CONTENT-BASED IMAGE INDEXING AND RETRIEVAL FRAMEWORK ON SYMBIAN BASED MOBILE PLATFORM

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ABSTRACT

This paper presents a content-based multimedia indexing and retrieval framework designed for mobile platforms running Symbian-based operating system. It is mainly developed by focusing on mobile platform restrictions and Symbian features. The proposed framework is built on a client-server architecture, where the client side basically consists of the user interface and controllers, and the server is responsible for performing main functions. Both the client and the server may run on either the same mobile device, or separately on connected devices. A sample content-based image indexing and retrieval application running on single Nokia 6630 device is implemented for testing the framework, verify its feasibility, and study further directions in the area. The implemented application provides mobile indexing and retrieval features as well as instant image capturing with onboard camera for queries. The experimental studies reveal relatively successful results in terms of semantic and process performance.

1. INTRODUCTION

Mobile phones have been indispensable in people's daily life essentially for easy and immediate communication since 90's. Mobile phone manufacturers have been offering attractive features on various phone models in order to keep and improve their shares at the competitive market, which is growing steadily worldwide each year. Nowadays mobile phones mean much more than just simple voice communication devices with all the offered user-friendly features, hence the "smartphone" term is used more frequently. Providing multimedia capabilities has been one of the biggest improvements in this field. Various camera phones providing multimedia capturing, browsing, editing, and sharing (e.g. via MMS multimedia messages) features have been released. Recently, third generation (3G) [1] phones and networks have also been released for allowing faster and more reliable sharing of multimedia as well as video telephony.

Camera phones have been widely adopted by people, and thus accelerated digital multimedia generation and sharing, which were already initiated with increasing computer, digital camera, and Internet usage. Nowadays there is huge amount of distributed digital multimedia available for personal and commercial use. An average camera phone user may even possess a large multimedia collection stored in memory cards. However, accessing and finding certain multimedia items within available multimedia collections is becoming more difficult. Content-Based Multimedia Indexing and Retrieval (CBMIR) field has been studying the handling and the management of large multimedia collections for a few decades. Various successful academic and commercial CBMIR methods and systems have been introduced for personal computers or workstations [2], [3], [4], [5]. There have also been limited amount of CBMIR studies for mobile platforms. [6] and [7] study a client-server system, where only the client runs on the mobile terminal. Nokia introduced Nokia Album [8] application, which indexes personal image and video clips using simple techniques, e.g. text annotation. However, more advanced CBMIR methods utilizing low-level features have not been studied on pure mobile platforms due to hardware and software restrictions. It is evident that the current status of CBMIR on computers cannot be achieved with current mobile phone technology, but it will be definitely possible in the future as the technology improves fast. Furthermore, current CBMIR studies on mobile platforms will contribute in advanced optimisation methods and performance of future systems. In this respect, a client-server CBMIR framework for mobile platforms based on Symbian [9] Operating System (OS) is proposed in Section 2. The reasons of using Symbian OS and its relevant properties are also described in Section 2. Section 3 introduces a sample implementation of the framework on Nokia 6630 device [10] using Series 60 OS [11]. The experimental results on this implementation are given in Section 4, and finally concluding remarks are presented in Section 5.

2. CBMIR FRAMEWORK FOR SYMBIAN-BASED MOBILE PLATFORM

Three sets of components play important roles in a general CBMIR scheme: multimedia items and databases, multimedia features and feature extraction, and distance measurement between multimedia features. Figure 1 illustrates general CBMIR scheme containing these three components. The figure also depicts the separation of offline indexing and online retrieval phases. In general, indexing complexity is directly related to the underlying feature extraction methods and multimedia data. On the other hand, retrieval complexity heavily depends on distance measurement and feature data. Although indexing requires more resources, retrieval requirements are more relevant from end user perspective since it is online and more often utilized. These facts mostly drive

the CBMIR studies, however they do not have the same effects when the underlying platform has limited and distributed characteristics as in mobile platforms. Limitations have to be considered more carefully and optimisations have to be utilized at each phase of a mobile CBMIR framework. Additionally, due to incredible changing (mostly improving) nature of mobile platforms, both in OS and hardware levels, mobile CBMIR framework have to be implemented using reusable distinct modules. Modularity also enables scalable and interoperable client and server implementations. Such issues have led to using Symbian OS for the proposed CBMIR framework.

