Pipeline Measuring Data Design and Realization of Real-time Display System

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Abstract. The measuring data produced by pipeline detector should be first stored then processed and analyzed before being applied in analysis of pipeline defects. The results are commonly expressed in form of graphs so that it is unable to give constant and intuitive display of pipeline defects. According to such situation, it aims at developing the visualization system which can be used in computer to simulate and give real-time display of pipeline’s detection situation, receive and deal with test data sent by the pipeline detector during its operation process, generate and display the simulated three-dimensional pipeline in order to help analysis of pipe wall. The practical application indicates that the system has the characteristics of instantaneity, authenticity, and validity etc., being able to provide demonstrations and reference for construction of other pipeline real-time visualization system.

Introduction

The measuring data will be produced by pipeline detector and be processed and analyzed by specific software and method [1,2]. The results are mainly expressed in form of graphs such as curve graph or scanogram [3]. And some scholars process the measuring data and form image [4]. Through these methods, the accurate analysis results about pipe wall can be obtained. However, the following two aspects are difficult to be satisfied: the first, the defect situation of pipe wall is expressed by numerical logic relationship through graphs, which makes it difficult for us to have intuitive understanding about spatial location of pipeline defects and the degree of defect; the second, instantaneity of pipeline measuring data is difficult to be expressed so that it is impossible to immediately determine whether the current pipe is deficient.

In order to solve the above-mentioned problems, the real-time display system of pipeline measuring data based on MFC framework and C++ programming language is realized; the pipeline measuring data is received and locally cached by User Datagram Protocol(UDP) then be analyzed and processed; Open Graphics Library(OpenGL) technology is adopted to generate real-time three-dimensional emulational pipeline based on the processed measuring data [5-7], and the pipeline will be shown on computer display; carry out dynamic browsing and multi-perspective observation on produced 3D pipeline after pipeline detector stops sending measuring data so as to help analysis of pipeline defects.

Design and Realization

The real-time display system of pipeline measuring data belongs to information visualization software. The system is realized by MFC framework and C++ programming language and the pipeline is generated and displayed by adoption of OpenGL technology. The display system is mainly divided into three modules: measuring data receiving module, measuring data processing module and 3D pipeline display module; the overall structure is shown in Figure 1, the core function of system is shown in Figure 2. The measuring data receiving module is used to receive pipeline measuring data transmit by UDP; the measuring data processing module realizes processing algorithm of measuring data 3D pipeline display module is responsible for generation and display of pipeline. Key problems of real-time display system are as follows:
(1) Acquisition of measuring data;
(2) Analysis of measuring data;
(3) Measuring Data processing;
(4) 3D pipeline Generation method;
(5) Pipeline photorealistic rendering.

**Figure 1.** Overall structure diagram of real-time display system.

**Figure 2.** System core function diagram.

**Acquisition of Measuring Data**

In order that the local computer which operates the pipeline display system can quickly receive the data sent by pipeline detector, the UDP is adopted to transmit measuring data. The main process is: to establish UDP inter-linkage before operate the detector; to store the measuring data in local buffer during operate the detector; to close the UDP link when detector stops operation or the measuring data is completely sent.

Establishment of instantiation objects through CUdpSocket, to store the data transmitted by UDP in computer buffer, to save the data in buffer at tail of buffering queue in order, the buffer queue is stored by adoption of vector-type instantiation variable objects; a part of the measuring data to be processed is taken out at one time from head of queue for processing. This part of data will produce a part of pipeline and the head of queue will point to next portion of measuring data to be processed. The measuring data in buffering queue will be processed in such circular way until the queue becomes empty.

**Analysis of Measuring Data**

Work sketch map of detector in pipeline is shown in Figure 3. The detector totally has three types of sensors: detective sensor (probe for short), mileage sensor and offset sensor. All of them are able to produce measuring data. There are a number of detectors evenly arranged in circle by circle center overlapping with circle center of pipe wall. When the pipeline detector runs along the heading direction, data set produced by detector is the data of one pipe circle at current location.
The mileage sensor and offset sensor are respectively used to record operational mileage of detector and rotational offset of detector in pipeline. Three types of data are included in the measuring data, as shown in Figure 4.

**Figure 3. Sketch map detector’s working principle.**

**Figure 4. Composition diagrams of pipeline measuring data.**

**Processing of Measuring Data**

With regard to measuring data, multiple groups of data produced by each detector will wave because of embossment or sunken of pipe wall in detector operation process. However, the wave data will be based on a base value (basic value for short), which plays a key role in future calculation of pipeline defects. Estimation the basic value of each detector by Ransac algorithm (random sample consensus) and average value method to work out basic value data. Parameter value of Ransac algorithm is obtained from experiment and it also can be set in system. The basic value is obtained at the end of algorithm iteration. The basic value worked out on basis of Ransac algorithm will be affected by parameter values. In order to prevent unexpected error value, average value of multiple groups of data is compared with the basic value obtained from algorithm. Result of Ransac algorithm should be adopted if within certain range of threshold; otherwise, the average value will be taken as basic value. Based on the given basic value and sensing value of detector, difference value between sensing value and basic value is obtained (with positive and negative differences). The unified adjustment is carried out by dividing the difference value with specific proportionality coefficient. Based on size of relative value, the sunken (negative value) and embossment degree (positive value) of pipe wall is determined so as to provide generated data for future 3D simulation.
With regard to mileage data, when the pipeline detector moves forward in the pipeline, numerical value size of multiple groups of data presents periodicity, see Figure 5, which can be used to judge whether the pipe detector moves forward based on the maximum value or minimum value provided within certain scope of data groups selected.

