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A Proposed Futuristic Framework for utilizing image Super Resolution Algorithms over mobile cloud Computing Platform

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Abstract: Super resolution imaging is to get high quality picture details either from multiple input images or from a single image. Currently researchers have developed several super resolution techniques to improve image quality. With evolution of broadband wireless technology and mobile device industry, the Mobile image processing has attracted researchers concern towards itself. In this paper we proposed a framework which focuses on utilizing Mobile Cloud Computing platform for the use of super resolution algorithms. Both super resolution imaging and mobile cloud computing are the most spotlighted research areas nowadays, so we intend to merge them in a way that researchers can get benefit from both of them. Super resolution algorithms (POCS, IBP, MAP, etc) are executed on the Cloud server, the mobile user will only to send the request (low resolution input images) to the cloud server, which will process his request accordingly and then send the high resolution image to the mobile user. The experimental results performed show the realization of our proposed framework.

Keywords:. Super Resolution Imaging, Mobile Cloud Computing, Mobile Image Processing, Projection Onto Convex Sets, Iterative Back Project, Maximum A-Posteriori

1. INRODUCTION

Images with high resolution are very important and desirable in many applications such as, TV to HDTV signal conversion, medical imaging for medical diagnosis, surveillance system, satellite imaging and many others. For such applications researchers have introduced software based resolution enhancement techniques. These techniques are called Super resolution techniques. The purpose of super resolution technique is to recreate a high resolution image from a single or multiple low resolution image(s).

SR techniques can be mainly categorized into two families: 1) Classical multi-image Super resolution. 2) Single Image Super Resolution, also called Example/Learning Based super resolution. Multi-image super resolution is a technique which uses low resolution images from a same observation to recreate a high resolution image. In single image super resolution technique as single image is processed to get the desired high resolution image. It is more complicated and complex then the previous one discussed. In super resolution literature these Single image SR techniques are usually know by Example based or Learning Based super resolution.

The most spotlighted and challenging research area of super resolution (and image processing) applications is low-end multimedia devices like smart phones. Recently it is observed that mobile devices e.g. smart phones, tablets, laptops are becoming more popular and has transformed our lifestyle. As these portable devices are not only limited for video or voice call but they are mostly used for messaging, emailing, banking, multimedia and location services etc.. Most of the mobile devices have built in camera, big enough (1 Giga byte (GB) or more) memory storage with high processor. So thousands of images and videos can be captured and stored on these devices. But still there are some limitations i.e. power consumption (less battery life), limited memory capacity, low computational processing speed, which are to be investigated and improved. So the solution to this dilemma can be found in the cloud computing infrastructure. Users/mobile devices can use the cloud infrastructure e.g. servers, networks, storage, software's and application programs via internet any where any time.

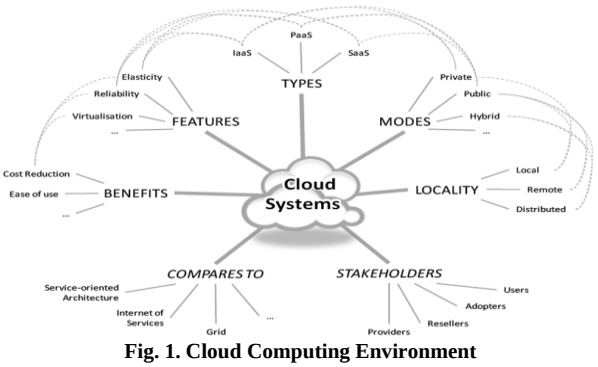

Fig. 1. Cloud Computing Environment

In our research we attempt to utilize the platform of cloud computing through the mobile device and mobile web (which can be internet or wireless, 3G/4G) as an

Educational Tool for image super resolution. It is beneficial for researchers, students and they can compare different super resolution algorithms applied to the low resolution images. We aim to create an application for the mobile user which will send the request (low resolution images) to the cloud, where it will be processed accordingly and in the return the mobile user will get the resulted high resolution image. The main advantage is to utilize the cloud computing for processing of complex computational demanding super resolution algorithms.

In the first we start with some basic concepts of cloud computing and mobile cloud computing. The architecture, advantages and applications of mobile cloud computing are discussed, which is then followed by our proposed framework for the image super resolution in mobile cloud computing. The experimental results of the proposed framework are validated at the end of the paper.