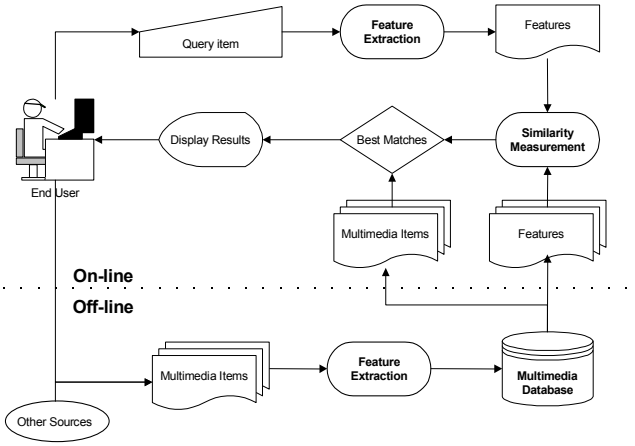

Figure 1: Overall content-based multimedia indexing and retrieval layout

Symbian is designed by considering limited hardware platforms, user interface and screens initially for Psion as EPOC OS [12] and later for wireless devices. It also offers extendable multimedia processing frameworks such as Image Converter Library (ICL) containing codec plug-ins and Multimedia Framework (MMF) containing audio/video codecs and playing utilities. Majority of the smartphones sold in the market uses Symbian-based OS. Nokia's Series 60 OS is mainly a Symbian-based operating system with customized UI, additional applications, and improved functionalities. Its user interface is designed for 176x208 pixel screens. Excluding the UI, a Series 60 application is easily portable to another Symbian-based OS, if it does not depend on particular functionalities offered by Series 60. Symbian also provides network and communication interfaces that do not depend directly on hardware implementations.

The proposed client-server CBMIR framework illustrated in Figure 2 may easily utilize the aforementioned multimedia and communication features of Series 60 OS and eventually Symbian OS. The framework has close relations with MUVIS CBMIR framework [2], [3], but also the following main differences:

- Distributed processing and client-server architecture,
- Using Symbian/Series 60 offered modules instead of own-implemented ones, and
- Mobile platform restrictions such as processor power, memory capacity, and screen size.

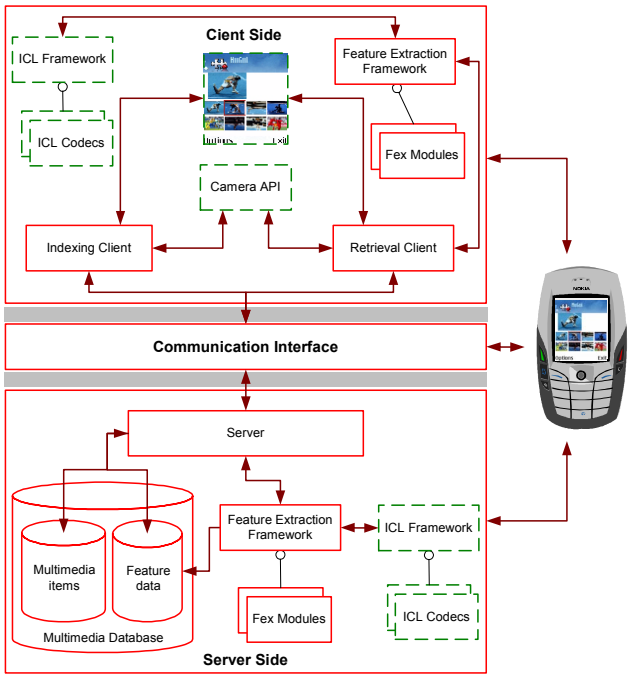

Figure 2: The proposed CBMIR framework for Symbian-based mobile platforms

The client side of the framework contains the indexing, the retrieval, optionally the feature extraction sub-framework, the UI, and the required Symbian/Series 60 modules shown in Figure 2. The UI module uses Series 60 UI components, and is not considered in this paper. The feature extraction framework defines an interface for using implemented feature extraction (FEX) module plug-ins. It is a modified version of the feature extraction framework described in [13]. Indexing client is mainly responsible for passing the user's indexing requests coming through the UI to the server, and also returning the results of these requests. The retrieval client has more involved tasks other than just passing retrieval requests and returning results. It might have to use codecs and feature extraction modules for the multimedia items that reside on the client side. Particularly, it may need to extract the features of query item and send the feature data instead of the item itself for efficient usage of communication bandwidth. If the client does not have the same feature extraction module as in the server side, it does not have any other option than simply sending the query item data. Indexing and retrieval clients can be combined into one module if the separation is not particularly required.

