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ITP5210
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A Web-Based Project Network Diagram Modelling System

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ABSTRACT
Surveys on existing research works indicate that diagrams are better than text in modelling complex structure such as a project. When a project is modelled using a network diagram, more mental resources can be released to allow team members to formulate their project plan and actions better. Nowadays, due to the changes brought about by globalisation, project stakeholders are often physically dispersed. This article presents a graphical modelling system designed to enable geographically dispersed project stakeholders to create a network diagram collaboratively over the Internet. Under the system, users can also improve on the diagram layout collaboratively.

PREAMBLE
Project planning plays a significant role in the project's success. At the very early stage of a project, the project team needs to collaboratively arrive at an agreed set of activities (that will need to be done) and their inter-relationships. A network diagram is often used to model the set of activities which are simultaneously subjected to precedence as well as other constraints. Throughout the life of a project, the diagram is often continuously changing due to modifications caused by uncertainties and scope changes.

Over the last decade, globalisation has brought changes to our business environments. Project Managers now often deal with physically dispersed stakeholders.

In this article, a web based diagrammatic modelling system, designed to facilitate project planning and control is presented. This web based system allows physically dispersed project stakeholder to collaboratively model the project and make changes to the diagrammatic model during the implementation phrase of the project. A prototype of the proposed system is created to demonstrate the feasibility of implementing such a system.

DIAGRAMMATIC REPRESENTATION VS TEXT-BASED METHOD
Stenning and Oberlander (1995), through their psychological experiments on "self-explanation", established that diagrams promote self-explaining, reduce abstraction and help "processiblility". Ainsworth & Loizon (2002) commented that the sentence "blood from the left ventricle flows through the left semilunar value, into the aorta", does not make clear the size and precise positions of these organs, whilst a diagram does. When diagrams are used instead of text, comparatively less memory loads and cognitive efforts are required from a learner. In addition, they established that "written text is processed by the phonological loop, whereas diagrams are processed by the visual-spatial scratch pad". Presenting information in two modalities, reduction in memory loads and cognitive efforts can therefore make learning more effective. It was also found that graphical representations can help promote the possibility of information being self explanatory, not just within one single diagram but across multiple diagrams.

From their experiments, Marus, et. al. (1996) found that there are differences between the use of text only and the use of diagrams when teaching students to understand a parallel electronic circuit and a serial circuit. They concluded that diagrams can enhance the understanding on the interactions among information elements within the presented information, and thus the demand on cognitive load will be decreased and understanding will improved.

Levin et. al. (1987) found that a diagram can help to organize events into a coherent structure, clarify complex and abstract concepts, and assist learner in recalling important information. A project is comprised of a set of activities that have to be done in certain order (i.e. subject to precedence constraints) and therefore, a diagram is the best choice in depicting the activities and their interrelationships. Thus, a network diagram should be the preferred input method for the modelling of a project, in particular, at its inception.

MICROSOFT PROJECT
Microsoft Project is currently the most owned PC project management software in the western world. However, it suffers from the following imperfections.

1. The clarity of how the precedence relationships (start to start, start to finish, finish to start and finish to finish) are presented in the network diagrams (known as PERT chart) needs to be improved, and
2. The spreadsheet control with Grant Chart as an entry method for project creation is not ideal.
3. The table listing all the activities' details and the network diagram cannot be presented simultaneously.

The proposed system will address the above issues

COLLABORATION OVER THE INTERNET
Recent globalisation has brought a lot of changes to project management environment. Nowadays, the members of a project team can be located in multiple local offices as well offices scattered across the globe. Gathering all team members and decision makers to join in a face-to-face meeting to formulate their project can be very costly. Costs are not just the expenses of travels, but also the loss of productivity and the stress to the participants.

Many web-based programs now exist which allow people in different countries to operate concurrently on a single document. Programs, such as Campbell's Co-Diagram (2004), allow multiple designers to generate diagrams and collaborate to solve design problems. Campbell indicated that when people have different intentions, working together, can interrupt each person's work. Johnson (1993), however, found that the occurrence of interferences were considerably rare. His experiment involved 10 groups of people with each group completing a 7-hour shared diagram creation activity. During the experiment, 65% of the operations on a shared diagram were found to be controlled by more than one person. The observations from the experiment indicated that the highest occurrence rates for all incidents and clear incidents (those that can be clearly identifies) of interference are once every 17 minutes and once every 59 minutes respectively. Campbell (2004), however, argued that although interferences may happen infrequently, serious problem can result when they occur.

MULTIPLE VERSIONS SOLUTION FOR RESOLVING THE CONFLICT ISSUE

When physically dispersed users are working collaboratively on a shared document or a graphical representation over the Internet, the enabling software should have the ability to resolving conflict issues aroused when multiple users are trying to modify the shared resource at the same time.

