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EVALUATION OF CLOUD COMPUTING PLATFORM FOR IMAGE PROCESSING ALGORITHMS

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Abstract

This paper evaluates the use of the cloud system environment for image processing algorithms, analysis, and storage capacity from point of view of architecture orientation and service level agreement. Due to the lack of studies in the adoption of a cloud computing platform for image processing as a service, cloud computing environment within needed deployment supposed to allow experts to process and analyze different type of images in that concept. Furthermore, it provides cost-efficient image processing and analysis as a service, which realizes significant cost savings associated with the utilization of the local data center and recruitment IT staff. Thus, it greatly reduces the costs of providing image processing services. In addition, a cloud computing platform for image processing algorithms allows collaboration between image processing environment practitioners. This deployment faces various type of technical, implementation, legal and administrative challenges. This paper makes two contributions to address these concerns by exploring the factors that hinder the adoption of the cloud computing technology for image processing algorithms and defining the key requirement that should be supported by service-oriented architecture (SOA) and service level agreement (SLA). The importance of this study is in the evaluation of the current state of the cloud-based image processing algorithms implementations with a service level agreement requirement. In addition, future research trends related to security, integrity and regulatory have been clarified in this paper.

Keywords: Cloud computing, Image processing, Service level agreement, Service oriented architecture, Software as a service.

1. Introduction

Image processing is usually approached as the problem of applying numerical algorithms to digitized gray-scale images and it is too expensive in terms of memory space and computation time. Therefore, it is worthwhile to look for more economical solutions [1]. Cloud computing is a solution for big tasks of image processing approaches. "Cloud Computing is a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction"[2]. Cloud computing has emerged as a computational model that enables researchers to build high performance and complex applications to manage large datasets based on cloud resources and infrastructures. All these cores will be tackled from point of view of services and deployment models. Cloud system environment for image processing platforms should be evaluated from point of views of oriented architecture and level agreement; it supposed to provide cost-effective services with the utilization of the computing utilities to allow the collaboration between its practitioners.

The use of cloud services is closely linked to popular cloud offerings, such as software as a service (SaaS), platform as a service (PaaS) and infrastructure as a service (IaaS), while an application is deployed in the cloud environment. All these services were addressed by the evaluation key requirements of image processing as service and exploring the implementation factors of adoption of image cloud ecosystem. The deployment of cloud computing for image processing as service faces various type of technical, implementation, legal and administrative challenges.

Due to the lack of studies in previous respects, this paper makes very important contributions to address these concerns by exploring the factors that hinder the adoption of the cloud computing technology for image processing algorithms and defining the key requirement that should be supported by SOA and SLA, where the importance of this study is in the evaluation of the current state of the cloud-based image processing algorithms implementations with a service level agreement requirement, which has never been done in terms of technical factors. There are four available deployment models: Private, Public, Community, and Hybrid Clouds.

The rest of the paper is organized as follows. Section 2 describes image processing cloud system environment. Image processing cloud computing reviewing factors is described in Section 3. Cloud computing impacts on image processing are discussed in Section 4, and conclusions and future work direction can be found in Section 5.

2. Image Processing Cloud System Environment

The image processing Cloud System Environment (CSE) consists of three establishing service layers: an infrastructure, platform, and software [3]. All these layers will formulate the needed environment for image processing cloud model, which could be one or more of the deployment models: Public, Community, Private and Hybrid Clouds. Figure 1 shows the proposed CSE.

CSE for image processing services summarized in an image processing algorithms execution environment providing algorithm functionality in libraries platform to be used in image application implementations and in the form of the environment middleware. The environment, thus, executes image algorithm components and provides common functionality for component communication and data storages. All needed components reserved according to image application understanding, requirements and evaluation. The core of CSE is the basic infrastructure layer, which consists of processing, storability and communication elements.