2. CLOUD COMPUTING

Everyday we hear about a new technology, a new gadget, a new device or a new feature, so technology is in continuous progression. Cloud computing is a new type of computing technology that provides resources and computing infrastructures such as high speed processors, memory storage, access to different applications/services on demand basis to the users through internet (Armbrust. 2010) (Buyya 2009). For example Amazon offers EC2 i.e. Elastic Computer Cloud and S3 i.e. Simple Storage service, to provide data storage on Amazon cloud using S3 and computation can be performed on the stored data using EC2. Likewise, Giga Space Technologies is a pioneer of a new generation of application virtualization platform and also provide opportunity to business and developers to predictably scale online systems under any peak demand, guarantee real-time performance under any data processing load and seamlessly leverage the economies of scale offered by virtual computing environments such as clouds or grids. Further about cloud computing companies can be found on.

Cloud computing has many advantages for business and service providers e.g. lower maintenance and operation cost, low initial capital investment, shorter start up time for new services, high utilization through virtualization and back up of data incase of any disaster or memory loss. Cloud computing has made it easier for a company to save money because they not have to spend in buying more computers/servers and software's for employees. **(Fig. 1)** shows about cloud computing features, beneficiaries, types, models and etc.

2.1 Mobile Cloud Computing

Nowadays cloud computing is not only limited to personal computer it also has influence and intense impact on the mobile technology. Mobile devices (e.g. smart phones, tablet computers, net books etc.), mobile applications (photo and video tools, music and audio apps, financial tools, map and locations services etc.) and the cloud computing resources are converging together into a new rapid emerging field of Mobile Cloud Computing (MCC).

Recently the demand for the mobile applications e.g. Google Apps, iPhone Apps, etc are increasing which require more resources to be provided to make user experience more better. So, mobile cloud computing integrates the cloud computing into the mobile environment and overcomes the following issues:

- Performance (e.g. storage capacity, battery life, bandwidth),
- Environment (e.g. heterogeneity, scalability and availability) and
- Security (reliability and privacy).

2.2 What is Mobile Cloud Computing?

Many definitions can be found on the internet and in books but the best one I found are the following two. The mobile cloud computing forum defines MCC as, "Mobile cloud computing at its simplest refers to an infrastructure where both the data storage and the data processing happen outside of mobile device. Mobile cloud applications move the computing power and data storage away from mobile phones and into the cloud, bringing applications and mobile computing to not just smart phone users but a much broader range of mobile subscribers"

Another definition for mobile cloud computing is in the Open Garden blog as "The availability of cloud computing services in a mobile ecosystem. This incorporates many elements including consumers, enterprises, femtoscells, transcoding, end-to-end security, home gateways and mobile broadband enables services" (Jun. 2011)

2.3 Architecture of MCC

Here we discuss the general architecture; MCC mainly consists of the following units or parts:

- Mobiles Devices
- Mobile network operators
- Internet service providers
- Cloud computing infrastructure
- Application service providers

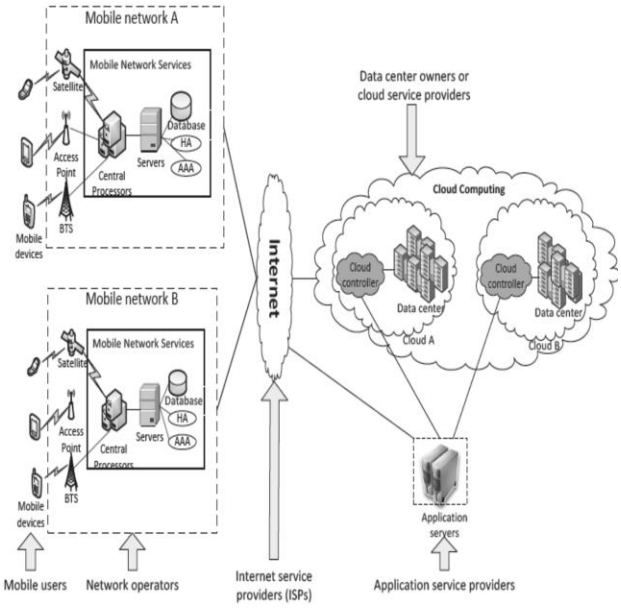

Fig. 2. General mobile cloud computing infrastructure.

Further details about each part are given below:

2.3.1 Mobile Devices

Mobile devices can be smart phones, portable personal computer (PCs), personal digital assistant (PDA), netbook etc.

2.3.2 Mobile Networks/ Network Operators

The mobile network consists of a Base transceiver station (BTS) or access point (AP) or a satellite which works as a base station and helps to control and create connections between the mobile devices and the mobile network (components). The mobile network also have central processors, servers, home agents (HA) and authentication, authorization, accounting (AAA) units. The mobile users request and identification information is sent to servers through central processors and different network services like (AAA) are provided to them. There can be more then one mobile networks.

