Enabling Engineering Document in Mobile Computing Environment

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Abstract

A multi-level hierarchical content organization and on-demand delivery framework is presented in this paper. This framework enables engineering content representation and exchange in Mobile Computing Environment. Engineering documents generated by CAD/EDA software are transformed into XML based vector graphics format, decomposed and organized into a semantically grouped hierarchical structure. The client selectively can download and render the decomposed contents based on various rules. The evaluation shows that the proposed framework increases the reliability of content exchange and improves the user-application experience.

1. Introduction and Related Work

The mobile technologies and computing models are changing the traditional business operations and practices. They enable working-on-the-go and facilitate engineering processes such as manufacturing mobility as well [1] [2]. However, limitations are presented too. Mobile devices usually have insufficient computational and visualization capability. The bandwidth of wireless communication is limited and the connection may be intermittent because of interference or obstacle.

Typically, an engineering document generated by engineering processes carries a large amount of information [3] [4]. The limitations of mobile computing pose challenges on processing engineering documents in the mobile computing environment. The challenges present in two ways: the operation might be interrupted due to low and unstable connection because of the long duration of transmission; the visualization on mobile may unbearable because of long time rendering and small viewable area.

This paper presents our study on engineering field service automation applications that involve in large amounts of data transmission and representation. The objective is to create a multi-level graphics modeling, representation and delivery framework. 2D engineering graphics organization and delivery are focused in our research. This concept can be extended to 3D engineering graphics and multimedia content as well.

Content optimization and organization is not a new research field. Hierarchical representation [5], server based computing [6] [7], and content adapting [8] [5] are the most commonly used methods in the fixed computing environment. However, there are very few research works which focus on processing large amount of engineering data in mobile computing environment. Existed mythologies are not optimized for representing and transmitting engineering content in mobile computing environment.

2. 2D Graphics Decomposition and Hierarchical Content Representation

Single large 2D graphics file requires delivering at once over connection and loading all the graphic contents into the device's memory. This process subjects to the bandwidth and computational capability of the mobile computing environment. To solve the problems, a multi-level 2D graphics representation model is introduced. The essential concept of this model is to decompose large content file into different levels and details while to maintain a hierarchical tree structure of content. The content are delivered to and rendered on mobile client in an on demand fashion.

Based on the properties and syntaxes of 2D graphics content, primitives with similar properties can be extracted and separated into different files. This process is defined as graphics decomposition. We use a three level graphics representation mechanism to represent the decomposed contents. Firstly, Common properties including name space, description, coordinate system, etc., are extracted. They constitute the top level graphics description file or the 'Root'. Secondly, Graphics views, profiles, blocks, and graphics objects (such as image, symbol, marker and graphics components etc) are extracted as Level 1 contents. Finally, Detail Graphic Primitives, Annotations, Dimensions, Primitive Groups, and Text etc. are extracted and Level 2 contents are formed. Criteria for decomposition can be based on primitive type, region of interest, pre-defined templates, and even user selection.

2D graphics decomposition follows the tree structure which is shown in figure 1. In the figure, GN represents a graphics domain which is a set of decomposed graphic contents; $LN1_i$ represents an object in Level 1; $LN2_{ij}$ represents the sub-components of object $LN1_i$; Symbol $\oplus$ represents content merging. We have the following relationships:

$GN = \sum LN1_i = LN1_0 \oplus LN1_1 \oplus \ldots\ldots \oplus LN1_n$, where $i \in (0, n)$

$LN1_i = \sum LN2_{ij} = LN2_{i0} \oplus LN2_{i1} \oplus \ldots\ldots \oplus LN2_{im}$, where $j \in (0, m)$

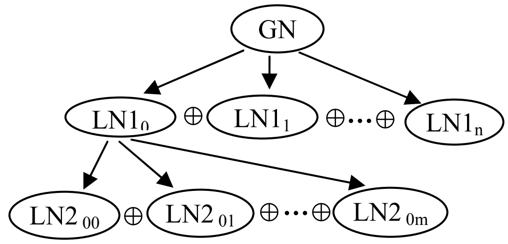

Fig. 1 Tree structure of the multi-level decomposition

Figure 2 shows an engineering drawing decomposition process and layout. The original graphics content has multiple views, textual annotation, drawing information, and dimensions etc. Each of these can be separated into different nodes (files) containing semantically related graphic information. Cross-references in decomposed content files are used to maintain a two way (Parent and Child) relationship between decomposed contents. Thus, the whole tree structure could be traversed. By decomposing large content into interconnected multiple small files, the content server doesn't need to maintain a long session status of conversation between client and server. Thus, the server can simultaneously support more clients and the delivery process is less likely broken. This feature is extremely valuable in mobile computing environment where the resource is limited.