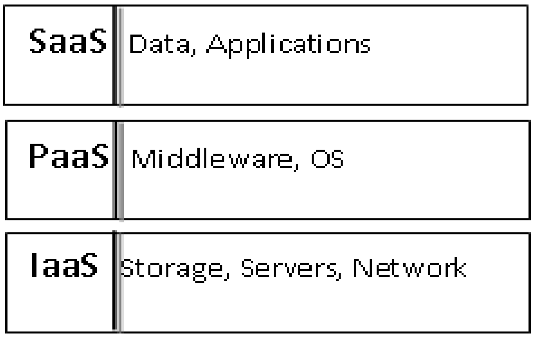


Fig. 1. A proposed Cloud System Environment (**CSE**).

2.1. Cloud infrastructure for image processing as service

The image processing infrastructure as a service (IpaaS) needs to address issues such as large storage and expensive computing requirements for image processing algorithms. An image base cloud resource refers to a server-based or server cluster in the cloud environment, which has high computation power and can support concurrent multi users [4]. The server may reside on a remote node and can be managed by a third party so that the cloud system customers do not need to concern themselves with software and hardware installation and maintenance. Due to image processing addressed problems, IaaS for image processing applications must have a reliable and flexible model based on CPU, RAM, Disk storage, Network and bandwidth on both sides pricing and technical specification. Scalable virtualization size with additional resources as needed, highly available and securely redundant infrastructure. Its goal is to provide a standard and flexible operating environment that becomes a foundation for PaaS and SaaS.

It is important to assess the performance and security of cloud environments, therefore modeling and simulation techniques are suitable for these issues. To build benchmarked image processing based cloud infrastructure, the service provider must face the challenges of integrating complex software and hardware from multiple vendors, i.e., heterogeneity. Table 1 shows the key requirements that must be taken into account when building cloud infrastructure strategy, those keys supported by service-oriented architecture (SOA) and service level agreement (SLA).

Back to the market, RightScale [5] conduct many surveys' to rich the policies of deployment infrastructures as a service model, It surveyed 997 professionals across different type of organizations on their adoption of cloud computing systems. 81% of respondents have a multi-cloud strategy. 96% of respondents are new customers. Enterprises benefit from an average of 5 clouds. Respondents already run applications in 3.1 clouds and test 1.7 again for a total of 4.8 clouds. Of those using any public cloud, the average is 2.7 public clouds used, with an average of 3.0 private clouds being used. RightScale uses its cloud maturity model on a level of segmenting and analyzing organizations. The cloud maturity model defines four distinct phases. Cloud adoption denoted by organizations from least to larger experience, this is shown in Fig. 2.

Table 1. Test model specifications and test conditions.

Key Requirement	Key Performance Indicators	Performance Criteria
Heterogeneity support	SOA	Benchmark
Manageability	SLA	QoS
Workload dynamicibility	SLA	QoS
Reliability	SLA	QoS
Availability	SLA	QoS
Security	SLA	QoS
Integration-ability	SLA	QoS
Manageability	SOA	QoS
Visibility and reporting	SLA	QoS

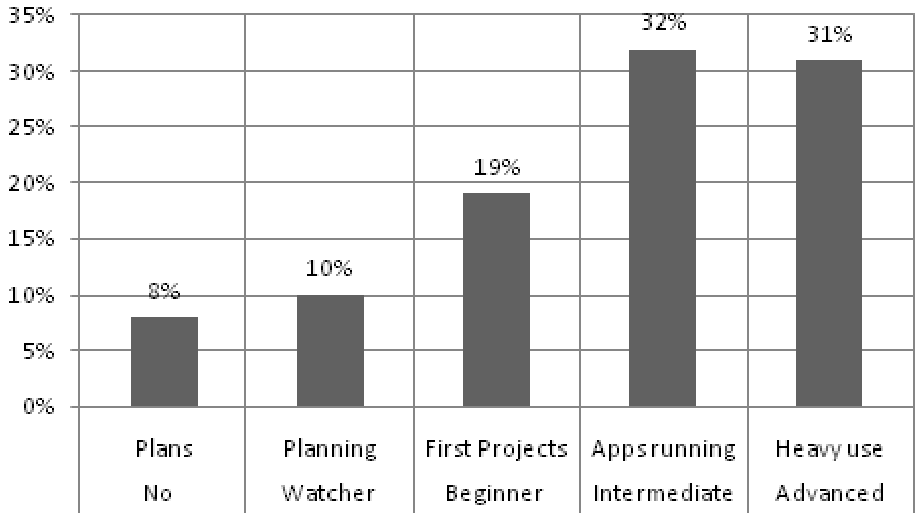


Fig. 2. Maturity respondents [5].