2.3.3 Internet Service Provider (ISP)

Mobile users request is delivered to the cloud through internet. Internet service provider is playing a role of bridge between mobile network and cloud.

2.3.4 Cloud Computing Infrastructure

The cloud architecture (Foster, *et al.,* 2009) (Tsai, *et al.,* 2010) is different in different context. In general cloud computing is a large scale distributed network system consisting of cloud controllers and cloud data centers. Cloud controllers are responsible for providing corresponding cloud services to the mobile users. These services are developed with the concepts of utility computing, virtualization and service oriented architecture (e.g. web, application and database servers).

National Institute of Standard and Technology (NIST) has portrayed cloud computing with five characteristics:

- Broadband network access
- Rapid elasticity
- Measured services
- On demand self service.

Cloud computing has four deployment models.

- Public
- Private
- Hybrid
- Community

Cloud computing has three service models.

- Software as a service (SaaS)
- Platform as a service (PaaS)
- Infrastructure as a service (IaaS)

2.4 Applications of MCC

Mobile applications are becoming more popular nowadays. It has opened a new developing research area in the global mobile market. Different mobile services are taking advantage of MCC. Following we have mentioned some of the applications of MCC.

- M-Gaming.
- M-Health.
- M-Learning
- M-commerce.
- Mobile searching services (images, videos, audio, voice recording tools, map location tools)

A lot of research and amazing developments are erupted in the MCC application area (Pendyala and Holliday, 2010) (Lagerspetz and Tarkoma, 2009) (Lagerspetz, *et al.,* 2007) (Cai-Dong *et al.,* 2011) (Angin, *et al.,* 2010) (Li, *et al.,* 2011) (Zhenyu, *et al.,* 2010) (Kelenyi and Nurminen, 2010) which endorse that MCC is promising future technology.

2.5 Advantages of Mobile Cloud Computing

The power of cloud computing is enabling the mobile devices to be like mobile computer. Mobile computing together with cloud infrastructure can overcome the li**mitations related to storage, computation power and security**.

2.5.1 Larger Storage Capacity and Effective sharing of Data

Mobile cloud computing offers the mobile users a facility to store their data on the cloud through wireless network. So mobile users does not need to worry about limited memory capacity on their mobile device anymore. For example Amazon S3 (Simple Storage Service) is offering file storage service for mobile users. Storage of data on cloud also helps convenient sharing of data, Flickr and Shozu do have their mobile photo sharing applications based on MCC.

2.5.2 Save Battery Lifetime:

One of the main problems with mobile devices is short battery time, but now no need to worry anymore. As, mobile cloud computing has in itself a solution for it by computation offloading technique presented (Kumar and Lu, 2010) (Yang and Hsu, 2010) where large and complex computations are transferred to the server machines in cloud. Experiments in (Rudenko, *et al.,* 1998) have proved that up to 45% of energy can be saved incase of large numeric calculations through remote process execution. In an other research (Kumar and Lu, 2010) (Yang and Hsu, 2010) has introduced compiler optimization for image processing which can reduce 41% for energy consumption of a mobile device.

2.5.3 Improved Security and Reliability:

Any communication system or device is incomplete without the security features in it. Any mobile user will never compromise on the security and privacy of his data whether on their mobile or through the mobile network they are using. At present most of the smart phones have improved user friendly security features e.g. using knock code, PIN code, fingerprints, pattern passwords etc. Samsung is providing a facility to their user to access or locate their phones incase the mobile is stolen. for better security of smart phones and clouds.

2.5.4 Network Bandwidth and Latency

Bandwidth and high latency of network are being improved now. 4G and 3G cellular systems are providing higher data rates similar to broadband network (Kremer, *et al.,* 2001) (Cox, 2011). (Satyanarayanan, *et al.,* 2009),

2.5.5 Network Availability and Intermittency

Mobile cloud computing must be ensure through a stable and high speed internet connection. A mobile user should be able to get an uninterruptable cloud service all the time. Several web caching techniques e.g. cache at mobile device (e.g. HTML5) and cache storage at cloud (gear6 web cache server, Amazon EC2 etc) have been introduced to provide seamless connectivity incase of poor internet connections.

