Process Visualization for Real-Time Applications

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1 Abstract

This document describes a new solution to the problem of visualizing real-time data. Nowadays field-bus systems are used to connect actors, sensors and monitoring computers. A new time-triggered field-bus system was been developed. Therefore a visualisation software was designed and implemented. This software implements some innovative features. These key features are multi-instruments for displaying several values in one virtual instrument, histories for displaying old and actual data at the same time, and redundant visualization. Easy and intuitive interaction and the regard for human perception resulted in an innovative piece of software.

Keywords: process visualization, real-time applications

2 Introduction

Since the early beginning of the industry time data of technical processes have been visualized and monitored using traditional, analog instruments. Later digital instruments were used and finally, computers are increasingly used to visualize processes. So process visualization is the visualization of data from technical processes and is therefore a sub-field of information visualization, but it is much older.

In recent years sensors and actors of processes are connected by a field bus. Also computers, which provide a monitoring facility, are connected to this field bus. Those field bus systems can be found in factories, power plants, aeroplanes, cars, buildings, etc.

In modern cars there is a need for connecting many actors, sensors and display elements. These connections have to be reliable, redundanat, fast and not too expensive. For these requirements a new field bus system was developed by the company TTTech from Vienna. This field bus is called "TTP" (Time Triggered Protocol) and follows the time triggered approach.

In other field bus systems source and destination of a message are addressed by a binary-coded address, which is a part of the message. In the TTP source and destination of a transfer are no longer recognized by an address but by the exactly occurrance in time. So the TTP avoids the overhead of transfering addresses with each message and has therefore a lower latency, which is important for example for implementing an ABS. The TTP is also designed as a multi-redundant system.

This field bus was too new to be sopported by the leading visualization tools or libraries, so visualization software was missing. So we designed and implemented a new visalization software in cooperation with the company Imagination (Vienna).

In the following sections we describe the state of the art (which products are on the market), the special requirements for visualization of real-time data (regard for human perception, redundancy, interaction, etc.), new extensions to process visualization (how we implemented the design requirements using virtual instruments), the implementation and evaluation of the software (application context, operating system, usability) and what future work we will do.

3 State of the Art

In the past data of technical processes have been visualized and monitored using traditional, analog or digital instruments. Nowadays process visualization is done by computers in software.

There are a lot of software tools available, offering a comfortable and intuitive way of process visualization. Existing software can be divided into three groups. The first, libraries of virtual instruments (VI), can be used in a user developed application. The second group consists of process visualization applications which offer a fully fledged visualization environment. The third group contains software for process visualization and process steering.

The first group, instrument libraries, is dominated by two products, which can be configured freely according to user needs (color, size, scale configuration, needle art etc.). The first is Global Majic Software Inc. [3] instrument library. This library consists of various instruments, that can be included in an user developed application. The second library is Real-Time Graphics Tools from Quinn-Curtis Inc. [6].

The second group, process visualization applications, is dominated by two products as well. The mostly spread monitoring tool worldwide is LabVIEW System from National Instruments [4]. The whole monitoring is done using VIs which are used instead of conventional instruments like gauges, LED displays, etc. Large libraries with several hundreds of VIs are available, and user can choose appropriate instrument. This system is missing dynamic configuration, it is not possible to configure views during run-time. The second largest provider in this field is V. I. Corporation and Data Views [2] system with more than 25.000 installed copies world-wide. It is used by major institutes and companies just as LabVIEW is. The dynamic configuration feature is missing here as well.

The software of the third group contains the most functionality from the first two groups, and the additional features used for process steering. Because this kind of software concentrates on the steering part it does not provide any better visualization facilities.

4 Special Requirements of Real-Time Process Visualization

The greatest problem in real-time visualization is the large amount of data which has to be displayed in time. Therefore runtime-performance is very important [7]. We use virtual instruments to visualize data. These instruments look like real-world instruments and so they can easily be recognized and used intuitively by the user. These virtual instruments must be able to be arranged freely and configured dynamically. In the following sections we describe the importance of regard for human perception, the displaying of old and new data at the same time, the functionality of multi-instruments and the need of scales and labels.

4.1 Human Perception

In real-time visualization it is very important to have regard for human perception since it is necessary that the user interprets the data correctly and recognizes critical situations in time. Therefore some special aspects of human perception should be mentioned.

The human eye focusses a round area with a limited diameter (of approximately 4 cm). So important information should be placed rather near this range [1]. Values which are displayed left are usually estimated to be more important than those displayed right [1]. Usually it is easier to quantify sectors of the full circle than portions of a bar. [5]. Pictures are recognized faster and more easily than alphanumerics [2]. The colors used by the system have to be chosen very carefully. They must guaranty the best perception. So the saturation must not be to high and they must differ in hue from each other as much as possible.

4.2 Visualization of Old Data

We call the values which have occured some time before the history of a value. These older values are of great interest because you can recognize changes and trends. We used rectangles resp. triangles which fade to the background for displaying those histories.
So the display colors must have enough saturation for displaying older values in colors fading to the background color.