The role of the cloud architect has emerged depending on an increment of cloud maturity; where 61 percent identify themselves as cloud architects and play its role. Figure 3 shows the cloud architect roles.

The needed infrastructure must be flexible configurations sized for any application, that means requirement hardware for building IaaS depend on image application to decide the memory size, virtual CPUs, disk space, and transferring speed, all these requirements are the responsibility of cloud as well as IT architects. Cloud provider's responsibility is to provide cloud consumer with required hardware within SLA, high availability and efficient reliability to achieve on-demand architecture.

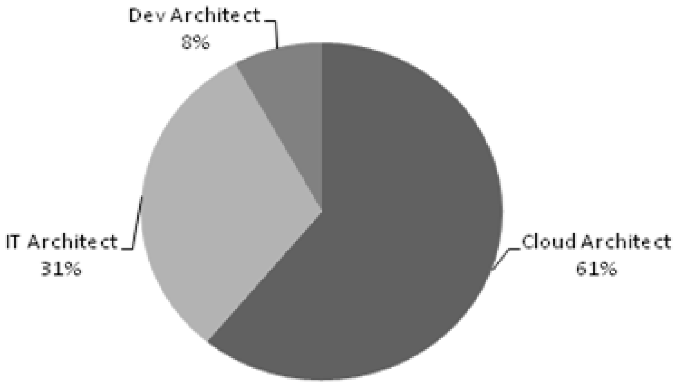


Fig. 3. Cloud architect roles.

2.2. Image-based cloud platform

In general, the image processing platform as a service (IPPaaS) is the provision of cloud services for image application infrastructure (middleware) as well the foundation technology for image processing (IP) algorithms. Cloud architects and IT planners in the fields of image processing application rely on the platform as a service (PaaS) in their construction decisions such as public, private and hybrid clouds. In the image processing field, PaaS is a cloud computing model that provides IP users with hosted IP development tools, database tools for image datasets, and IP application management capabilities. In this case, IP PaaS is often used as extendable platforms for new or expanded IP applications. The service offered tends to operate through the usage-rate pricing model, allowing for scalability and flexibility aspects. The cloud platform can consist of three basic modules to support image processing algorithms. These three basic modules were: image data set reception, image processing computing, and application delivery algorithm, Fig. 4.

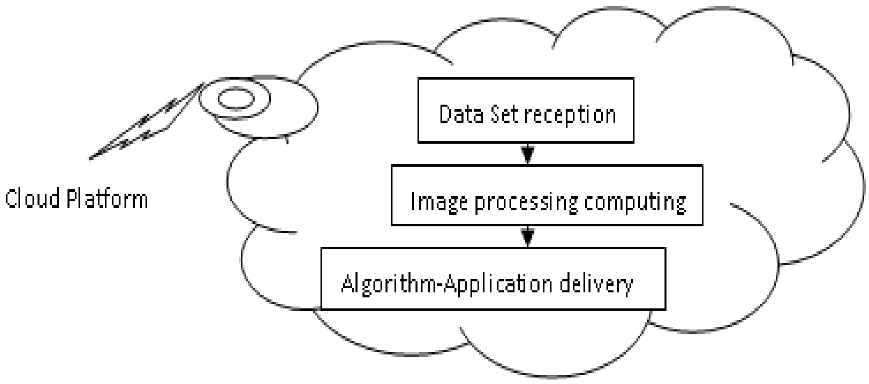


Fig. 4. Image processing cloud platform based.

