New Developments and Value of the RELAP5-3D Graphical User Interface (RGUI 1.2)

George Mesina & Jim Galbraith
Idaho National Engineering and Environmental Laboratory
P. O. Box 1625
Idaho Falls, ID 83415-3880, USA
Phone: 208-526-8612, Fax: 208-526-6971
Email: azb@inel.gov

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ABSTRACT

Graphical User Interfaces (GUIs) have become an integral and essential part of computer software. In the ever-changing world of computing, they provide the user with a valuable means to learn, understand and use the application software while also helping applications adapt to and span different computing paradigms, such as between different operating systems. New developments leading from version 1.1 to 1.2 of RGUI are chronicled. The value of RGUI in terms of usage and adaptation for RELAP5-3D is explained.

Keywords RELAP5, Graphical User Interface (GUI), 3D Visualization

1. Introduction

Today, most software applications come with a Graphical User Interface. In fact, the GUI is such an integral part of the application, they are recognized only in terms of their graphical interfaces. Consider, for example, Netscape, Turbo Tax, Microsoft Word and many gaming applications. The entire computing industry, with the exception of the scientific computing segment, has been heading in the direction of visual operating systems and application software for over a decade. Whether in the home or office, GUIs have become the dominant form of computing interface today. It is likely that market forces will dictate that computer industry development continue in this direction until virtually all non-visual operating systems and applications are developed with or replaced by visual implementations.

Although scientific computing has lagged far behind other areas of computing in the use of GUIs, use of visual computing has grown immensely in the last half-decade. There is a rich literature about creating GUI's for existing software packages; see for example [7]. Many well-known scientific software applications, such as FLOW3D and FLUENT, now come equipped with graphical interfaces. Following this trend, the US Nuclear Regulatory stated in 1995 that all their software products, including RELAP5, would henceforth have GUIs. The INEEL, the US Department of Energy co-lead laboratory for nuclear energy, began to develop the RELAP5 Graphical User Interface (RGUI) [10, 11, 12] under the Laboratory Directed Research and Development Program in 1997.

This project really builds on other GUI and user aid initiatives undertaken over the past 15 years. Three basic categories of RELAP5 user aids and interfaces have been developed: input model builders, transient aids, and post-processors. Input aids help the user create an input deck for RELAP5; among them are PYGMALION [5], ATHENA-Aide [2], TROPIC [1], and SNAP [4]. The NPA [0] and RELSIM [15] are examples of transient aids that both display results and allow the user to interact with a calculation in progress. Post-processors gather and display results of a previous calculation; among them are XMGR5 [6], NPA, and PYGMALION. A complete list of RELAP5 GUIs and user aids can be found in various surveys [8, 9]. The development of RGUI is chronicled in cited papers [8-11].

This paper presents not only the latest developments in RGUI, but also its value to the RELAP5-3D computer application and its user community. The latest developments, improvements and upgrades that lead from RGUI 1.1 to RGUI 1.2 are detailed in Section 2. Its value is examined from four perspectives in Section 3 including usage/accessibility to users, adaptation to computing paradigms, and melding of features and capabilities. A short Section 4 showcases some new developments that will be available in RGUI 1.3.

2. Developments in RGUI 1.2

The two largest improvements from RGUI 1.1 to RGUI 1.2 were the addition of a 3D-pipe representation of the plant model and the upgrade of XMGR5 to run on both MS-Windows and Unix platforms. Other improvements include point-and-click plots, dynamic color maps for displaying variable values, user on-screen annotations, adaptation to HP platforms, and the inclusion of many user conveniences. Each of these are explained and illustrated in turn.

2.1 3D Pipe Isometric Image

With the touch of a button, the stick figure image of a model is transformed into a 3D-pipe representation. Pipes can be represented as *wireframes or solid surfaces* with lighting and shadow effects added. The pipe radius can be fixed or based on cross-sectional flow area. The 3D-pipe representation of the plant model provides a more realistic and easily understood visualization of the system than the stick figure. Unlike the stick figure, the 3D-pipe figure shows lighting effects and disappearance of objects hidden behind other objects relative to the user's viewing position, making it easier to locate and recognize features.

