition

The technology exhibition was successfully held on June 4, 2011 in Sir Run Run Shaw Hall, The Chinese University of Hong Kong. We display the on-line design platform and the curriculum in the technology exhibition.

優 質 教 育 基 金
Quality Education Fund

Appendix 5 The Design Curriculum

The curriculum is based on "Strand 1 - Design and Innovation" of the New Senior Secondary Design and Applied Technology (NSSDAT). Both Chinese and English versions are prepared. There are five parts:

Entry Level: Fundamentals of design are discussed from the technical point of view. Fundamentals and basic concepts of design are introduced. In completing the Entry Level, students should understand what a design brief is, what design specifications are and also their importance. Besides, students should also be able to grasp the general flow of a design process and master some skills for gathering information and generating ideas.

Basic Level: Design is discussed from the aesthetic point of view. Basic design elements and combination methods for aesthetic design are introduced. In completing the Basic Level, students should grasp the key concepts of aesthetic design and have a brief idea of the needs of it.

Essential Level: Issues related to social responsibilities in design such as matters concerning product safety and environmental protection during product design are discussed. Examples of the related standards and regulations are also given.

Advanced Level: How to fulfill business needs is the main discussion focus. Concepts such as marketing positioning, the marketing mix and designing for effective manufacturing are introduced. In completing the Advanced Level, students should have a brief idea of how design looks like when it is based on business needs.

Theme learning section: Robot design is to be learnt. Based on the VEX Robotics Design System, 3 practical examples in total referring to the Entry Level, Basic Level, and the Essential Level respectively are given to illustrate the concepts.

The following is the school list which implemented the curriculum:
Weo Chang Pui Chung Memorial School
Ma Kam Ming Charitable Foundation Ma Chan Duen Hey Memorial College
TWGHs Chang Ming Thien College
TWGHs Kap Yan Directors' College
TWGHs Yow Kam Yuen College
CCC Tam Lee Lai Fun Memorial Secondary School
Wa Ying College
Shau Kei Wan East Government Secondary School