4.3 Multi-Instruments

One of the features is the possibility to create multi-instruments. Those multi-instruments are designed to visualize different values at the same time. Those multi-instruments are necessary for comparing values especially in redundant systems.

4.4 Redundant Visualization

Whenever important information has to be visualized, using redundant display methods are a good idea to help the user interpreting the visualized information correctly. So redundant visualization should be done whereever it does not waste too much space. For this reason we used color-assignment for showing which numeric displays are belonging to which value.

4.5 Scales and Labels

Because the values change fast, the user is not able to read each value on a numeric display. The display technics of virtual instruments like needles or bars can be followed fast by the user but they give no exact representation of the value. So the user needs more help in form of a grid or scale to read the exact value from needles or bars also.
Those scales have minor lines and major lines. Major lines are a little bit longer than minor lines and have a label showing the numeric value.
Because of the small focus of the human eye we decided to display numeric values nearby the moving display item, for example at the end of the needle of a gauge.
But if the needle moves too fast the user is unable to read the "jumping" numeric display. So we tried to find a compromise between readability and correct position.
Now we calculate a slower movement, which means less positions per time, for the moving numeric displays.
The developed algorithm covers also another problem, the problem of overlapping displays. Now the numeric displays are arranged in a manner, that they do not overlap and not move too fast or too frequent.

4.6 Red Ranges

In real time applications values often have ranges, which should not be reached during normal operation. If these red ranges are reached, the user has to recognize this immediately. Therefore these ranges must be represented in a special manner.

4.7 Hard Limits

Similar to the red ranges described above there are also hard limits. These hard limit are values which cannot be reached when the system is working correctly. If they are reached there is a system-failure or a misconfiguration of the system.
If those hard limits are overrided, the user gets a warning and a special sign on the instrument where the value should be displayed.

4.8 Interaction

The interaction with visualization software for real-time data has to be intuitive, because the user has no possibility to stop the application for reading instructions or even a manual. Because of this reason, also all configuration must be able to be done at run-time.

5 New Extensions to Process Visualization

The result of the state of the art analysis was, that a new software has to be developed to reach the design goals. In the following section we describe the new extensions to process visualization we implemented.

5.1 Bar and Multi-Bar

The bar is a simple rectangle which changes its height or width according to the value to display. The bar is the standard visualization instrument. Figure 1 shows three examples of the bar. The left-most shows an simple standard bar with the "bullet" and the actual value display. In the middle there is a bar with the "history" mentioned above. You can recognize older values by lighter and smaller rectangles. The right-most example shows a multibar, the multi-instrument version of the bar. You now recognize the importance of the brown "bullet" showing the actual value of the brown bar. This is an screen-shot of a fast moving multi-bar, so the actual value displays are not exactly at the same height as the bars.

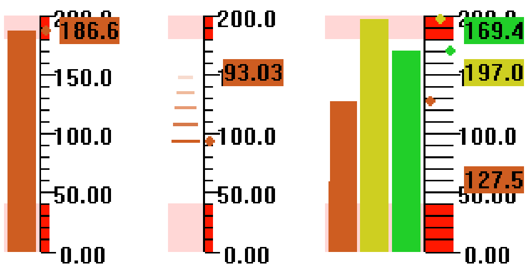

Figure 1: simple bar, history bar, multi bar.

5.2 Gauge and Muli-Gauge

The so called gauge is a round instrument which looks like a tachometer. It has a kind of needle which changes its orientation according to the value it has to display. Figure 2 shows two example gauges.
The left one is a simple gauge showing his value with the needle, the bullet and the numeric display. The red ranges are implemented as red and pink sectors.
The right one shows the multi-instrument version with history. The history is

implement as little triangles following the needle like a tail. Those triangles fade to the background as in the barinstrument.

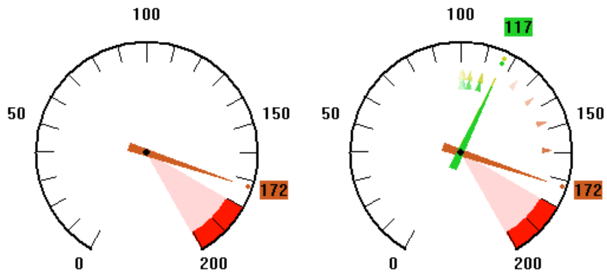

Figure 2: simple gauge, multi history gauge.

5.3 Trace

The trace is a instrument which memorizes many time-value pairs and prints it down just like a oszillograph. So it looks like a pen drawing the value on paper by time. Figure 3 shows an example of this instrument. The scale, red ranges, numeric displays are implemented as in the barinstrument.

Figure 3: trace displaying two values.

5.4 LEDs

In this instrument a value equal to zero is displayed as an off-LED and a value different from zero is displayed as an on-LED.

5.5 Icons

This Instrument shows predefined Pictures for values. So the user can choose an image for each possible value. This is often used for displaying status information.

6 Implementation and Evaluation

For the TTP a visualization tool has to be developed. This tool communicates over a device driver with an standard ethernet controller. This ethernet controller communicates with a monitoring node installed in the field bus system. So the tool runs on every PC, where the special device driver is installed. The whole status of the field bus is stored in a shared memory in the PC using the monitoring node and and the ethernet connection. This shared memory can be accessed by the visualization tool to get the desired data of the field bus.