In Figure 2.1, the plant model of the typpwr.i input file is represented pictorially with a wireframe pipe. The figure is monochrome gray in color and has a fixed radius. The eye easily discerns that the pressurizer surge line goes behind the steam generator. Individual bends in the loop seal are clearly visible.

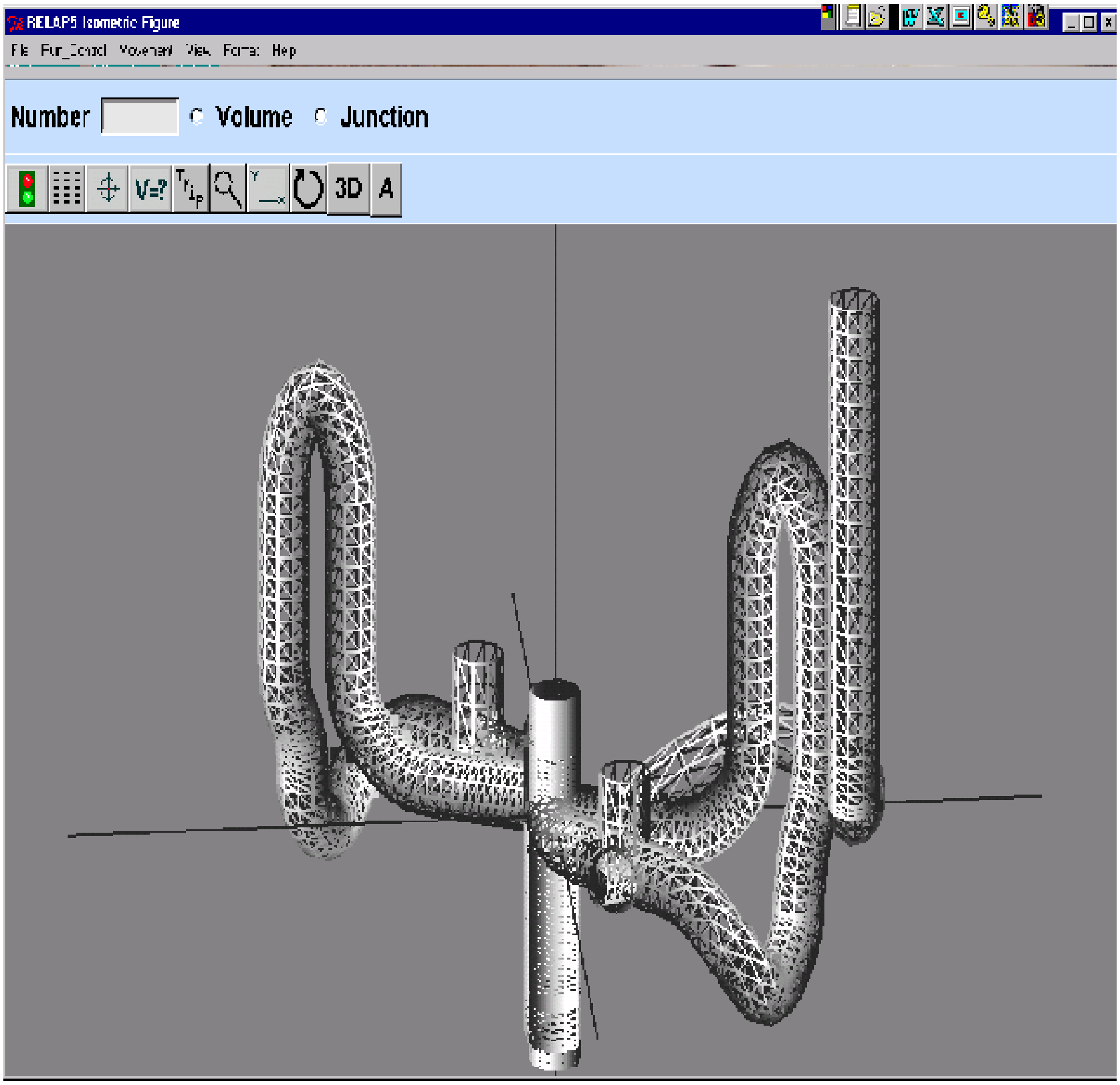

Figure 2.1   3D Wireframe View of Typical PWR

Further, the 3D-pipe figure has two more important features. It can show the *flow area* within a pipe or vessel, rendering each pipe segment with the radius that corresponds to the flow area. It can also display the value of a variable at each pipe segment through a *color map* in which purplish blue is the lowest value and red is the highest. The user selects the variable and its range of values.

In addition to the above features, some other useful features are available. The 3D image can also *display numerical values* adjacent to the control volume or junction, just as the stick figure does. Thus the user can see three pieces of information at every control volume; its radius, color map for one variable, and the numerical value of another variable. Another feature is the *user pipe radius multiplier*. This can be used to change the size of the pipes when zooming or panning. For a 3D vessel, this allows the user to see inside to interior rings and pipes. It also can be used to make things run faster by reducing the complexity of the rendered image.

All features of the 3D-pipe view can be modified during the transient or replay.

2.2 tkXMGR5 Graphing

Three significant upgrades have been made to XMGR5 the plotting program, now called tkXMGR5. It can now run locally on MS-Windows, without the need for an X-Windows client. The other upgrades are new features that work under both Unix and MS-Windows, namely the self-renewing plot capability and the point and click plot feature.

