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Design of a Vibrations and Curvatures Sensor based on Optical Fibers Using an FPGA

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Abstract. In this work, we present the simulations results for a building monitoring system design. The goal is the flexibility to activate one or more alert modes (alarm sound, warning light, or both) to alert the population in the most effective way possible to a seismic movement. The mechanical effects we are testing are vibration, curvature, displacement, and strain. By the proposed sensing setup, using mono-mode optical fiber and an optical fiber sensor, can be analyzed remotely the data acquired and take decisions in an opportune way. The use of a Field Programmable Gate Array (FPGA) is proposed for data acquisition and processing. The simulations we realize, using six different data sets, are very promising, because of that, many other applications in corrosive or electromagnetics environments could be explored. In future investigations, industrial equipment, conveyor belt structures, or motors will be tested with this design, to detect breakage or malfunction promptly.

Keywords: FPGA; DOFS, optical fiber.

1 Introduction

Optical fiber has taken a leading role in recent decades, specifically, optical sensors are highly versatile [1]. This, coupled with the possibilities offered by distributed optical fiber sensors (DOFS Distributed Optical Fiber Sensor), has led to their being implemented for dissimilar applications; among which we highlight the evaluation of the health and integrity of the structures [2]. A DOFS has distinctive features compared to traditional electronic sensors, including the ability to provide long-distance monitoring of strain, vibration, and many other physical parameters with a single wire mode [3] [4].

For a long time, a human being has been looking for different ways to generate an alert before a seismic movement. This effort has resulted in many ways to do that from an empty bottle placed inverted on the floor, too expensive impact sensors placed in cars, showcases, and buildings, etc. However, how efficient are these systems? This

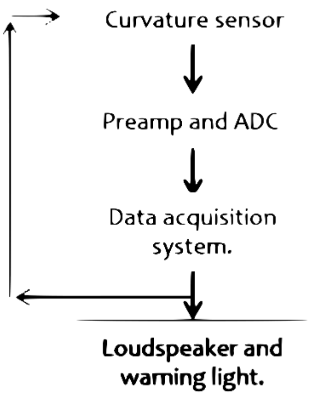

Fig. 1. Block diagram for the seismic warning system.

question is one of the reasons that can cause more problems when choosing a seismic alarm.

In countries prone to seismic activity, there are certain construction standards that respond to studies of the demand and displacement capacity of structures [5]. However, due to the high construction costs, on some occasions, structures are designed with lower resistance than elastic since these demands are not considered in the correct way [5]. Consequently, the damages or collapses in buildings due to seismic activity are generally greater than those predicted by the engineers who worked on their design [5]. Although the economic losses that the collapse of a structure implies are, at times, invaluable, if we consider that they may be the cultural heritage of a certain region, the most important damages are the human losses that they could cause [6, 7]. Therefore, it is important to design policies that minimize these effects [6, 8, 9].

For these reasons, we present the design of a system that allows us to monitor the vibrations, curvatures, displacements, and strain of any structure. The proposed setup uses optical fiber as a transmission medium and a Field Programmable Gate Array (FPGA) as a data acquisition card [10]. With this system, it will be possible to remotely monitor buildings to alert people, using one or more alert modes (alarm sound, warning light, or both), in the most effective way possible to a seismic movement. Additionally, this system takes the advantage that the fiber optics system has magnific immunity to electromagnetic field [11–13]

2 Design

A seismic warning system is composed of a typical vibration signal processing and measurement system. It is made up of a vibration transducer, a pre-amplifier, a data acquisition card, and, in most cases, a loudspeaker. These transducers transform vibrations into electrical signals [14].

The main structure of a curvature sensor is formed by an optical fiber filament through which a beam of light is sent and depending on the change in refraction that

Table 1. Experimental data for curvature.

Curvature [m⁻¹]	Voltage [mV]	Analogic data	Binary data
50	4.66	3.817472	0100000011010000000000000000000
52	4.84	3.964928	01000000011111011011110000000000
54	5.02	4.112384	01000000100000111001100000000000
56	5.2	4.25984	01000000100010000000000000000000
58	5.38	4.407296	01000000100011010000000000000000
60	5.56	4.554752	01000000100100011100000000000000