3 MOBILE IMAGE PROCESSING

With an evolution of wireless technology (3G, 4G, WiFi, Wimax etc), the speedy upgradation of mobile devices and rising requirements of mobile users, now it is very important for the mobile devices (such as smart phones and PDAs) to be capable to perform image processing tasks efficiently and with more accuracy. Now most of the mobile devices have several GB memory capacity and built-in camera, so that pictures and videos taken can be saved on them. Here we mention some very important functionalities:

- Access of some specific image or videos through network.
- Fast processing of image/video processing tasks.
- Sharing and storing the data for back up on other servers.
- Sharing images/videos with other devices/users through the wireless (internet) network.

Using MCC as an educational tool for image super resolution, de-nosiing, de-blurring, image enhancement and face detection.

For the efficient execution of the above functionality we consider mobile device as a terminal or end user. The requested service from the user is sent to the cloud (which provide large storage capacity and superior computing resources) the request is processed at the cloud platform and then result is sent to the end user. The communication interface between end user is cloud wireless network (3G/4G, Wifi, etc) or ISP.

In (Ye, Chen, and Li, 2010) mobile locating service is proposed that allows user to capture image or a short video clip of the nearby building from their mobile and then send it to the cloud computing system through the mobile network. A SIFT based building matching algorithm runs on cloud servers containing a large database of images and videos. After processing the cloud return a tagged image with location's summary and available services.

(Cai-Dong *et al.,* 2011) introduced orthogonal semantic tags for images uploaded from the mobile users and store them on cloud, designed search algorithms are to applied to retrieve appropriate images through sorting matching indexes, weights etc. Their method is designed for images stored on private cloud computing.

Research work in (Yang, *et al.,* 2008). (Zhu, *et al.,* 2009) (Chen, *et al.,* 2009) focus on applying Content based image retrieval (CBIR) on mobile devices. CBIR provides access to specific sets of images rather than searching through all images.

Health Management System (HMS) application (Somasundaram *et al.,* 2011) is implemented in the MCC environment, that can save the health records, medical image data (e.g. MRI, X-ray, ultrasound images) of patients. By using HMS application doctors can provide prescriptions to patients. The experiments for this application are performed on the mobile phone with Android OS.

4 PROPOSED FRAMEWORK

4.1 Research Motivation

The main goal of this research is to help students and researchers in the field of image processing especially image super resolution. Figure 3 shows the framework for our proposed design. We exploit the concept of mobile cloud computing in the context of image super resolution. Following are the key features:

- To give researchers and students an educational tool to understand, perform and compare Super Resolution (SR) algorithms.
- It can also be used for other image processing tasks for example image de-blurring, de-noising, wrapping, feature extraction, face detection, image enhancement and etc.
- To use the Cloud Computing (CC) environment for storage and execution of super resolution algorithms on it, because of their (CC) fast processing speed and (make use of) huge memory.
- To provide real time access to super resolution algorithms.
- Super resolution algorithms implemented are IBP (iterative back project), POCS (projection onto convex sets), MAP (maximum a- posteriori) and Bicubic Interpolation.

4.2 Research Method

The mobile user will do the following:

- Using our designed super resolution application the mobile user will browse the low resolution images (from the same scene).
- Select the desired magnification factor and super resolution technique
- Press the Send Information icon
- The resulted high resolution image is sent to the image gallery.

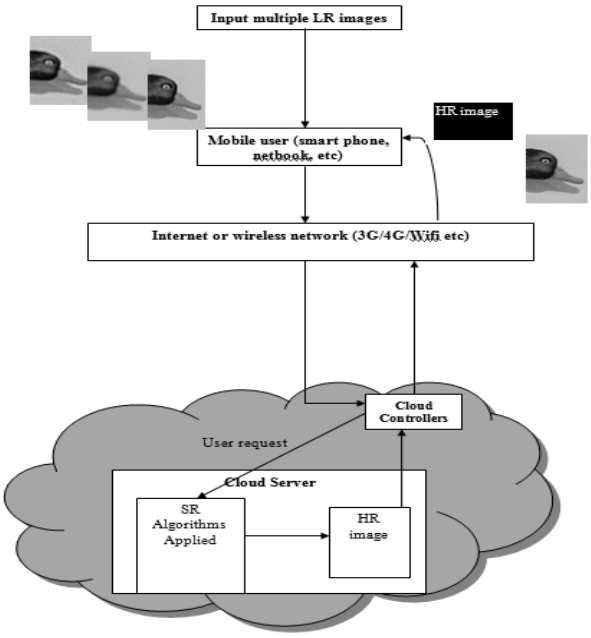

Fig. 3. Framework of our proposed approach

In our methodology we first design a super resolution application for the mobile device, which will give a user choice of selecting the required super resolution technique and also send low resolution images to the cloud server. For data transmission we are using TCP/IP. The mobile user will communicate through that. We also do the socket programming for both mobile device and server. For the SR algorithms we also write program for Server.