The upgrade to XMGR5 allows tkXMGR5 to run locally under both *MS-Windows* and Unix operating systems with one unified source. This means that it runs from a DOS prompt or Windows shortcut on MS-Windows platforms. It does not use an X-term emulator and therefore can interact naturally with MS-Windows. This was accomplished by porting the X-Windows interface to Tcl/Tk.

The *point and click plot* feature allows users to bring up a configurable postage-stamp sized plot for volume or junction by placing the cursor over it and right-clicking the mouse. The user then selects a variable from a scroll-down list. The resulting plot is a fully functional tkXMGR5 plot configured for minimal size without visible toolbars and menus. The plot appears next to the selected node. However, the user can resize it, place it anywhere on the desktop, and/or re-enable its menus and hot keys. See Figure 2.2. Multiple point-and-click plots may be displayed simultaneously.

The *self-renewing plot* feature means that the tkXMGR5 point and click plots are dynamic during a transient calculation. Upon initial display, a Point and Click plot retrieves all available data from the plot file for initial display, with all dynamic updates adding to this data. The parameter plot curve and the x- and y-scales automatically adjust as the RELAP5-3D transient calculation advances and makes more data available. However, for replay, the plots use all the data from the restart-plot file.

2.3 User Annotation on Screen

Users can now annotate the 3D screen for the purpose of identifying the model, parts of the system, the transient being simulated, etc. The annotation is activated with the “A” toolbar button followed by clicking the mouse button in the isometric display area. Text can be modified or repositioned at any time. See Figure 2.2.

The annotation feature introduces a new concept and way of working to the isometric image screen; it is called an operational mode. When user annotation is started, the user enters a new mode of operation in which the normal usage of the mouse is overridden by the bindings of the annotate feature. For example, when in annotate mode, the left mouse button click will place a text box on the isometric image only.