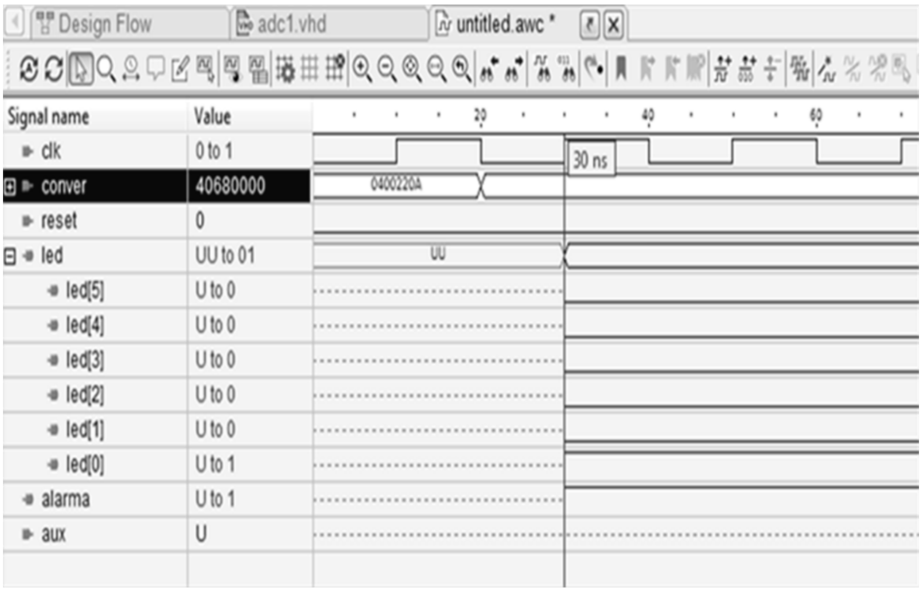

Fig. 2. Simulation's testing.

occurs, a product of the curvature existing in the optical fiber, the curvature is quantified [15]. Curvature sensors allow us to obtain a highly sensitive and compact sensing system when determining small variations in displacement [16-21]

In our project, a curvature sensor will take the place of the vibration transducer, while as a data acquisition card we will use an FPGA from the Altera brand, from the Cyclone V family, model 5CSEMA5F31C6N.

As a first step, the ADC converter equation was cleared. The original equation was obtained in the card's user manual:

$$ADC_{dato} = \frac{4096 \times V_{muestra}}{5v}. \quad (1)$$

Once the equation was obtained, the conversion of the voltage obtained in the sensor to the analog data was carried out, to place it in the code. The analog data were converted to binary; however, when we realized that the analog data obtained was with decimals, we proceeded to use the IEEE 754 protocol, obtaining the following table of results (**¡Error! No se encuentra el origen de la referencia.**).

As the last step, the code was made using the "Modelsim-Altera" software. This allowed us to select from the beginning the FPGA with which we will work and, in this way, make the code with the respective pins.

3 Simulations results

Considering the table of values shown in the development, we conclude that we have six different cases, which is why in our system we will have a series of LEDs that indicate each of the cases, in addition to activating a loudspeaker. The simulation has the reading of the ADC pin, placing a variable that has a range of 4096 bits (which is the maximum value of bits of our ADC).

4 Conclusions

The results obtained during the simulations have been satisfactory, since we have used different tools to perform an adequate calculation, such as the IEEE 754 standard (used to make our programming code).

This system is viable to monitor housing structures by recording the data of vibration, curvature, displacement, and strain to which they are subjected during an earthquake to be able to predict structural effects, even when they are not visible to the naked eye.

This system will allow to intervention in a timely manner in houses, rooms, walls, columns, or any other civil works whose structure has not been affected by the earthquake in its verticality or geometry, however, it has structural damage that could cause total or partial collapse of the work, thus avoiding the possible material losses or human lives that it could entail.

It should be noted that, although our system is oriented to structures such as buildings or homes, it can be adapted to any structure and/or industrial area, such as monitoring motors, conveyor belt structures, etc.

By using fiber optics, it allows us to monitor large spatially distributed structures with a single cable (multi-mode or mono-mode fiber optic). It must also be taken into consideration, that the system has high durability and low-cost maintenance because of the use of fiber optics as a transmission medium.

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Sistema óptico HSI mediante la conjugación de la pupila con la superficie de un espejo refractor

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Resumen. En un sistema óptico formador de imágenes con luz incoherente, el estudio de imágenes espectrales es de gran importancia debido al gran contenido de información que se puede obtener de algún objeto en cuestión. Con ayuda de un objeto colocado en la pupila de salida, y siguiendo la teoría de formación de imágenes se muestra el diseño un sistema formador de imágenes que permite observar el espectro óptico de un objeto de prueba, en este caso una abertura circular y un filamento de una lámpara incandescente, mediante la conjugación de la pupila sobre un espejo refractor que, con un sistema mecánico para realizar el escaneo, obtenemos un conjunto de imágenes hiperespectrales.

Palabras clave: Spectral imaging, image processing, optical systems.

1. Introducción

El diseño de sistemas ópticos formadores de imágenes ha visto un desarrollo desde hace tiempo en las técnicas espectroscópicas, como medio de análisis e inspección no invasivo, debido a la posibilidad de obtener información sobre los componentes de una muestra basándose en la absorción de la luz [1-4]. Con el apoyo de las técnicas espectroscópicas del visible/infrarrojo cercano y las técnicas de visión por computadora, ha surgido lo que se conoce como espectroscopia de imágenes [5-7]. Las imágenes hiperespectrales son un mapa de intensidad de luz que se puede extender en una o varias regiones del espectro electromagnético [8]. Las imágenes hiperespectrales son un conjunto de datos tridimensionales de un objeto o muestra, estos datos contienen información espacial y espectral. Al conjunto de datos tridimensional comúnmente se le denomina “cubo hiperespectral”. Los datos de un cubo hiperespectral pueden revelar información oculta, como por ejemplo la composición química o anatómica de un objeto [9]. Las imágenes hiperespectrales a menudo se utilizan para detectar elementos físicos y geométricos. Características tales como color, tamaño, forma y textura. También se puede utilizar para extraer información química y molecular intrínseca (como agua, grasas, proteínas y otros constituyentes) de un producto. Los sistemas de imágenes hiperespectrales o también llamados HSI tienen la capacidad de obtener