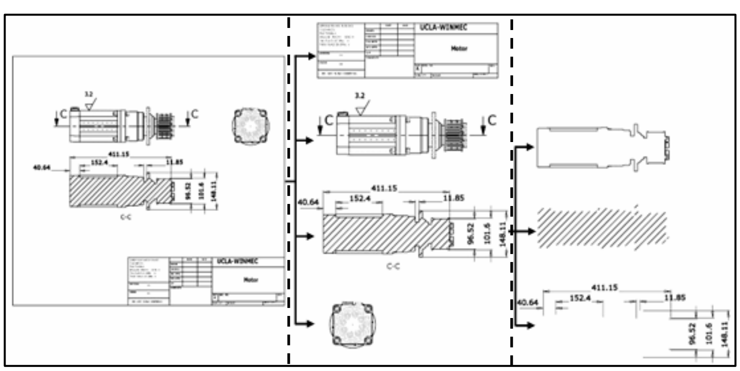

Fig. 2 An instance of decomposition process and layout

4. Content Delivery, Merging, and Rendering

This hierarchical representation model supports three types of delivery models. The first one is manual delivery. The delivery process is selectively started from any node/file. Only current node is downloaded and loaded into memory. A list of all the content in the next level are rendered as descriptions or links that allow client to select. The second method is delivery the content based on the attributes of the graphics. The desired content is pre-defined at client. The last one is intelligent delivery. The server decides which content should be delivered based on the device profile or presenting network status that obtained from client.

The client maintains both a global Document Object Model (DOM) [10] and a local DOM when renders the content. Each loaded content file forms a local DOM. the entire local DOM could be insert into the global DOM to replace the virtual node which represents the local DOM. The client has the options to render any content node and its child content node to screen based on various rules.

Figure 3 shows an example of manual delivery and rendering process. When the root content node is loaded, only description is presented on the client screen. The client can selectively download next level content to display.

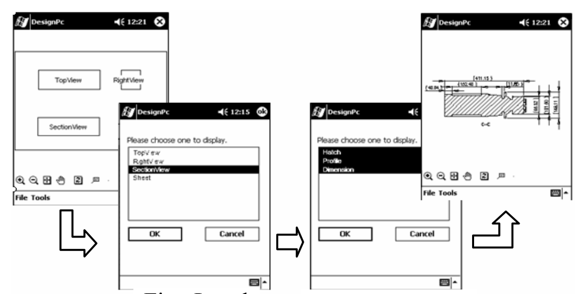

Fig. 3 On-demand delivery and rendering

5. Performance Evaluation

We performed evaluation both at client side and server side. At client side, user experience test is conducted by comparing the operation response of different size of graphics on Pocket PC (iPaq 5450). As shown in Figure 4, the client is agiler when small size graphics content present. During the testing, we also observed that wireless connection may be disrupted when the system is busying in rendering large amount content. This problem did not happen when the granular/on-demand transmission and representation approach is used.

At server side, we compared the capability of supporting multi-users of traditional content organization and hierarchical decomposed content organization. The response error rate of the server is measured. As shown in Figure 5, the hierarchical content organization shows significant improvement over traditional approach especially when a large number of users are trying to download content concurrently.

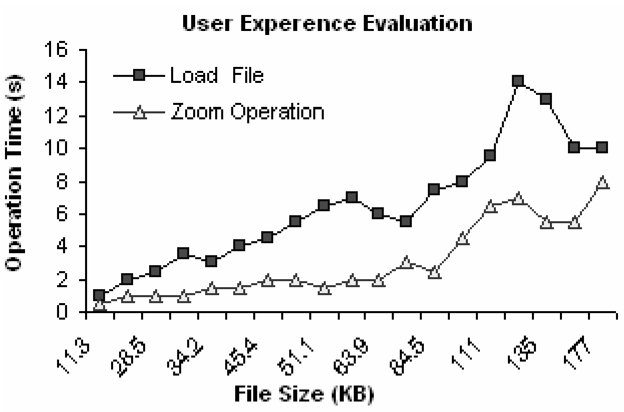

Fig. 4 User experience evaluation

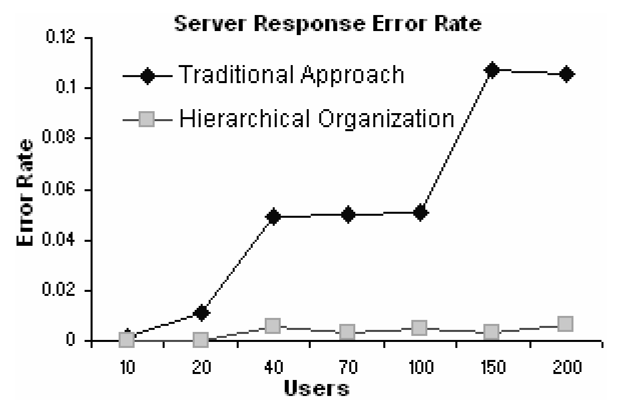

Fig. 5 Server side performance evaluation

6. Summary

The objective of this research was to enable engineering content exchange in mobile computing environment. The architecture of 2D graphics decomposition, hierarchic content organization and on-demand delivery mechanism is presented. Currently, the framework is being implemented. The prototype has performed satisfactorily in representing different engineering graphics content (drawings, schematics, layouts), which is quite encouraging for field service applications. The future works of this research will be focused on the optimization of content decomposition and organization, intelligent content adaptive and delivery.

7. Acknowledgements

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