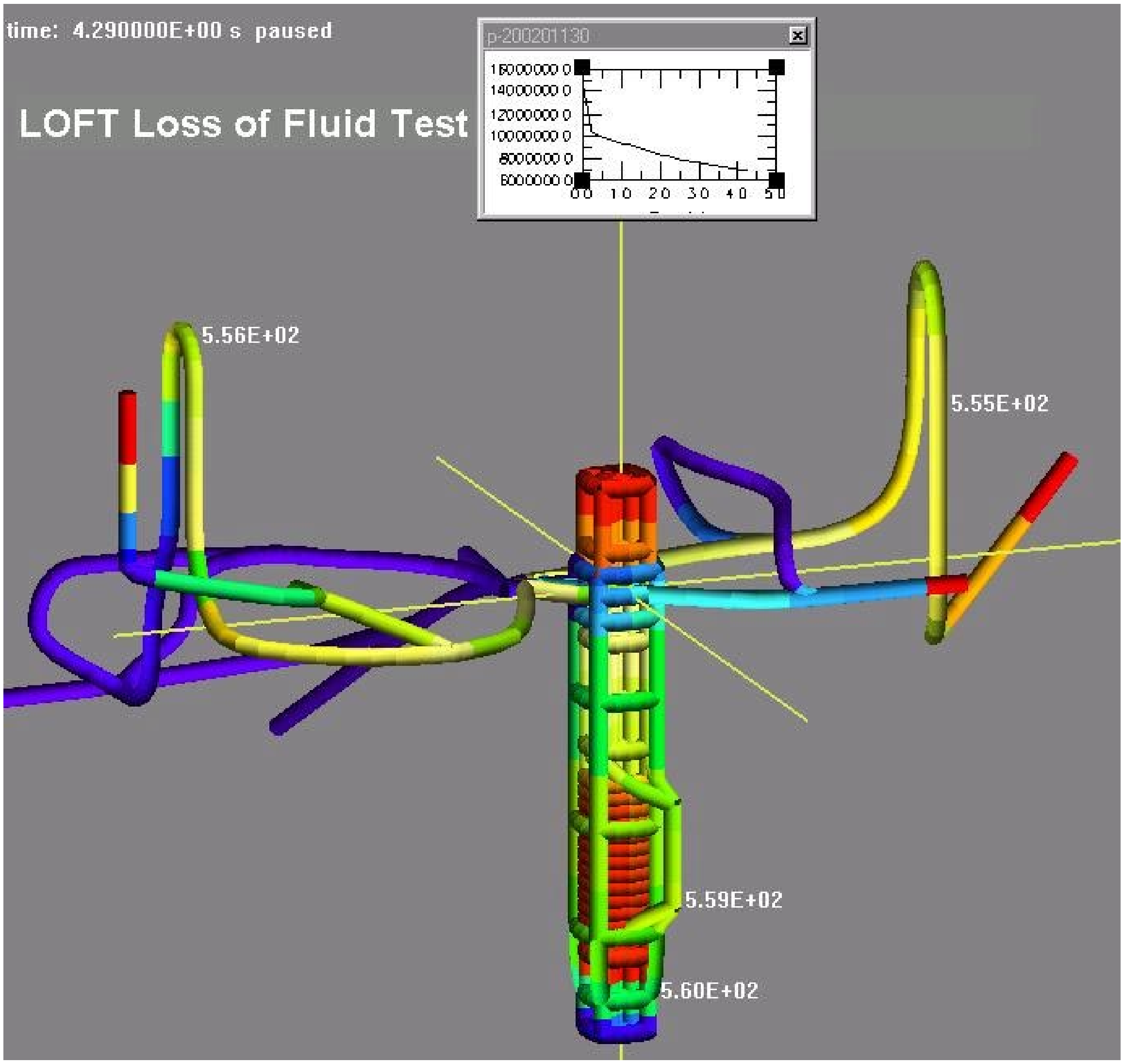

Figure 2.2 LOFT model with 3D Pipe color map of void fraction, user annotation, point and click plot, and display node selection.

2.4 Miscellaneous Improvements

Numerous improvements and error corrections were in the areas of functionality, documentation, ergonomics. Some of the more important ones are summarized here.

RGUI was ported to *Hewlett-Packard* Unix workstations. "*Select Display Node*" was added to the decimate dialog; it allows precise selection of nodes to display numerical values via mouse clicking through a new decimate feature; see Figure 2.2. Help button documentation was expanded to incorporate explanations of the new features. It also reflects upgrades to existing features.