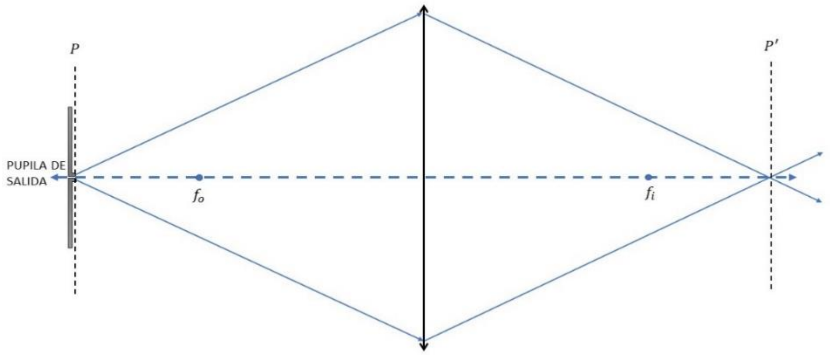

Fig. 1. El objeto en este caso, la pupila de salida, y los puntos de la imagen en P', corresponden entre sí y pueden intercambiarse.

imágenes de más de 100 bandas espectrales. Los elementos principales de un sistema formador de imágenes espectrales son los siguientes [10]: Fuente puntual de luz, lentes y filtros, sensor de imagen, sistema de barrido, y hardware y software para procesamiento de imágenes.

2. Conjugación de pupila

Se entiende como conjugación de planos cuando el plano P, es el plano P', tal que los puntos P son imágenes de P'.

En relación con la conjugación de pupila, tomamos la salida de la pupila como el plano P, y a la superficie del espejo refractor como el plano P', de manera que la pupila es imagen de la pupila que se forma sobre la superficie del espejo difractor.

Teniendo como base la teoría de formación de imágenes, y aplicando el tratamiento matemático para el caso con luz incoherente, se puede describir matemáticamente la obtención de las imágenes hiperespectrales mediante la conjugación de pupila y obedeciendo a la siguiente ecuación:

$$\ldots\ldots g(x,y) = h(x,y) * O_i(x,y).. \, , \tag{1}$$

donde g(x,y) corresponde a la imagen, h(x,y) al sistema óptico y O(x, y) la intensidad del objeto.

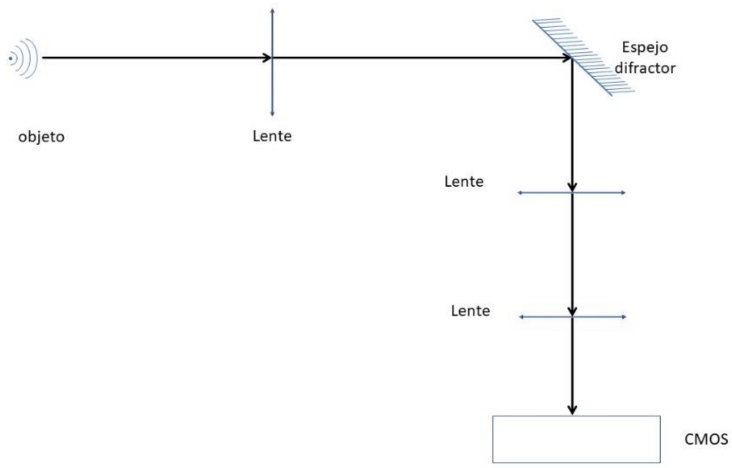

Fig. 2. Esquema del sistema formador de imágenes.

3. Diseño de experimento y resultados

3.1 Diseño de experimento

Con ayuda de un objeto prueba, colocado en la pupila de salida del sistema óptico, se monta un sistema formador de imágenes que permite observar el espectro óptico del objeto. Para este trabajo, se utiliza un espejo que contiene una rejilla sobre su superficie lo cual da a lugar a una conjugación de planos para obtener la formación de imágenes, este método se conoce como conjugación de la pupila.

– El sistema se probó utilizando una apertura circular en el plano del objeto, para simular una fuente cuasi-puntual.
– Posterior a la pupila se colocó una lente para colimar los rayos de luz provenientes de ella.
– En seguida con el haz de luz colimada de coloco un espejo difractor de forma cóncava.
– Finalmente, con el reflejo de la luz ya difractada se monta un sistema de lentes telescópico y se forma la imagen sobre el detector CMOS.

Un sistema mecánico realiza el escaneo en el plano imagen, la cantidad de imágenes obtenidas pertenecen a imágenes hiperespectrales.

Fig. 3. Resultados de la segmentación de frecuencias de la luz emitida por LED.