Commonly used strategies to resolve conflicts issues are:

- "Single-operation-effect"
- "Null-effect"
- "All-operation-effect"

"Single-operation-effect" (often known as "floor control") is the most commonly used solution strategy (Ceglar and Calder, 2001 and Campbell, 2004). Under this strategy, only one person is allowed to operate at any time. This solution could successfully avoid interference, but it decreases effectiveness as it disallows parallel operation. Later models such as the one proposed by Stefik et.al (1987) dispensed with synchronisation and left control to users utilizing a "Social Protocol" to avoid conflict. Under the "Social Protocol", users are responsible for managing their work so that it does not interrupt with that of the others. However, Greenberg and Marwood (1994) indicated that social protocols (just like in the case of power struggles) cannot defend against negative consequences caused by deliberate manipulation from a "power-hungry" user.

Under "Null-effect" conflict solution strategy, when conflict occurs, none of the actions will be allowed to change the target object. The Null-effect solution can avoid the conflict, but it also nullified the consequence of both operations that lead to a conflict. In other words, this solution stops the users from understanding the intents of the users that lead to the conflicting operation and hence learn from the incident.

Under "All-operations-effect" solution, the consequences of the operations that lead to a conflict are contained in difference versions and all appear in the terminals of every user. In this way, users are able to see what choices are available and decide collaboratively to agree on a selected version. Campbell (2004) suggested that such a learning opportunity may allow new collaborative systems to be designed so that they can foresee interference and promote interaction. Compared to other solution strategies, the "All-operations-effect" solution is better as it provides users more opportunity to understand what causes the interference, to concurrently perform better interactions and to coordinate their actions better.

A collaborative system utilizing multiple versioning by Sun et. al. (1998) is a successful example of the application of an "All-operations-effect" solution. He reported that the system provides three features (*causality preservation, convergence*, and *intention preservation)* which can successfully solve the three inconsistency problems (*divergence, causality violation and intention violation).*

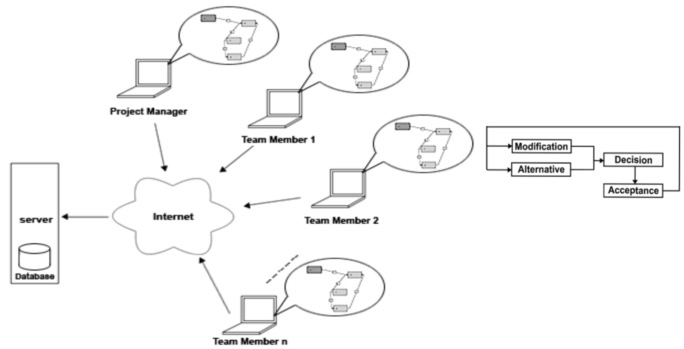
Divergence

Operations arrived but executed in different orders at different sites, cause divergent states of document displayed at each terminals. *Convergence* in Sun et. al.'s work ensures that all copies of the document are the same after executing the same collection operations at each site.

Causality Violation

This describes the situation when operations arrive and are executed out of their natural cause-effect order at each terminal. Causality violation will cause confusion to both the system and the users. *Causality Preservation* in Sun et. al.'s work solved the problem by sorting out the causal related or dependent operations and arranging them in their natural causal order.

Figure 1. System Architecture



Intention Violation

When the actual effect of an operation is different from the intention of the operation, the intention of the operation is violated.; *Intention Preservation*, in Sun et al.'s work, ensures the effect of executing an operation in any document state is consistent with the effect of executing the operation on the document which the operation was created from, and that the effect of the operation can not be modified by independent operations.

SYSTEM DESIGN OVERVIEW

Figure 1 shows the architecture for the proposed system (left-hand side). The flow diagram describes collaborative process (right-hand side). From the flow chart of the collaborative process, it can be seen that the network diagram is constructed in stages. At the end of a stage, the administrator will issue an "accepted comment" to commit the partially completed graph to the database. At the same time, the partially completed diagram will be locked from modifications by other team members. The member taking control will then allowed continuing with the diagram creation. The system, however, allows another member to take control and create an alternative version of the addition to diagram which will appear with a different colour from the original addition. Depending on whether most of the members agree with the selection of the original addition or the alternative addition, the administrator will accept the selected addition and move to the next stage of the diagram construction process.

The design of the system is based on the discussions on collaborative models, in particular, Sun et. al.'s work. The conflict resolution scheme used by the system is a combination of the "Single-operation-effect" model and the "All-operation-effect" model. The scheme possesses *convergence*, *causality preservation*, and *intention preservation features* as recommended by Sun et. al.