Ergonomic improvements reduce the user's learning curve, enhance their understanding of how to accomplish things and generally make the interface more intuitive. More buttons were added to the isometric image toolbar, more intuitive icons were devised for them, and they were regrouped by functionality. The isometric image Hot Keys were remapped to be more mnemonic. With the introduction of operational modes on the isometric image screen, namely Normal, Select Display Node, and Annotation, the mouse cursor was made to change with the mode to help the user recognize the mode in use. This idea is borrowed from an industry standard in paint and draw programs

User conveniences make it easier and quicker for a user to accomplish a task or to do so with less chance of error. All dialogs now have default "OK" buttons that activate when the Return/Enter key is pressed. Replay and Rerun buttons were added to the RELAP5-3D Run Options. The default input model has been improved.

3. Value of RGUI

The greatest impact of RGUI on the RELAP5-3D program and user community will not be making the data easier to access or increasing the effectiveness of code users, although it does that. Rather it will be in three other areas: accessibility of RELAP5-3D to users, adaptation of RELAP5-3D to new trends in the computing industry, and incorporation of new and old capabilities into what will be perceived as RELAP5-3D. The first two of these last three items are examined in Sections 3.2 accessibility and changing trends. Incorporation and functional synthesis is covered in Section 3.3. Current usage of RGUI 1.2, with actual examples of how effective and helpful RGUI has been, is presented in Section 3.1.

3.1 Current usage of RGUI

Users of both RELAP5-3D and ATHENA [16], particularly new users, are employing RGUI in a variety of ways. Some of these are listed below. They are grouped according to the 3 basic categories above and they are illustrated in subsections 3.1.1 through 3.1.3. Note that these incorporate only the currently available features, not those under development.

Input model building

- Immediately create a visualization of the input model specified in the input file.
- Reveal connectivity errors in input models.
- Create 3D nodalization diagrams from an input file for its input model.
- Immediately generate "3D-pipe" pictures of plant models in wireframe or solid surface pipes for a plant model.

Transient Aid

- Numerical display of key variables (minor edit quantities) on the 3D picture of the plant model.
- Color map display of key variables (minor edit quantities) on the 3D pipe picture of the plant model (wireframe or solid surface).

- Display of one, two or three key variables simultaneously per location on the 3D-pipe view of the plant model.
- Create self-renewing xy-plots of key variables vs time.
- Control a transient calculation in a way similar to the NPA.
- Navigate within the picture to zoom in on a key area to observe.
- Save views for later resumption of work.

Post-Processing

- Replay whole transients or portions of transients much faster.
- Create xy-plots of data calculated in the transient.

With the above-listed features, and a host of user conveniences, many users are finding that it is easier to run RELAP5-3D through RGUI than via other methods. Others have reported efficiencies in spotting modeling errors and locating variable values quickly. In the following sections, examples of RGUI usage are given.

3.1.1 Input Modeling

The most common type of modeling error plaguing RELAP5 users today is the "cut-and-paste" error. This involves the "reuse" of a component from another input model that has already been translated into RELAP5 input format. The relevant lines of the file, "cards," are copied from the first input file, "deck," and pasted into the second. The lines are then modified to refer to the appropriate volumes, junctions, heat structures, etc. When it works properly, it saves a lot of time. However, when it fails, it can take several days or sometimes a week to find.

The problem with cutting and pasting is that it is possible to misconnect the borrowed component in various ways. One example involves an ATHENA user from the fusion program who connected a borrowed component upside down. This lead to ridiculous results and the error was very hard to find. In fact, it was not found until the "deck" was sent to the INEEL for review. Another involved a borrowed component that was connected at the wrong volume within the component and caused minimal time steps.

Both errors were found through visualization of the plant model with RGUI. In both cases, the error was immediately obvious when the node numbers were displayed. This powerful capability alone makes RGUI valuable to thermal hydraulic analysts.

A second use in input modeling is to create a nodalization diagram for a plant model that does not have one. These situations arise for various reasons, but most frequently result from an input file between transmitted from one installation to another. RGUI has been used on several occasions to create nodalization diagrams for users. Once, the request came from a user in France and the diagram was printed and faxed. However, it is much better when viewed on screen where the stick-figure can be rotated and zoomed.