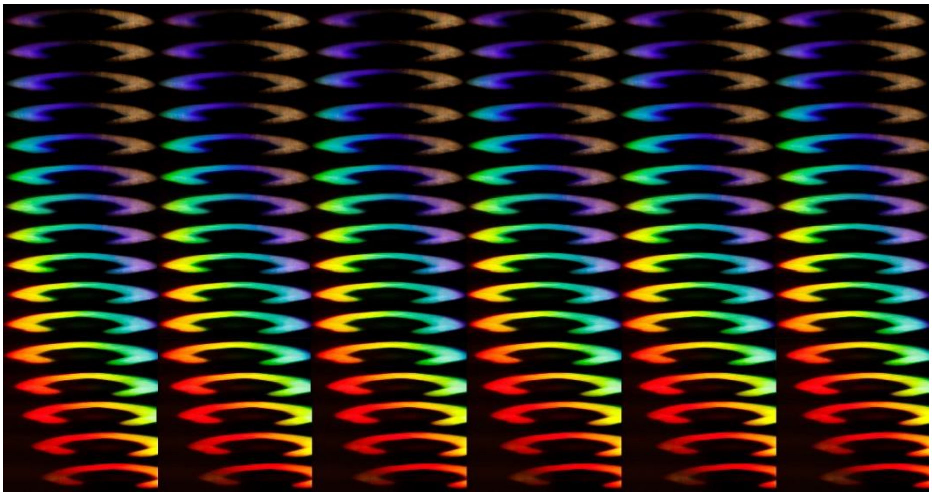

Fig. 4. Segmentación frecuencial del filamento incandescente.

3.2 Resultados

Las primeras pruebas se realizaron con un LED blanco, al cual se le coloco una pupila enfrente de manera que se pudiera simular una fuente cuasi-puntual, de esta prueba logramos obtener un set de imágenes donde se observa la transición de las frecuencias del espectro óptico en las que emite el LED, se puede apreciar claramente como en las zonas más frías del espectro emite con mayor intensidad, pero en la zona del espectro rojo, se aprecia en menor medida.

Se volvió a realizar el procedimiento, pero se sustituyo el LED por un foco incandescente, el cual nos permitió observar un mayor rango de frecuencias del espectro mucho mejor definidas y con más intensidad en su filamento, lo que nos permitió corroborar como el sistema es capaz de obtener una gran cantidad de imágenes a lo largo de todo el espectro óptico que emite un objeto.

4. Conclusiones

Con un sistema formador de imágenes se puede tener una gran cantidad de imágenes en el ancho del espectro de la luz visible, como se puede observar en el filamento del foco incandescente, inclusive la configuración, no cambiaría mucho si se desea medir infrarrojo cercano y el UV.

Esta técnica permite realizar análisis de imágenes espectrales que contienen una gran cantidad de información en áreas como los son el estudio de muestras biológicas o químicas, para así conocer su estado, defectos o incluso si están contaminadas con algún agente externo.

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Overview of Cloud Simulation Tools: A Comparison of Cloud Computing Simulators

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Abstract. Cloud computing comprises of transferring of secure, maintainable, dependable, scalable and fault tolerant infrastructures for simplifying web oriented application facilities. These applications consists of different deployment, setup and composition requirements. When cloud computing deployment and adoption expands, its distinguishing to obtain cloud computing environs performance. Simulation and modeling feasible for obtaining security and performance issues. For testing of cloud framework, cloud simulators required to diminishing complication and sift out quality concerns. Some cloud simulators specifically made for testing of cloud computing environs performance. This paper presents review and compare characteristics of different kinds of cloud computing simulators.

Keywords: Cloud simulators, GroudSim, Green Cloud, CloudSim, EMUSIM, OCT, SPECI, ICANCLOUD, MDCSIM, CDOSIM, DCSIM, GDCSIM, TeachCloud, CloudAnalyst, CloudReports.

1 Introduction

In every day’s life, the origin of digital technology and Internet extremely transformed mode people act and interrelate in both specialized and personal situations. Family, work and social life are becoming gradually intertwist with the Internet, sometimes even blurred together. The office no more uses only for workplace, people mostly used to deal with personal problems, through instant messaging, e-mails or social media. Inversely, proficient and professional actions spread all over the day while traveling, during lunch break either at home or at office, or after completing work, people don’t feel hesitation to complete their work and to check their e-mails.

Without direct access to their computer, from any place and at any time, people are capable enough to achieve their professional or personal documents. Thus, Internet has become a necessity, in most advanced and developed countries.

Ubiquitous computing is an effort to fulfill or to answer user's need for ubiquity. Without trying to resolve any specific technical or business problem, UC shows struggle to describe new opportunities based on connectivity and pervasive computing. Computing has become fundamental part of our everyday life, nowadays. In the computing industry, technological advances like electronic devices are used and placed in the environment in such manner that it is invisible to end user's.

CC (Cloud computing) is the next evaluation step in computing [28]. For the internet, cloud is a metaphor, focused on how it is illustrated in computer system graphs and is a notion for the difficult or complex structure it covers. It is a form of computing in which IT-related capabilities are sold as a kit, enabling customers to obtain technologically-enabled services over the internet without know how of the expertise or technology infrastructure that supports them. When you store your pictures online using social networks, websites rather than using home computer and laptop, basically you are using a service called cloud computing.