According to Fig. 4, data set reception is built on consumer request within application needed format. All needed requirements and approaches to building it must be covered by both SOA and SLA.

2.3. Image processing software as service

Image processing software as a service (IPSaaS) is a distributed software model where a third-party provider hosts applications and makes them online available to customers. In image processing, these applications mean a set of computational techniques for image analysis, enhancement, compressing and reconstruction, as well providing image processing services for medical, forensic analysis, remote sensing, and other daily life image applications, Fig. 5. It is suggested being a computing layer for image processing implementation in a field of image usages. An image processing techniques and approaches will be a subject of both SOA and SLA agreements from point of scalability, reliability, availability, and security. Although all these issues are related to cloud capability, they will be varying degrees of importance. Therefore, it is necessary to examine the benefits and risks of cloud system environment to fully assess its integrity and safety [6].

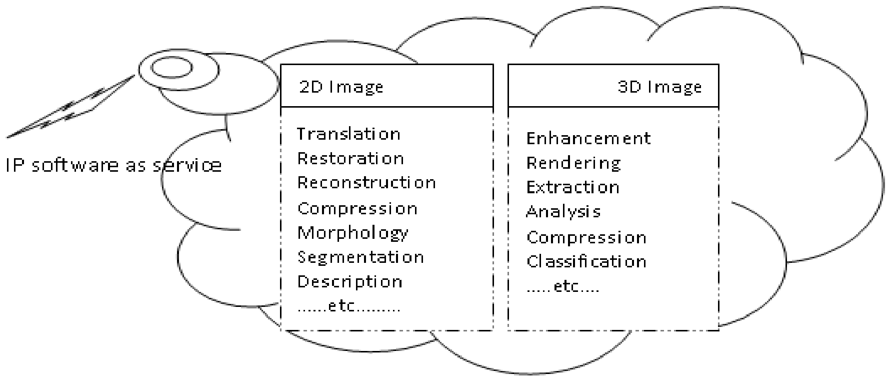


Fig. 5. Type of image processing services on a cloud.

In literature as well as market, there are some experiences in building such as service in image usage fields. According to Liu et al. [3], iMAGE cloud is an example of using the software as a service (SaaS) for securely, conveniently and efficiently medical image processing. The iMAGE cloud consists of infrastructure, platform, and software cloud computing layers. Where, the infrastructure layer consists of needed processing, storing and communication nodes. The platform layer consisted of four fundamental modules to support medical images in terms of data reception, integration, processing, and delivery, while the software layer provides image query and processing functions. Mirarab et al. [4] reviewed cloud medical image processing, its challenges, and benefits, also they introduced medical images processing methods and tools based on a cloud environment.

Nanda and Hansen [7] proposed a cloud with multi-layered architecture for Forensics-as-a-Service (FaaS), which able to deal with the challenges of time-consuming and expensive solutions. It introduced a new forensic infrastructure-level that supported by cloud providers. Their proposed architecture supports cloud based automated digital forensic analysis, where all major challenges are addressed, and the missing bridge between the cloud provider and investigating agency were built as SaaS forensic model. Based on studies by Guo et al. [8], OpenRS-Cloud explores the use of cloud computing to process remote sensing images. OpenRS platform executes parallel remote sensing image processing applications on a massive data set. It is clear that the use of SaaS is widespread as image processing application platform services. This paper follows some of them because there is no marketing analysis for image processing SaaS. Gartner [9] says that worldwide public cloud services are growing market, financially wise, however, performance and technically are not tackled, in which, it is a question of research for this paper. In section 3, we will discuss some reviewing factors for some third-party image processing/manipulation services. These factors will include performance, availability, scalability, capacity, and reliability.