3.1.2 Transient Analysis

Two useful features are the 3D data visualization and self-renewing plots. It is very difficult to access, organize and visualize data in 3D regions without a graphical view. RGUI can display the data either numerically, via a color map, or both simultaneously and easily. The self-renewing plots allow the user to select XY-plots at various points in the region to monitor the progress of key quantities. The plots can be resized and moved to wherever is convenient.

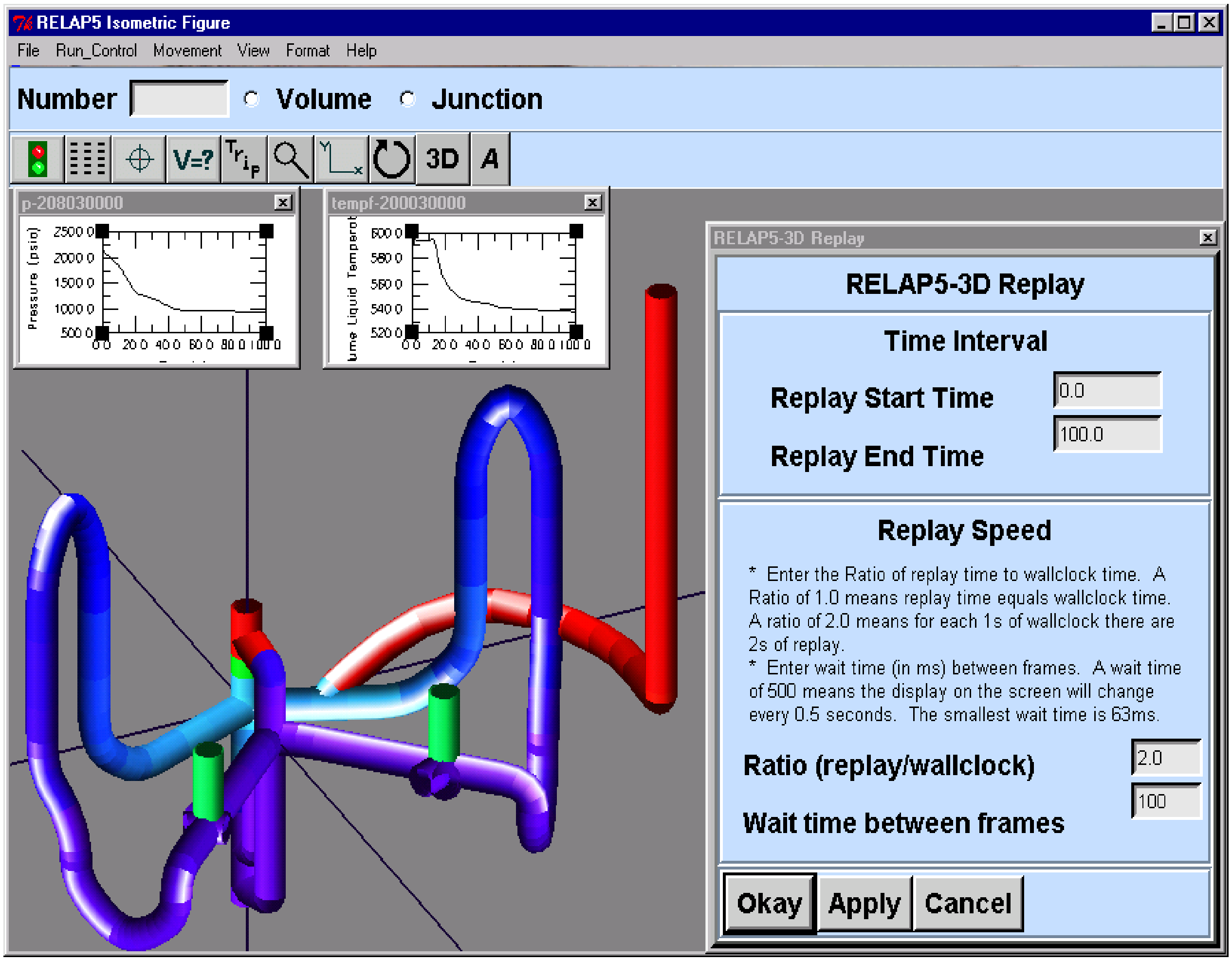

Figure 3.1 Replay of Typical PWR with a color map of void fraction and point and click plots of pressure and liquid temperature