Cloud computing offers shared pool of resources, including networks, data storage space, user applications and computers processing power. Cloud services are famous because they could decrease the cost of owning and operating networks and computers. Cloud users do not need to buy cloud infrastructure, get software license etc. Clouds provides everything as a service.

Hence there exist three types of services, one of them is (SAAS), 2nd is (IAAS) and the 3rd one is (PAAS). In IAAS providers offer virtual machines and other resources. In SAAS, providers provide access of databases and application software's to the users. In PAAS, providers offers the operating platform involves operating system, programming languages environment etc. [27, 38].

Just like cloud services there are different deployment models with deviations in physical position and distribution which have been accepted by the cloud computing. A cloud can be categorized as public, hybrid, private and community based on the deployment model. Cloud provides potential benefits but clouds faced several information security issues and risks. Issues can be differ according to the sensitivity of data how it will be stored and processed and how will choose the cloud service providers. Cloud computing main power is delivered by the grouping of data centers, for offering computing environment, which has been used to be installed with 100 to 1000's of servers. At the higher level there exists application services such as data processing, webhosting, social networking etc.

The lower level comprises of storage server and these servers are used to be managed by the higher level virtualization services and these services provide the opportunity of fault tolerance and security. The main difference b/w data center and cloud is that data center is an on premise hardware which keeps data store inside organization's local network, cloud, on the other hand, is an off-premise mode of computation which stores data or information by using internet.

In research areas, now-a-days cloud computing is an interesting and beneficial field and quickly gained fame of scholars, researchers and industries. On the internet, it is basically the distribution of computing resources and facilities. There are several firms which are running in cloud computing atmosphere and supply facilities and resources firms such as IBM, Microsoft and Amazon etc. With the advancement of cloud technologies, new possibilities for internet based applications are emerging. These new application prototypes might be assembled into two classes. On one hand, there are

Cloud Applications	Social Networking	Webhosting	Data Processing
Virtual Machines	Virtual Machine Windows	Mac OS	Linux OS
Application Server	Virtual Machine Monitor		
Storage Server	Storage Virtualization Management		

Fig. 1. Cloud Based Typical Data Center.

large scale programming framework suppliers that produce applications, cloud service providers, on the other hand, exist. To reduce overheads, these applications can get profit from cloud infrastructure administration.

To minimize complication and separate quality issues, cloud simulators are needed for cloud structure testing [1]. Simulation-based approaches support Information Technology organizations by helping them to analyze their services in a managed and repeatable environment, as well as experiment with various task configurations and resource performance scenarios on virtual systems for designing and testing adaptive application provisioning strategies.

Available distributed system simulators does not provide an atmosphere which we can directly use for sculpting cloud computing atmosphere, CloudSim, on the other hand, is a simplified simulation tool that gives the permission of experimentation of evolving application services and cloud infrastructures. On cloud computing there exists two types of simulators, one is software-based, and the other is software-and-hardware-based. Number of cloud simulators are increasing day by day and they have been specially designed for performance analysis of cloud computing atmosphere. Cloud simulators' several capabilities will hasten the development and introduction of new technologies.

The remainder of the parts are organized as follows: Section 2 focuses on background about several available simulators. Section 3 define and explore numerous cloud simulators such as CloudSim and many others. Section 4 provides the comparison of various cloud simulators and the paper comes to a close with section 5.

2 Background

In earlier days, Grids developed an infrastructure to provide high performance services for the computing of scientific operations. To facilitate research numerous grid simulators proposed, analysis and growth of new grid modules and policies. Some of them are GridSim, GangSim, MicroSim, SimGrid, OptorSim and CloudSim. 1st 3 emphasis on Grid computing based systems. For studying cloud systems, CloudSim is the only framework or simulation toolkit. Hence, in cloud infrastructure gridsim is used to calculate costs of implementing distributed applications. For the simulation of distributed applications, SimGrid is mostly useful. For modeling of grid based resources and organizations, GangSim provides support. For various grid resources, GridSim is the simulation toolkit and it provide support for forming of grid objects

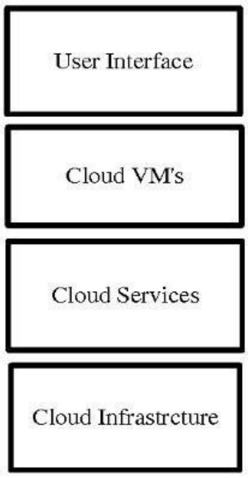

Fig. 2: CloudSim Components.

users, networks and machines etc, but no one is capable to support infrastructure and application level requests.

For providing real time exchanging of services, cloud simulation toolkit provide support for economic objects like cloud dealers and exchange. Between the currently existing simulators discussed above, to provide support for application scheduling simulation and resource management, GridSim is the only simulator [9,12].