The clients communicate with the server through an interface, which is based on either a network communication protocol e.g. using Bluetooth or inter-process communication (IPC). The network protocol is used when the client and the server run on different devices, and IPC is used otherwise.

The server side contains the server itself, the database, the feature extraction sub-framework, and the required Symbian/Series 60 components. The database contains multimedia items and the associated feature data. The server mainly handles all indexing and retrieval requests issued by a client, and utilizes other components for this purpose. The server side feature extraction framework is the same as in the client.

An optional component of the proposed framework is the capturing module on the client side enabling immediate capturing of query item using onboard device camera. Symbian OS defines a camera interface, however the implementation is left for the manufacturers. Nokia has its own product specific implementations that can be used through the Symbian OS camera interface.

3. SAMPLE IMPLEMENTATION ON NOKIA 6630

Although the proposed CBMIR framework follows the general characteristics of an ordinary CBMIR system, its new features and feasibility on target platform have to be verified in practice. In this respect, a simple client-server content-based image indexing and retrieval (CBIR) application is implemented on Nokia 6630, where the server and the client run on the same device. Nokia 6630 is one of the latest 3G mobile phones using Series 60 2.6/Symbian 8.0 OS and having onboard high resolution camera (1.3 megapixels sensor). It has 10 MB of user memory and a RS-MMC slot for additional memory space. The processor of Nokia 6630 is 32-bit ARM9-based RISC CPU [14].

The implemented application works only on Jpeg compressed images. DCT-based downscaling is applied during Jpeg decoding before feature extraction processes for reducing processor and memory usage. As presented in [15], DCT-based downscaling does not affect colour-based retrieval performance significantly. HSV and RGB colour histogram feature extraction modules are implemented for using in indexing and retrieval experiments. The indexing and the retrieval modules are combined into unit client, which incorporates the capturing module using onboard camera. It does not include the feature extraction sub-framework. Since the server and the client reside on the same device, IPC and shared memory are used during the client-server communication.

The underlying indexing and retrieval methods of the implemented CBIR application are adopted from the MUVIS CBMIR framework. The image database and feature data formats are similar to the MUVIS defined formats. The querying scheme also contains similar multiple feature-based querying, weighted distance mean, and feature weight adjustment features of MUVIS.

Figure 3: The implemented application's user interface displaying the results of a query

Figure 3 presents a screen shot from the application's UI on Nokia 6630. The screen shot displays the results of a query, where the captured query image is located on a 80x60 pixels rectangular area, and each of 8 retrieved images from the database is located on 40x30 pixels rectangular area. Figure 4 contains a set of four other screen shots displaying the user menus and options.