3.1.3 Post-Processing

Two post-processing features of RGUI are replay and XY-plots. Replay allows the user to review the calculation at any time and speed without watching the whole transient; see Figure 3.1. XY-plots allow the user to represent multitudinous data curves on a single and even have many such plots all available through RGUI. Neither feature requires the additional post-processing of the restart-plot file; the restart-plot file is accessed directly and quickly.

3.2 Accessibility and changing trends in computing

Among the most important reasons for creating RGUI is to make RELAP5-3D accessible to a broader group of people than currently use it. This group includes the class of new, young nuclear scientists and engineers, the management of organizations that currently or in the future will use RELAP5-3D and those in industries outside the nuclear field. There are myriad ways that RGUI can benefit RELAP5 with respect to these groups. It helps them see how it can be useful to them and helps them learn how to use it.

In general, a GUI makes the program easier to access and start. It provides quick and easy access to documentation through multiple help features. It aids users in visualizing the results of their calculations, and can provide more means of displaying the results. Through combining symbols, colors and text, it aids users in recognizing a feature or capability and intuitively understanding its function. The use of industry standard organization of menu, tool bar, and mouse-maneuvers provides the users with a sense of familiarity with the software.

Now the three groups of people listed above will be considered in order. The first group, who will benefit from RGUI, are new young entrants to the nuclear field. With the prevalence of visual operating systems and GUI-equipped applications, both in the homes and classrooms, recent and future graduates have only been trained with visual software. In fact, many younger users disdain and are actually illiterate of command line style operating systems and non-visual application software.

Those who have graduated since the since the advent of personal computers equipped with windows operating systems (Windows-NT, 95, 98 and Macintosh) have known little else in the schools and homes than these kinds of visually-oriented operating systems. They have little or no experience with computer software that does not have a graphical interface. Most of such experience is likely to have come from writing “toy” programs for academic assignments. They have come to expect and demand a graphical interface and equate professional software with such. Not only do they expect and demand an effective GUI, they also expect the GUI to continually be enhanced with advances in methods of presentation and software interaction.

For these recent graduates who enter the nuclear field, such as the FY2000 summer students at the INEEL, it is culture shock for them when first exposed to Unix operating systems and application software that runs from a command line prompt without displaying anything. The shock is compounded when a RELAP5-3D expert then takes the output of the completed run and feeds it to a completely separate application to draw an XY-plot. That seems as old and outdated to them as vacuum tubes and cardpunches seem to the current generation of nuclear scientists and engineers.

However, it is not just the promising next generation that must be considered. The people, who make decisions on the funding and the tools we use in the trade, bear greater consideration. With some exceptions, managers and planners throughout the world are migrating computing environments to computer platforms primarily on the basis of cost and compatibility. These platforms come equipped with windows style operating systems and readily exchange information with a variety of application software written for these operating systems.

With these platforms in hand, the decision-makers usually choose site-wide application software packages for such purposes as word-processing, email, and databases. The chosen software seldom runs on the scientific compute platforms because the vendors do not make the applications available on those platforms. These decisions impact the scientific computing community in numerous ways, such as reduction in computing services and difficulty in purchasing new scientific workstations and software.

The trend established by these decisions is clear. RELAP5-3D and other scientific software must be prepared for use on these MS-windows type platforms. RGUI helps do this by providing compatibility with the O/S and application software and supporting the native look and feel. The print feature allows graphics output that can be imported into most word processors. The improved XMGR5 will generate plots on both MS-Windows and Unix platforms. The isometric image itself makes it possible to display the results of RELAP5-3D calculations visually to the decision-makers, regardless of the hosting computer platform.

Finally, there are those who would apply RELAP5-3D to uses other than nuclear power plant safety analysis. It is far easier for them to learn to use RELAP-3D through a graphical interface than through extensive training courses and study of the RELAP5-3D manuals. For these other markets, a GUI is necessary to generate interest and then to respond to their unique needs as they arise.