Convergence

Whenever an operation on the diagram is completed, the system will call a "save" function to save the current change into the database and then issue a "read" function to refresh the graph on each team members' terminals to reflect the changes. This "database driven" approach will ensure that identical diagrams will always appear at all sites.

Intention Preservation

The system avoids intention violation by allowing only one person to control the system at any time. In other words, when one person controls the screen, other members have no access to interrupt the operation. Therefore the intention of the person in control will always take precedence over others.

Causality Preservation

The cause of causality violation is often caused by the issue of different network bandwidths being associated with difference terminals, the relatively complex operation at the terminals to create the graph and multiple people being allow to work simultaneously on the diagram. The design of combining “Single-operation-effect” with “database driven” system naturally avoids the problem. Diagrams are constructed simply from the x and y co-ordinates of the nodes along with the information on which arcs are connected to which nodes. These are available direct from the central database.

“All-Operation-Effect” Feature

The “All-operational-effect” strategy is adopted in the system. The accepted sections of the network diagram are committed to the database in stages. Up to two versions of modifications since the last acceptance are stored in temporary tables for evaluation (see Figure 3). The selected version will then be committed as the accepted section.

THE PROTOTYPE

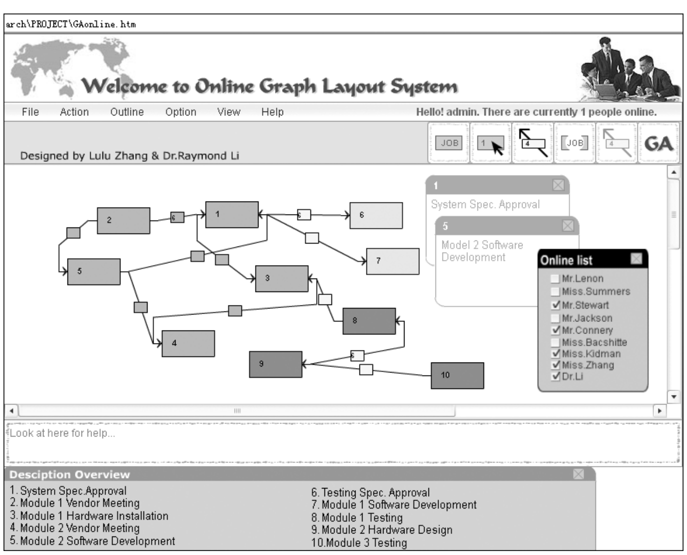
A prototype was created to demonstrate the feasibility of implementing the proposed system.

“Single-Operation Effect” Feature

The project manager, with an administrator right, can assign access rights to those (team members and stakeholders) who are jointly responsible for creating the project network diagram. A “Mentor” in the system is just like a chairman of a meeting. The Project manager can assign the right to others if he does not want to be the mentor for a session. The project manager can view the number of people on-line via the Online List Pop-up window (see Figure 2) and decide whether to go ahead with an on-line session.

During each session, a mentor will control the session by allowing only one person to “operate” on the diagram at any one time. If another person attending the session disagrees with the current change made, the mentor will give this person the right to control the frame and to show his suggestion to the diagram (in green). In this way, the modification (in green – the two top-right activities) and the alternative (in red – the two bottom-right activities) will appear on the screen of all session attendees for them to voice their opinions (see Figure 2). Chatting software such as MSN or ICQ can be used to provide communication between all people online and for the mentor to find out which version is to be accepted as the best choice. The version that is accepted will then appear in blue (together with all those previously accepted). The team can then continue with the creation of the project diagram.

Figure 2. The Prototype



Interface Design for Defining Predecessor-Successor Relationships

In a precedence diagram, there are four types of predecessor-successor relationships between each pairs of activities. They are *Finish to Start (FS)*, *Start to Start (SS)*, *Start to Finish (SF)* and *Finish to Finish (FF)*. Each relationship can also have *lead* or *lag* duration.

In the prototype, each node (activity) object is designed with five “clickable” regions (see top, left diagram of Figure 3). A text label in the centre shows the activity’s identity. The left and right end regions are for defining start and finish relationship respectively without time lead or lag relationship. The top and bottom regions are for defining the start and the finish of a relationship respectively but with time lead or lag. For instance, if a user wants to create a standard *FS* relationship, s/he clicks on the right end region of the predecessor node and then clicks on the left end region of the successor node to complete the definition for the predecessor-successor relationship. If the clicking actions, however, involve the top or bottom region, a “Lead/Lag Duration” dialog box (see bottom, left diagram of Figure 3) will appear allowing the user to define a time lead or lag relationship. Figure 3 (top, right diagram) shows the displays for all type of relationships (please note how the routing of an arc minimize its overlapping by the nodes). An arc representing a relationship with time lead or lag will have an elongated rectangle. A mouse-over the rectangle will bring up the “Lead/lag duration” dialog box showing the lead or lag details.