3 Cloud Simulators

Simulators for grid computing are useful, but they can't accurately model the cloudframework. Simulation now a days suppose the growing portion in the evaluation and believable results and atmosphere condition testing. It is a weakness of the real-world solution and system's operation. Simulation is the direction how to explore the model. Simulation is the method of producing and discovering d/f directions about a computerized mathematical model of a physical structure or framework. Developers and researchers can quickly monitor and verify the performance of newly built software using cloud simulators. Cloud simulators help new applications develop faster. We offer an overview of the various cloud computing simulators in this section, which are mostly used to assess the stability and security of cloud computing systems as well as provide cloud environment support [10, 34].

3.1 CLOUDSIM

CloudSim is generalized simulation application, for single and internetworked clouds, which supports modeling, cloud operating platforms, application services, and infrastructures are being tested [9, 5]. Using a distributed system simulator to estimate and calculate the performance of cloud systems, policies, and server workload under a variety of system usage needs and configurations is challenging. CloudSim may be used to overcome this difficulty. To put it simply, we can say for the simulation of cloud scenarios, CloudSim is a development toolkit [25]. CloudSim toolkit provide support both behavior and system modeling of cloud constituents like data centers, virtual machines, and resource provisioning plans are also things to consider. These elements may be combined to allow users to quantify new policies, routing, algorithms, and scheduling, among other things. It’s important to mention that CloudSim is a database, not a ready-to-use solution, for creating desired scenarios and collecting results for cloud application success and security review. CloudSim needs to write a java program using its components. Through message passing all components communicate with each other. Without observing low level details associated with applications and cloud services, by using CloudSim users can analyze system problems [42].

In the University of Melbourne, Australia, CloudSim is developed as CloudBus project. Gazebo is an open source web framework that incorporates preconfigured devices plotted to run popular open-source robotic tools and simulators [4].

All CloudSim components communicate with one another through message passing. CloudSim framework’s multi- layered architecture or design, lower level or 1st layer called simulation engine which is responsible for the communication between components and it supports numerous essential functionalities like processing of events, construction of cloud system objects like virtual machines, hosts, servers, and data centers, as well as simulation clock control. CloudSim is a simulation layer that aids in the design of cloud based data center environments with interfaces for virtual machines, storage, bandwidth, and memory. This layer is responsible for basic tasks such as VM hosting, monitoring complex system state (condition), and managing programme execution. Top-most layer is user code layer which depicts basic objects for number of tasks, hosts, number of users and their applications, number of VM’s [23]. WorkFlowSim, CloudSimEx, RealCloudSim, Simpleworkflow, CloudAnalyst, CloudAuction, CloudMIG, CloudReports, and Xpress are some of the other simulation tools that help to extendCloudSim power [16, 8, 29, 21].

3.2 CLOUDANALYST

CloudAnalyst is a simulator with a graphical user interface that was derived from CloudSim and enhances some of its capacitances and functionality [4]. It distinguishes between simulation analysis and programming activities. In a cloud environment, CloudAnalyst is applied to analyze performance of large scale internet application. It permits users to store simulation results in the PDF format. CloudAnalyst allow users to run experiments speedily and efficiently.

It has the ability to display interactive simulation outcomes as graphs and tables. CloudAnalyst is created using a variety of techniques. a) Java (with java) The CloudAnalyst simulator is written entirely in Java. b) Java Swing, which makes use of swing components a graphical user interface component has been developed c) SimJava, CloudAnalyst mostly used some features of SimJava tool [19] d) CloudSim, CloudAnalyst used CloudSim features for designing data centers. CloudAnalyst’s main features include: a) an intuitive graphical user interface (GUI); b) the ability to express simulations with a high degree of usability and configurability; c) experiment replication; d) fortify technologies and ease of extension; and e) graphical performance [36, 41].

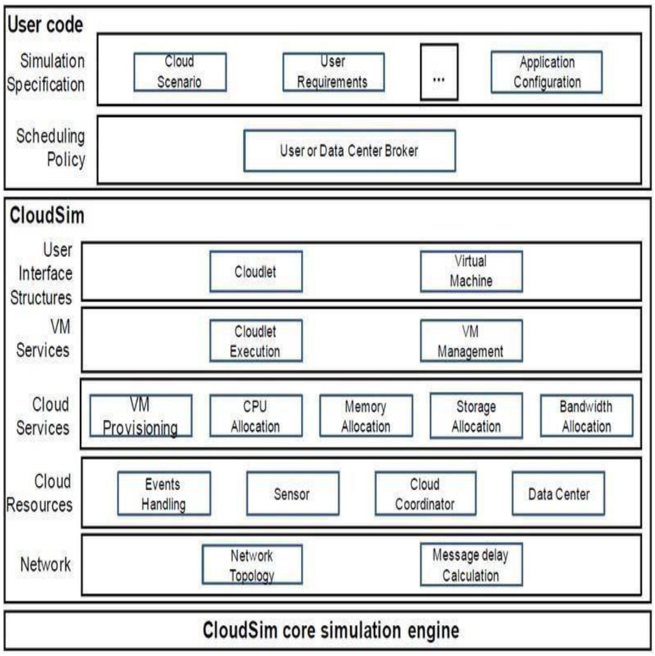

Fig. 3. Layered Architecture of CloudSim.