However, after all these points are made, one final fact must be considered. Most of the usage of RELAP5-3D today is on Unix operating systems and without a GUI. This will remain so for a while, but that will change due to the above-mentioned market forces and the tide of young talent as it enters the field. Therefore, it is necessary to both establish and maintain an effective GUI and support both Unix and windows style operating system compatibility

3.3 Incorporation of capabilities and functional synthesis

Another value of a graphical user interface is the incorporation of capabilities into a software package and thr subsequent synthesis of functionality into a greater and more useful whole. The users of the application are frequently the visionaries who drive these improvements.

Consider a text editor as an example. A text editor is a program that modifies text files and need not have a GUI. The popular Unix "vi" editor is a perfect example. It displays lines of a file on the screen and responds to keyboard sequences to perform editing. In contrast is MS Word; it is a combination of GUI and an underlying text program, but no one thinks of it that way.

Unix provides a separate non-graphical tool for spell checking. However, in early versions of MS Word, spell checking was incorporated into the software package through a GUI menu called "utilities." It was more convenient to access these capabilities from within the editor than as a separate application. However, having it available within the editor package lead to synthesis and further inventions. Now, spell checking is always on by default and a misspelled word is immediately flagged via special underlining. An invention that followed was grammar checking, still not available in Unix to my knowledge. This also underwent a synthesis and is now automatically on by default also.

This incorporation and functional synthesis is very important in the development process of any software package. It is already well underway in RGUI. One example is the XY-plot capability. As discussed in Section 2, XMGR5 was integrated through RGUI to the RELAP5-3D package. It was modified to do point-and-click plotting which means the user can request a node and a variable with the mouse and immediately have a plot of the quantity at that point! The user does not have to go through the tedious process of selecting the kind of data, name of data file, and other dialogs. This is a true functional synthesis and was devised by users who envisioned short cutting the process.

Another example of incorporation has been replay. Replay runs RELAP5-3D and places the relevant data into RELAP5-3D's memory locations directly from the random-access restart-plot file. This allows the user to run RELAP5-3D from RGUI and immediately run a replay from the "Run Options screen" without ever leaving RGUI. A suggestion has already been logged to be able to run the replay from the isometric image screen. That would be another level of synthesis.

Plans for future incorporations include PYGMALION and an input model and deck generator.

4. Features in the version 1.3

Version 1.3 will include some very important and popular capabilities. Some are already installed in newer developmental versions. These capabilities include enhanced printing, balloon help, PYGMALION, and isometric image modifier.

In versions prior to 1.3, RGUI "prints" by writing a post-script file. The print capability can print to an actual printer to produce hard copies. It can also create a JPEG file rather than a post-script file. This means that isometric images and XY-plots can be imported to other applications, such as word processors or desktop publishers, for use in creating reports and technical papers. This printing capability is available from both the isometric image, and tkXMGR5 screens. The 3D Station has a similar print capability, but a text file is produced rather than a JPEG file. Figure 2.2 illustrates the print JPEG feature.

Balloon help puts a small window just below and to the right of an icon. The window contains a short description of the function that is invoked when the button is clicked. This feature activates 1 second after the cursor enters the button unless it leaves in less time than that. The feature can be deactivated.

PYGMALION is an old program that takes as input a RELAP5 restart-plot file that has been run to steady-state and its input file and produces a new input file with the steady-state conditions. This makes a convenient starting place for constructing new input files that model operational transients or accident scenarios. It had not been maintained for years and recent work has corrected many machine dependencies. Also, a GUI front end has been written for it. It will be accessible from the 3D Station.

The isometric image modifier will allow the user to adjust the picture presented on the isometric image screen through a mouse and dialog system. The user will be able to move whole components or individual nodes. This is necessary to separate channels that otherwise overlap on the screen image. The adjusted image can be written in terms of RELAP5-3D input lines (cards) and saved on a file for future inclusion in the input file that generated the original picture.

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