![Figure 5. Sketch map of mileage data characteristics.](image)

The process is: comparing a group of mileage data with maximum and minimum value from beginning, when a certain value is bigger than maximum value or smaller than minimum value, marks of maximum value and minimum value being respectively 1 and 0. If both maximum value and minimum value arrive at location of 1, it indicates there is a half cycle. If there is more than a half cycle of change in mileage sensor, it is deemed as the pipeline detector moving forward. Besides, on basis that whether the extremum of last time is maximum value or minimum value, the location of mark will be put back to 0 for judgement of next time. As shown in Figure 6.

![Figure 6. Judgement method diagram.](image)

With regard to offset data, its initial value is used to judge rotational state of pipe detector. When there is change in data sent back by rotational offset sensor, the offset is calculated by dividing the initial value with cycle so as to judge whether there is rotational offset happening. If there is offset, the detector will change the original position but the detector data can be corrected to original position through offset amount.

### Generation Method of 3D Pipeline

Three-dimensional objects can be constructed through face model-based, volume model-based and hybrid model-based method. As the pipe is hollow in middle and the pipe detection pays more attention to defects of pipe wall, the volume model-based construction method is not suitable for construction of 3D pipeline. Some scholars take curve or surface as element to construct three-dimensional pipeline [8,9]; therefore, it belongs to face model-based construction method. There is another method which forms 3D pipeline by stretching or rotating the basic graphics provided by 3D software [10]. This system adopts face model-based method to construct pipeline.

The generation method of emulational 3D pipeline adopts GL_LINE_LOOP provided by OpenGL. OpenGL constructs the spatial model by connecting the three points which constitute the pipeline together and forming a triangular patch through adoption of GL_LINE_LOOP method. The emulational 3D pipeline is made up of these triangular patches.
After the base value processing of detector data, the relative value which is higher (embossment) or lower (sunken) than pipeline semi-diameter is obtained. The practical value of pipeline semi-diameter is obtained by adding the relative value to standard pipeline semi-diameter. Then by decomposing the practical pipeline semi-diameter along the X direction and Y direction, X and Y coordinate values of spatial model constructed in OpenGL is obtained but the Z coordinate value is mileage of pipeline detector. In this way, the space coordinates used to generate pipeline points are obtained.

When the detector is judged to move forward based on mileage data, the adjacent two groups of detector data is used to work out spatial points and generate triangular patch. The procedure is as follows:

1. The initial point, namely first point of group n data is taken as the starting point of triangular patch; the second point of group n is regarded as second point of triangular patch; the second point of group n+1 detector data is taken as third point of triangular patch. In this way, a complete triangular patch is formed;

2. The second point of group n+1 data is taken as first point of triangular patch; the first point of group n+1 data is adopted as second point of triangular patch; the first point of group n data is regarded as third point of triangular patch. In this way, a complete triangular patch is generated;

3. The second point of group n data is taken as initial point of first step to implement the process of first and second steps until total completion of implementing the whole group data;

4. The first point of group n+1 data is taken as initial point of first step to implement process of first, second and third step until the detector stops moving forward or it stops sending measuring data. The generation method of triangular patch is shown in Figure 7.

Pipeline Photorealistic Rendering

Visual effect of three-dimensional pipeline made up of triangular patch is triangular mesh structure. In order to achieve better realistic effect of generated pipeline, firstly the OpenGL is utilized to fill color of produced triangular patch, calculate normal vector of each triangular patch and add material effect for each triangular patch. At last, by providing space lighting, the effect of pipeline is more close to real effect.
Computational Results and Conclusion

The 3D pipeline real-time display system is adopted to participate in pipeline detection project of certain company so as to verify the effect of real-time generation pipeline. Each group of pipeline detectors send 106 measuring data which include 104 detector data, one mileage data and offset data. The measuring data is received through UDP and it is able to carry out multi-perspective browsing and internal and external playback of dynamic condition of pipeline after generation. The operating interface of this system and generated pipeline effect are shown in Figure 8.

![Figure 8. System operating effect picture and real-time generation of realistic-effect pipeline.](image)

The 3D pipeline real-time display system has realized visualization of pipeline measuring data so that the pipeline measuring data can have an intuitive and real-time display, which has characteristic of practicability, authenticity and scientific. It has facilitated the relevant personnel’s detection and maintenance of pipeline.

References