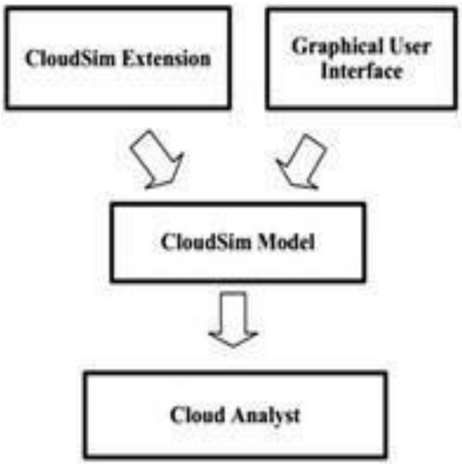

Fig. 4. Pictorial View of CloudAnalyst.

3.3 CLOUDREPORTS

CloudReports tool simulates distributed computing environs depend on cloud computing. In simple terms, CloudReports is a graphical representation of CloudSim provides easy and friendly atmosphere [4]. CloudReports offers various facets for scholars to play part of users and service providers. It is same as CloudAnalyst offer

Table 1. Comparison on basis characteristics.

Factors of Comparison	CloudAnaLyst	CloudReports	CloudSim
Accuracy	Higher	Higher	Higher
Adaptability	Mid	Mid	Higher
Speed of simulation	Higher	Higher	Mid
Efficiency	Mid	Mid	Higher
Scalability	Mid	Mid	Higher
Reliability	Higher	Higher	Higher
Consumptionmemory Overlap	Mid	Mid	Low
Repeatability	Higher	Higher	Higher

atmosphere for simulating cloud computing model without programming abilities and generation characteristic shapes it simpler to comprehend simulation outcomes via exhibiting charts and simulated environs features lists [35]. In CloudReports, supported kinds of extensions are: VM's provision strategies, broker strategies, VM's resource consumption models and schedulers and power consumption models. Ability of user are set quantity of VM's every consumer owns, broker is liable for assigning these resource utilization algo's and VM's set quantity of hosts (computational nodes) and their resource configuration, that contains RAM amount, execution time, processing capacity, resource utilization and available bandwidth and facilitate service providers to estimate their cloud atmosphere before hiring facilities to consumers [37, 6].

Given below tables demonstrates comparison among characteristics and parameters of CloudAnalyst, CloudSim and CloudReports.

3.4 GREENCLOUD

With attention on cloud communication, GreenCloud is established as an innovative packet or carton level cloud network simulator. In simple words, with minimal environmental damage, the principle of planning, producing, and ordering computational resources is known as GreenCloud [22]. It is a supercomputing initiative at Notre Dame University. It provides a computer software environment or network that reduces running costs. It offers a modelling platform for energy- conscious cloud storage data centers. GreenCloud differentiates 3 energy consumption constituents,1st is communicational energy, 2nd is computing energy and the third is an energy aspect that is connected to the data center's physical infrastructure. GreenCloud basic purposes include, to develop high level computing systems like clouds, clusters and data centers that assign resources to application hosting internet facilities or services to fulfill user needs. GreenCloud extracts, collects and makes information fine grained about the

Table 2. Comparison of simulation parameters.

Simulation Parameters	CloudSim	CloudAnaLyst	CloudReports
Data center	√	√	√
Regulationon allocation	√	√	√
Simulation time	√	√	√
Simulatehost	√	√	√
Load balancing	√	√	×
Cost estimate	√	√	√
VM's Option	√	√	√
Request and response time	√	√	√
Social network	√/×	√	×
Federalcloud	√	√	×
Extendservicebroker algo	√	√	√
Cloudletoptions	√	√	√
VM Migration	√/×	×	×
Resources management	√	√	√
Topologiesin data centers	√	√	×
User base modeling	√	√	√
Power consumption	√	×	√
Task scheduling	√	√	√
Energy Efficiency	√	√	√
Security in cloud	×	×	×
SLA Modeling	√	√	√
PaaS Modeling	√	×	×
SaaS Modeling	√	√	√
IaaS Modeling	√	√	√

communication elements of thedata center like network switches, communication links, computing servers etc.

Fig. 5. User view of GreenCloud.

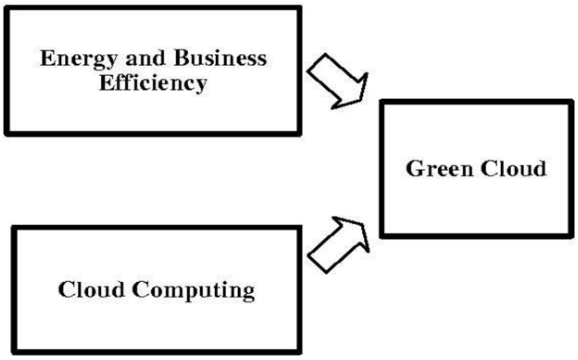

Fig. 6. Pictorial View of GreenCloud.

GreenCloud simulator is an extension or we can say new version of network simulator (NS2) simulator. Disadvantage of GreenCloud tool is that due to its higher simulation time and huge memory requests, it restricts its scalability to only fewer number of data centers [42].