3. Image Processing Cloud Computing reviewing Factors

In general, there are a number of factors that should be considered seriously before moving to cloud services in image processing or to utilize cloud computing to address big imaging datasets. Therefore, the factors mentioned in the previous section will be tackled from a technical and applied point of view and somehow tested on third-party image processing/manipulation services. These factors organized based on service level architectures (SLA) and their key performance indicators (KPI) [10], Table 2.

Table 2. Cloud SLA categories with its KPI [10].

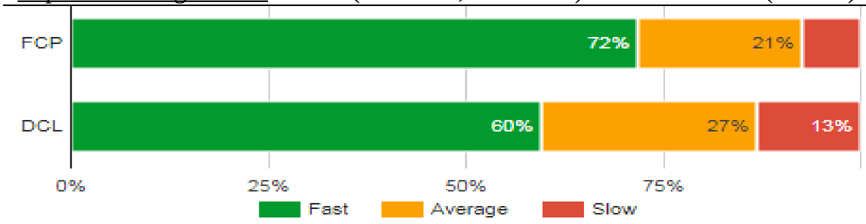
SLA	KPI	Description	Measurement unit
Availability	Service slot	A slot of time within KPIs are measured	Time range
	Availability of service	Percentage of time for availability of service	%
	MTBF	Mean time between failure	Time unit
	MTTR	Mean time to recovery	Time unit
Performance	Response time	Length of time for the task to respond	Second
	Elapsed time	Amount of time for the task to complete	Time unit
	Throughput	Number of requests processed per time unit	Request count
Capacity	Bandwidth	Service connection bandwidth	BPS
	Processor speed	A clock speed of a processor	MHZ
	Storage capacity	A temporary or persistent storage capacity	GB
Reliability	Reliability of system	The probability of system failure free	Percent
Scalability	Scalability of system	The ability of a system to expand	YES/NO

3.1. Performance factor

The performance factor can be measured as a service level category with response time, elapsed time and throughput key performance indicators. Thus, response time can be used as a good parameter in the SLA agreement [11]. Table 3 shows some 3^{rd} party image processing – manipulations services companies, they were checked by page speed insights as an example for performance service level category [12]. Performance checked by measuring First Contentful Paint (FCP) when the user sees a visual response from the page. The fastest times are likely to make users committed to the cloud service provider. The documents object model content loaded (DCL) was measured when HTML document was loaded and analyzed. The fastest times have been shown to be associated with low bounce rates.

Table 3. Page speed insight check for some 3rd party image processing-manipulations services companies.

Company_URL	Page speed	Optimization
http://www.imgix.com/	Fast(0.7s FCP, 1.1s DCL)	Medium (75/100)



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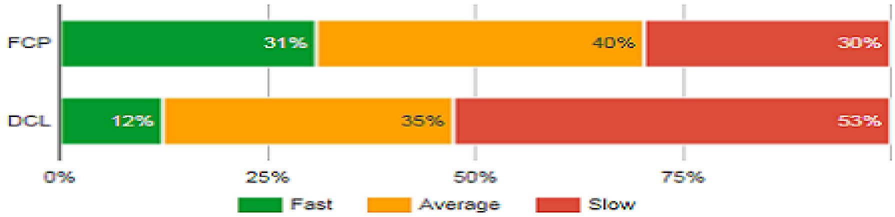
Company_URL	Page speed	Optimization
http://cloudinary.com/	Slow(2.2s FCP, 4.4s DCL)	Good (86/100)



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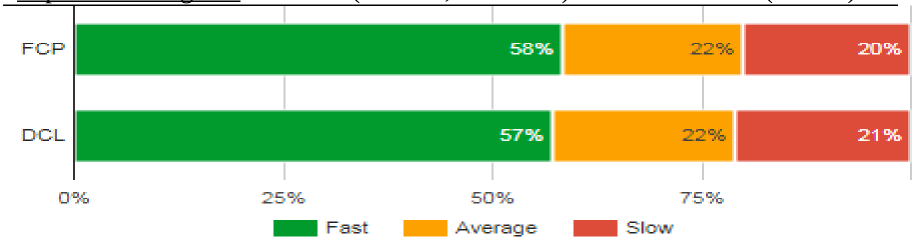
Company_URL	Page speed	Optimization
http://cloudimage.io/	Fast(.7s FCP, 1.1s DCL)	Medium (64/100)