The central region of a node has two functions. Its modes depend on whether the “Move-Activity” option  on the tool pallet (see Figure 2) has been selected or not:

- When the option is selected, an activity can be dragged to a new position by moving the mouse with the left-button held down. In this way, the teams can manually improve the layout collaboratively (see the Figure 3 for an example – bottom, right diagram shows the improved layout).
- When the option is not being selected, a mouse over the central region of a node will bring up an “activity description” popup detailing the activity (see Figure 2). A mouse click on the central region of the node will bring up a persistent “activity description” dialog box which can be dragged to avoid blocking the user’s view of any nodes or other dialog boxes. A click on the dialog box will close it.

The interface was implemented using Macromedia Flash. A Job Class and Activity Class were created to take advantage of the OO approach that is now available under Flash. The backend system was implemented using Macromedia ColdFusion utilizing the newly available Flash Remoting technology.

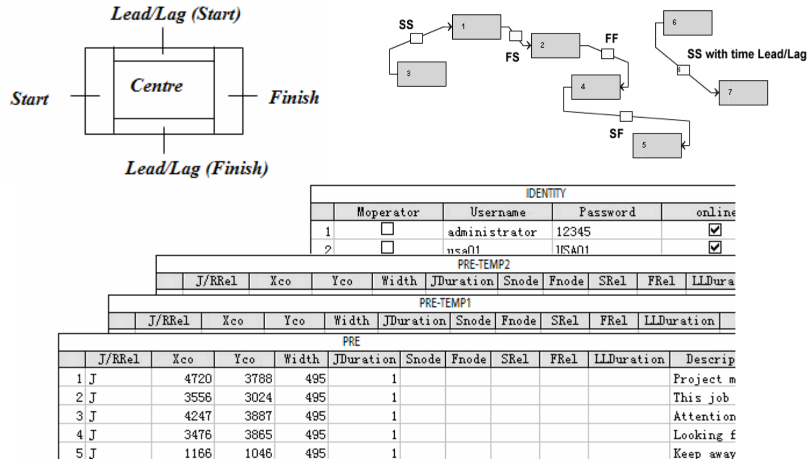
DATABASE DESIGN

Figure 3 shows a sub-set of the tables of the database supporting the prototype. The IDENTITY table controls who have the rights to access the project diagram and reflects the current status of the team members. The checked box in the *Moperator* field indicates who the current assigned mentor is and *Online* field shows that is online for the current session. The PRD table stores the confirmed part of graph. The tables PRD-TEMP1 and PRD-TEMP2 show the two versions of the addition/ modification to the diagram. The accepted version will be copied over to the PRD table and contents with the two tables will then be dumped.

ANALYSIS OF THE PROTOTYPE

The prototype, though incomplete, can demonstrate the feasibility of implementing the proposed system. The features that have been demonstrated by the prototype are:

Figure 3. Interface and Database Design



- A workable conflict resolution scheme based on the combination of “Single-operation-effect” strategy and “All-operation-effect” strategy.
- A “database driven” approach that provides the required mentoring feature and ensures the system satisfies the causality preservation, convergence and intention preservation requirements as recommended by Sun et.al.
- A feasible project diagram creation system addressing some of the issues associated with Microsoft project such as:
  - Better presentations for all types of predecessor-successor relationships.
    - A better input method for modelling a project using a diagrammatic approach.
    - A simultaneous viewing of network diagram and job description listing.
    - A system that has a workable feature which allow users to arrive at a better layout for the shared project network diagram.

CONCLUSION AND FUTURE RESEARCH

To address the globalisation issue, this paper presents a feasible web-based system that allows a project network diagram to be created collaboratively by geographically dispersed team members. This system provides a friendly working space for dispersed stakeholders to collaboratively create a project management diagram through the Internet. Under the proposed strategy to resolve the model over conflict issue, project managers and their team members can now efficiently operate graphs without conflict.

Diagram is a better tool to model a project than text and a good layout diagram can help to reduce cognitive load thereby releasing more mental resources for project manager to formulate their plans and actions better. In the proposed system, the “Move-Activity” feature will allow the layout of the network diagram to be manually improved by the member who takes the control.

Based on the research by Halim (1996) and Ramesh (1997), the research team has now completed an automatic layout program based on Genetic Algorithm and is now in the process of integrating it into the system described in this article.

Future development directions are:

- Evaluating the developed project under a real project management setting.
- Incorporating a chatting program and a display panel that shows the voting for the two versions of modification into the system.
- Extending the number of concurrent versions of modifications for selection.
- Improving the response time at the client’s terminal.
- Addressing security issues.

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