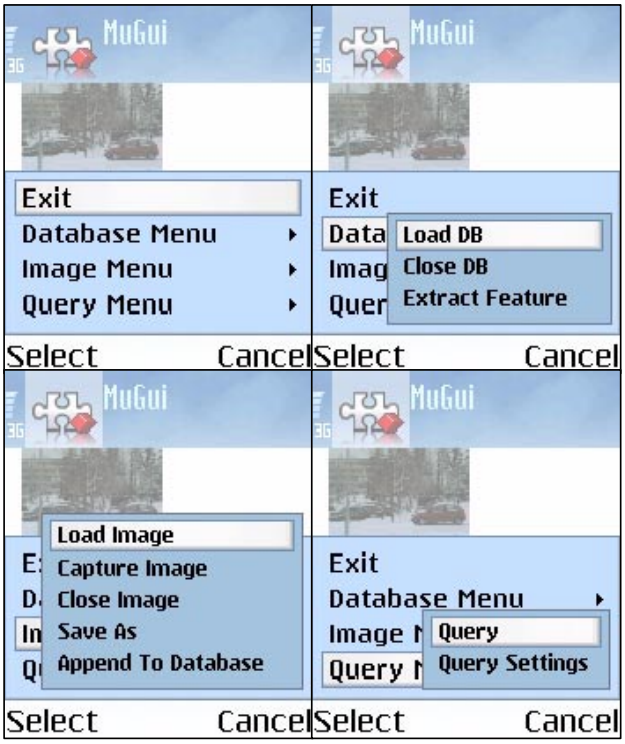

Figure 4: The menu options of the implemented application on its user interface

4. EXPERIMENTAL RESULTS

Using Nokia 6630 camera, 50 images are captured with 1280x960 pixels resolution and high quality options. These images are indexed by extracting their HSV and RGB colour histograms on the implemented CBIR application. The extracted colour histogram bins are 8, 4, and 4 respectively for each colour component. Figure 3 displays the result of a query from the experimental database on the application. The result of the same query with the same image on MUVIS browser is shown in Figure 5. As shown in both figures, expected results are observed on the image queries.

The process times for certain operations on the mobile CBIR application are listed in Table 1. The numbers in the table reveals that Jpeg decoding is the most time consuming process affecting the whole performance. The following items have direct effects on the listed numbers:

- Picture size (1280x960),
- Jpeg decoding,
- DCT scaling factor (4 in this case),
- Colour histogram extraction, and
- Euclidean distance calculation between histogram vectors.

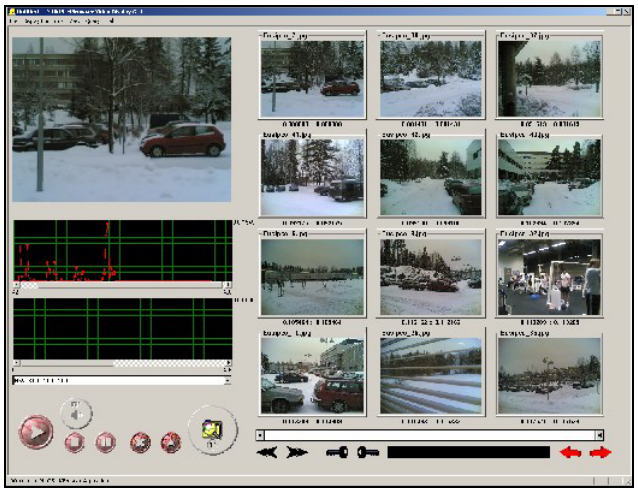

Figure 5: Query results displayed on MUVIS Browser application user interface

Operation	Time consumed (sec)
HSV colour histogram feature extraction on query image	0.18
RGB colour histogram feature extraction on query image	0.16
HSV colour histogram feature extraction of whole database (offline)	96
Total query time, including displaying the results	13

Table 1: Times consumed for executing certain operations

5. CONCLUSIONS AND FUTURE REMARKS

A scalable client-server CBMIR framework is proposed for Symbian-based mobile platforms, where advanced optimisations can be employed for overcoming the restrictions. The framework utilizes Symbian/Series 60 OS multimedia functionalities, and can be ported into various Symbian-based platforms after applying required modifications, e.g. on the UI. It can also be ported to other distributed platforms if the Symbian dependencies are replaced with proper implementations. A simple version of the framework is implemented for Nokia 6630 device. Although the implemented application is not fully optimised, certain methods have been used improving its performance, e.g. DCT-based downscaling. The application is used for indexing and retrieval experiments on a Jpeg image database, and the results verify that such a system is feasible on mobile platform. The proposed framework provides the indexing and retrieval modules integrated for distributed Symbian-based systems. It will be improved further by incorporating more optimisations in its modules and other multimedia capabilities of Symbian OS. The implemented application may also be developed further by implementing the remaining parts of the framework. Once the entire framework is implemented, it will be utilized for extensive experiments for mobile CBMIR. The system will also be used to study user experience and usability of mobile CBMIR systems in order to improve the user interface and contribute in fast adoption of such complicated systems on limited devices.

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