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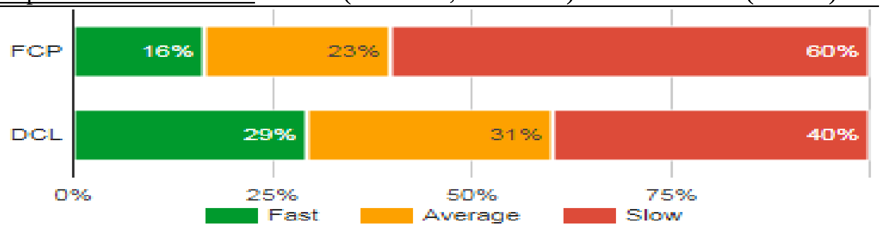
Company_URL	Page speed	Optimization
http://www.blitline.com	Slow(2.6s FCP, 2.5s DCL)	Medium (63/100)



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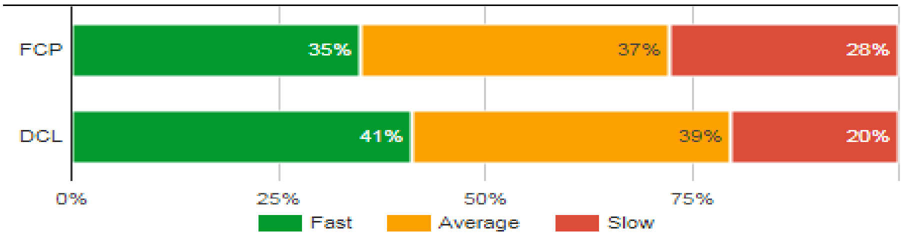
Company_URL	Page speed	Optimization
https://transloadit.com/	Average(1.4s FCP, 1.6s DCL)	Medium (75/100)



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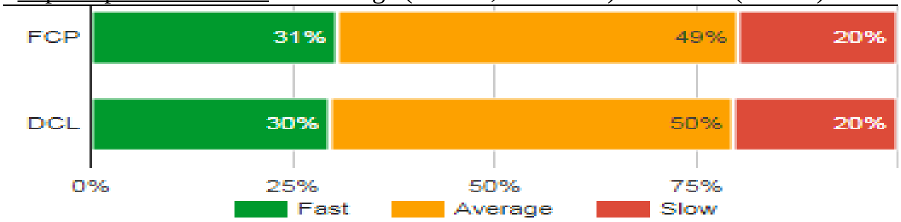
https://uploadcare.com/	Average (2s FCP, 2.7s DCL)	Good (76/100)



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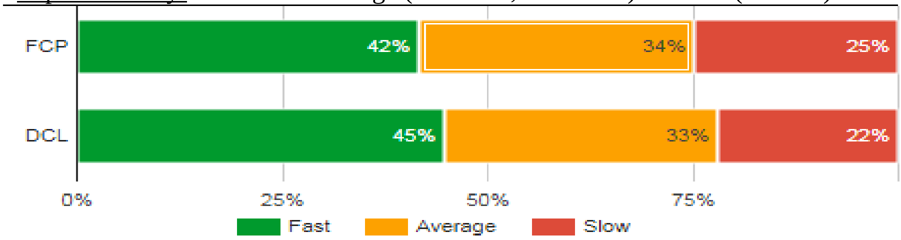
http://embed.ly/	Average (1.2s FCP, 1.5s DCL)	Good (77 /100)