4.3 Steps for the Proposed Framework

Now we see the key steps for our proposed approach:

- Mobile user through super resolution application will send the low resolution images (from same scene) + desired magnification factor + choice of super resolution technique to be performed using TCP/IP connection to a set socket having a specific IP address and port number. For that purpose the network we use can be 3G or a WLAN. The mobile user will press "Send Information".
- The server after getting the request will apply required SR technique and process the low resolution images according to the request of the mobile user. Image super resolution algorithms are executed in the server. Where low resolution images are processed and resultant image is generated.
- After processing the server will sent the high resolution image to the mobile device

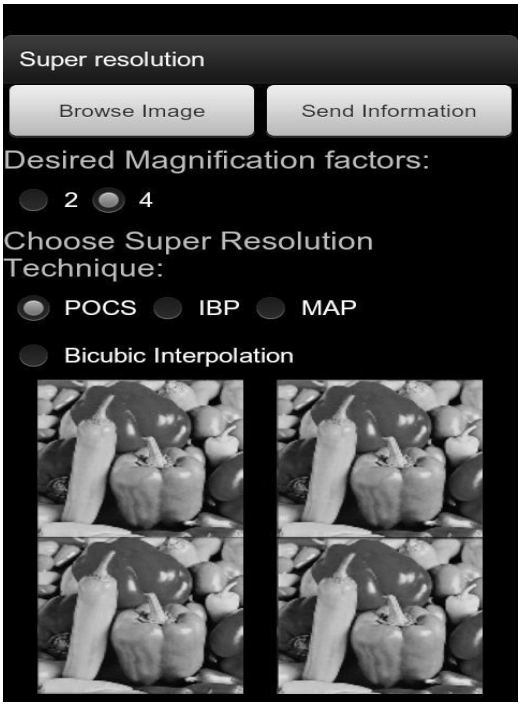

Fig. 4. GUI of the SR application on the Motorola Mobile device

5 EXPERIMENTAL SETUP

For experimental purpose we used the following hardware:

5.1 Server:

HP notebook with Pentium IV 2.0 GHz, 2GB RAM and 150GB hard disk is used. The operating system used is Windows XP Home edition.

5.2 Mobile Device:

The mobile device we used is Motorola Milestone with Android OS (Android version 2.3.7) running on it. It has a 550MHz processor with RAM 256MB and a built in camera of 5 MP. It also has the functionality of Wifi and it supports 3G/4G networks.
We used the following software tools:

5.3 MATLAB:

We used MATLAB 7.6 (R2008a)on the server end to process images (execute super resolution algorithms) according to the request sent by the mobile user.

5.4 Android SDK:

To develop super resolution application on the mobile device, we used Android SDK. It is used to develop Graphic User Interface (GUI) and the socket programming (for the port to receive and send data). Android SDK is a comprehensive set of development tools that are required for developing applications on the mobile operating system.

5.5 Java:

Java is used for calling MATLAB exe (executable) file for image processing on the server.

5.6 Results:

Fig. 5 shows the GUI of our designed super resolution application. The mobile user select the Magnification factor 4 and the super resolution technique POCS. Four low resolution input images are uploaded given in Figure 4. The mobile device waits for the server to process the low resolution images using MATLAB (applying POCS methods). Figure 5 shows the resulted high resolution image sent from the server to the mobile user (with magnification factor 4 and POCS resulted image).

Fig. 5. Resultant high resolution image of the super resolution technique (POCS) sent back to the Motorola Mobile device

From this experiment we have proved that our framework is implementable. Right now we have only few options and operations which can be further extended in future.

6 CONCLUSION

In this paper a super resolution tool is proposed, which utilizes the mobile cloud computing platform for processing of highly computationally complex super resolution algorithms. A super resolution application is designed for a mobile device so that researchers and students can use that for performance analysis of super resolution algorithms. The mobile user only need to install the super resolution application, it does not need to run the super resolution algorithm on the phone or high speed processor or large memory capacity. Because the super resolution algorithms are stored, implemented and executed on the server in the Cloud. The Cloud after receiving the request form he mobile user, execute it accordingly and then sent back the required high resolution image to the mobile device. So far we have limited options in our method but they can be extended in future. We plan to add more super resolution algorithms to this application and also this framework can be tested for Cellular network (3G/4G).

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