Because of the existing driver for Windows NT, the visualization tool was developed with MS Visual C++ under Windows NT. This Windows NT Application consists mainly of two section. The first section consist of the data sources, which are represented in a hierarchical tree. So each data source has its place in this tree. There are several structures of tree elements. So you can choose whether the data sources (they are called messages) are grouped by frame (this is the smallest data unit transported by this field bus) or by slot and so on. There are five different grouping possibilities. The second section is the display section. Here the virtual instruments described above are created, configured and displayed.

The interaction of the system consists mainly of two main parts. The first consists of configuring the system. This is done by dragging data sources onto the view. Then the user can change the position and the properties of the so created instrument. The second consists of monitoring the hardware system. This is mainly done by switching between views.

In the phase of testing the software tool, we had the possibility of evaluating, whether the software meets the design requirements, we have found out before. The test phase showed us, that the implemented tool was easy to use, because the user is able to create a virtual view in a few second by draging and dropping all desired data sources. Then the system is working already correctly. Now you can configure all instruments at run-time and see the effect immediately.

7 Summary

Process visualization is the visualization of data from technical processes and is therefore a sub-field of information visualization. Today the computer, which does the visualization, is connected with the process over a field bus system. TTTech developed a new field bus, the TTP (Time Triggered Protocol). Because the TTP is not yet supported by visualization tools on the market, a new visalization tool has to be developed.

Therefore we give an overview of the state of the art to have a look at available tools on the market.

We worked out the special design requirements for process visalization, which are mainly regard for human perception, redundancy, performance and intuitive interaction. Perception is the most important aspect, because the user often has to observe complex systems with a large amount of data.

Then we describe the application context, which is a monitoring node connected to a standard-PC running Windows NT, and how we implemented the virtual instruments including the displaying of old values, multi-instruments, redundancy and scales. Virtual instruments are bars, gauges, traces, LEDs and icons.

At the end we evaluated the system and found out, that our solution is a very useful and innovative implementation.

8 Future Work

To improve our software tool there are some features that can be implemented in the future. Visualization in 3D has some advantages, auto arrangements can assist the user. The using of several levels of detail and the technique of focus and context can help the user to obtain a general view at any time.

8.1 2D vs. 3D

In 3D you have all display possibilities as in the real world. You can visualize data corresponding to the origin in the real world. You can even use more different attributes (size, orientation, texture, color, rotation, ...) to visualize values. But in 3D you often have the problem of overlapping, and its not so easy to navigate. In 2D you have the main advantage of fast display rendering and easy navigating with standard input and output devices. But because of the missing dimension you have often to display data in an abstract way.

8.2 Arrangements

It would be nice, if the use does not have to arrange all elements of a visualization software manually. So automatic arrangements based on logical or physical dependencies are desired.

8.3 Levels of detail

To optimize usage of screen space, several levels of details (LOD) are used. One LOD shows only if a value is valid or not. Another LOD shows of which reliability the value has. The next LOD shows the value in its decimal representation. Then there could be displayed a full featured gauge.

8.4 Focus and Context

Especially in real-time applications the user must have an overview of the system at any time, because he must not miss any critical event.
But in most cases there is not enough space to display all data values of the system big enough to read the exact value. So the method of "focus and context" was

developed. With this method you see the item, which has the focus in more detail, and you see its context, maybe less detailed, too. So the overview and detailed information are guarantied at the same time.

8.5 Intelligent projection

The use of special projections to display important information in more detail. A good example are "billboards". Billboards are little 2D display elements which are positioned in a 3D scene, facing exact to the user, independant of the orientation of the 3D model.

9 Conclusion

The main requirements of process visualizations are regard for human perception, redundancy, performance and easy interaction.
Regard for human perception is so important, because the user often has to keep an eye on a complex system. He has to interpret all data correctly and recognize critical situations in time. To ensure that, informations must be displayed redundant, but without wasting display space. Values must be displayed in suiteable colors, at a not too high rate, in the right location.
For displaying really all important data in time, you need a software system with good performance because of the large amount of data.
The interaction with a real-time application must be easy to learn, intuitive and effective, because the user will not have the possibility to stop the system for studying a manual or going through tutorials.

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References

[1] Mei C. Chuah and Stephan G. Eick. Managing software with new visual representations. In *Proceedings 97 Information Visualization*, pages 30–37. IEEE, 1997.

[2] What is dataviews. http://www.pr-wiesbaden.de.products.dv/watisdv.html. DataViews Corp.

[3] Activex controls. http://www.globalmajic.com. Global Majic Software.

[4] Labview. http://www.natinst.com. National Instruments.

[5] Peter Purgathofer and Thomas Grechenig. *uSER iNTERFACE dESIGN, Reader zur Vorlesung.* Vienna University of Technology, 1997.

[6] Real-time graphics tool. http://www.quinn-curtis.com. Quinn-Curtis Inc.

[7] Points to consider. http://www.telsa.hl.com.au/ddvt.htm#Optimal_-performance_1. SL Corp.