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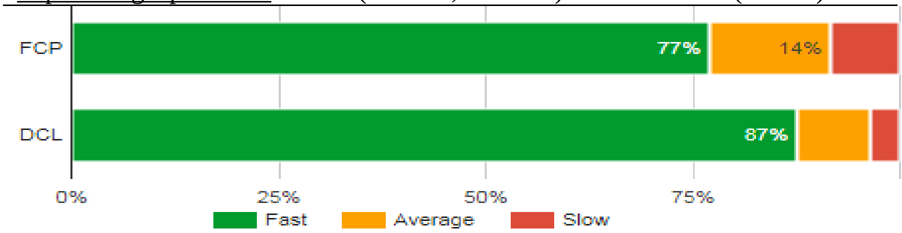
https://imageoptim.com	Fast (.4s FCP, .3s DCL)	Good (87/100)



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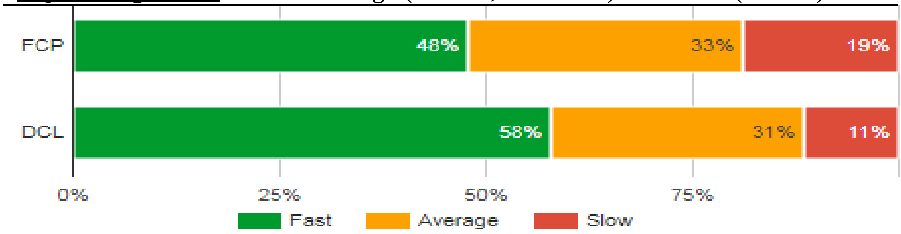
https://imagekit.io/	Average (1s FCP, 1.1s DCL)	Good (92/100)



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3.2. Performance factor

The availability factor as service level category could be measured by service slot, availability of service, mean time between failure and mean time to repair. Availability measurement depends on SLA in terms of its measuring and monitoring to the given availability percentage. Cloud availability is often measured in nines. Low-level services may offer two nines (99 percent) uptime. A solid solution may go for four nines (99.99 percent) availability. But when it comes to cloud resiliency, five nines (99.999 percent) uptime is the target most of the industry considers the upper echelon [13]. High availability has been one of the greatest challenges for service providers, and many services can be used to improve availability, such as check pointing, load balancing, redundancy, and replication. In addition to services, infrastructure and middleware solutions could be found [14]. Availability is a percentage value of how often the application is available to handle a request for service when compared to the total planned run time. The availability formal calculation includes repair time; therefore, it is calculated using several measurements such as mean time between failure (MTBF) and mean time to recovery (MTTR), where the availability formula looks like

$$Availability = (MTBF/(MTBF + MTTR)) * 100 \tag{1}$$

Previous 3rd party image processing – manipulations services companies could be tested for availability factor using IBM cloud, availability monitoring [15]. The simulation will give results of up, down and response times for a given period of time, which it suggested being one month; Availability will be calculated according to Eq. (1), and it should be five nines for high accessible and reliable image processing cloud service.

3.3. Reliability factor

Reliability is one of the key factors to consider in a cloud system environment. It is defined as the probability that a particular element will perform its specified function for a specified period of time under a given set of conditions [16]. It is usually measured in terms of the mean time to fail (MTTF); based on the accumulated data from long use of the cloud system and determined as follows [17]:

$$R(t) = \int_0^t f(t)dt \tag{2}$$

where $R(t)$ is the reliability at time (t) and $f(t)$ is the failure density functions.

For most cloud services, SLAs contract is defined based on availability; where the reliability of the cloud system environment is depended on its error tolerance and situation adaptability. The reliability degree depends on system fault free or failure resistant. A various type of failures could be detected in the cloud system environment such as software, overflow, timeout, database and resource failures [18].

3.4. Capacity factor

This parameter measuring the capacity of components of a cloud computing environment from point of view of network infrastructure bandwidth that host the image processing as service, storage capacity for image processing datasets and servers processors speed. Providers of image processing as service should calculate the bandwidth of the desired customers by considering the available amount of bandwidth as well as using the needed average for a variety of applications.

The architect of the image processing infrastructure as a service should take into account the transmission risks calculating the required uploading time for both primary and all outstanding backups. For this reason, providers of cloud computing backup are working hard to improve the overall bandwidth connections. To sort out from bandwidth problems an incremental backup and link load balancing technologies could be used for reducing or balancing the transmitted amount of data. In addition, both reduplication and file compression techniques used to decrease the number of transmitted files over cloud infrastructure bandwidth. That means the bandwidth is a critical factor of any application deployment on the cloud [19]. The other parameters of this factor, i.e., CPU speed and storage capacity can be determined by pay as you use policy that means the average cost of CPU (per hour), average bandwidth (per GB/month) and average storage (per GB/month) [20].

3.5. Capacity factor

Cloud system resources and computing power are provided through virtually distributed and shared services. Through cloud computing, services can be updated to deal with the increasing rate of data on the internet [21]. Scalability includes the ability to increase workload within existing infrastructure without affecting performance. In general, a scalable system is a system that improves performance after adding devices, commensurate with added capacity [22]. Scalability is one of cloud computing characteristics, which can be performed at different levels: server scalability, network, and platform scalability [21]. By agreement level, scalability factor could be defined as a degree that enables the service or system support a specific growth scenario. SLA focuses to ensure the required performance and scalability delivery for customers in a cloud system environment. Therefore, scalability is the resource increasing capability to yield linear increasing of capacity. The key characteristic of a scalable application is that additional load required additional resources rather than extensive application modification. The system scalability defined by it is load, performance and resource utilization. In this case, the efficiency of a scalable system (ESS) can be determined based on the system's effective capacity (SEC), Eq. (3) [23].

$$ESS = \left[SL(t) - SL(\min)\right] / \left[SEC(t) - SEC(\min)\right] \quad (3)$$

where SL (t) refers to system load during the evaluation period of time, and SL (min) refers to the minimum system load. SEC (t) represents system effective capacity for SaaS during the evaluation period, while the SEC (min) represents the minimum system effective capacity for SaaS. To increase the scalability of image processing algorithms as service one of the following approaches must be applied: doing more computing in the clients, using database abstractions, and shifting the time of usage to periods when there is usually low load. For the hardware infrastructure, there are two approaches to take: vertical and horizontal scaling, where vertical is the process of upgrading the hardware while horizontal deals with the process of adding more hardware to increase the aggregate computational power [24].

4. Cloud Computing Impacts on Image Processing

Cloud computing benefits include low-cost, network availability, expandability, innovation power, friendly utilization, and environmental protection [25]. Fortunately, the cloud system environment not only provides an efficient data management service but also provides a convenient image processing algorithms implementation. Rapid image processing services should be integrated into the unified cloud system architecture. The cloud system architecture should provide users with a complete image processing service through efficient data management and distributed parallel processing.

Cloud computing platforms must provide scalable resources to implement complex image processing algorithms. Image processing algorithms and application should use the benefits of tasks distribution and parallel extraction across available multiple nodes of cloud computing infrastructure for performance improvement. Cloud infrastructure as service should provide and carry out processing tasks for image analysis, reconstruction [26]. With cloud-oriented architecture, cloud system environment provides a good solution to address issues such as mass storage of datasets and the high computational needs of processing different image processing requests [27]. A different type of images, i.e., 2D or 3D can be processed over cloud computing use benefit of splitting merging techniques, which enhance the performance of imaging analysis and reconstruction as well its idle time [28]. Cloud computing services and deployment models could formulate a digital image processing environment. The latter is a distributed architectural node that provides a set of algorithms to implement image processing applications as service within programming, services, and communication [29].

5. Conclusions

The improvement of cloud environment technologies has provided investigation opportunities in all aspects of cloud computing deployment and services. CC is becoming more attractive for many image processing algorithms due to fact that it provides multi-computing services like storage, host and processing servers. Although, there are numerous benefits and advantages of image processing based cloud computing such as cost savings, reliability, manageability, and scalability. The aim of this study is to survey on cloud computing infrastructure and platform for image processing as service, while the future work should be a survey on its privacy issue and optimal security solutions. IPaaS security is recommending future research direction.

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