3.5 MDCSIM

MDCSIM stands for multi-tier data center simulation. It is a CloudSim tool that has been tweaked. It assists the customer in predicting and examining data center hardware constraints such as switches, servers, and routers. MDCSIM is developed at Pennsylvania state university [36].

In the architecture of MDCSIM, in a server node, CPU has devices such as a network access card and a disc, as well as procedures. It is assumed that the NIC, CPU, and disc are the essential computational resources in a node that are responsible for processing requirements. Simulation is constructed in 3 layers a) user-level b) kernel-

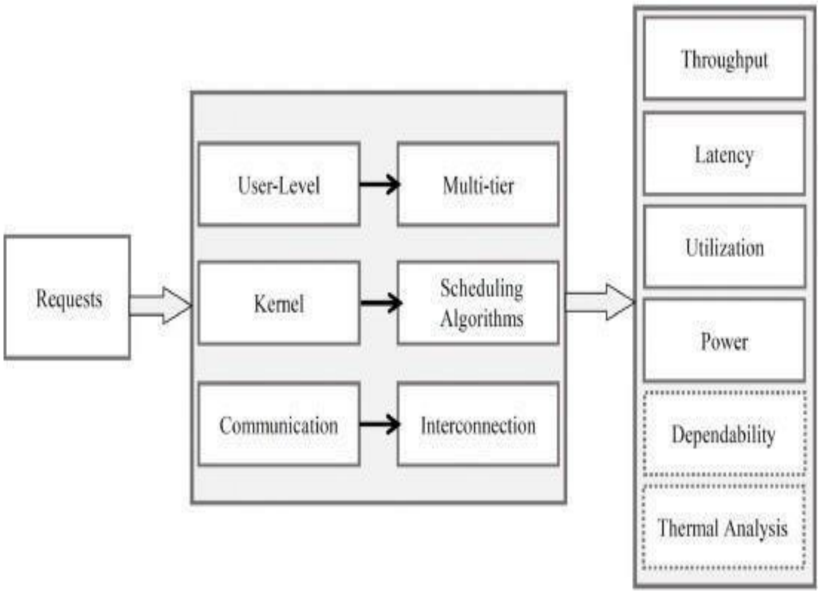

Fig. 7. Multi-tier data center simulation.

level c) communication level layers. To analyze design, 3 layer abstraction provides scalability and flexibility. It is used as a most prominent tool due to its low overhead simulation and in the form of directed graph its network platform keep maintains a data center topology [24, 13, 26].

3.6 TEACHCLOUD

TeachCloud is an extended form of CloudSim. It is comprehensive, efficient and easy to use simulation toolkit. For cloud computing TeachCloud is a simulation and modeling atmosphere. It is basically a research based tool used for the development and justification of research theories in CC (cloud computing). TeachCloud is used by students to do experiments using the d/f cloud modules like datacenters, networking, processing of elements, web-based application, virtualization, business process management and management of resources. Users easily update various cloud system components and their parameters, examine results and can run simulations. TeachCloud was developed primarily for educational purposes. Scholars and students will conduct tests using a basic graphical user interface [20].

3.7 GROUDSIM

Ostermann recommended GroudSim as an event-based simulator for science applications [34]. Forcomplex simulation set- ups, GroudSim offers a comprehensive set of features. SimEngine is the key part of CloudSim which implements the time advance, keeps track of the recorded objects used for tracing during simulation and

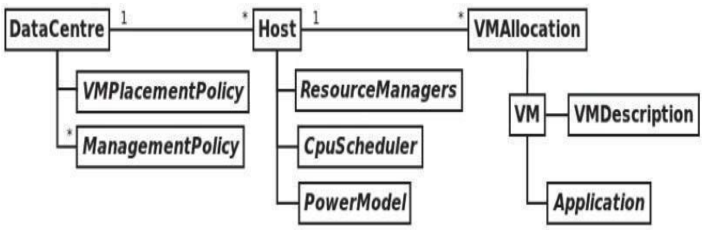

Fig. 10. DCSIM Architecture.

creates a predicted case list. While it is mostly based on Infrastructure as a Commodity, it can quickly be expanded to support other utilities such as DAAS and PAAS. Simulations can be easily parameterized. It offers some research views and statistics after runtime to enable users to quickly write more complicated analyses.

SPECI referred to as simulation program for elastic cloud infrastructures. It simulates the behavior and performance of data centers [39].

It is a type of simulator which scale up the performance of future data centers. It deals with inconsistencies that arise after failures happen.

Discrete event simulations (DES) are simulations in which events are ordered in time and held in a catalogue. SPECI uses currently package for DES in java. SPECI is a combination of 2 packages, topology and data center layout and the constituents for experiment implementation and measuring. The simulator's Experiment section is based on SimKit that provides random distribution drawing as well as event scheduling [2, 3].

3.8 DCSIM

DCSIM stands for data center simulator. It is a Java-based extended data center simulator that's designed to make experimenting and evolving data center management algorithms and methodologies easy. It is focused on developing a simulator to analyze and improve data center management technology in a virtualized data center that provides IAAS. It focuses on continuous workloads, but it can easily be expanded to model other types of workloads. Primary class is data center, which comprises of VM's, hosts, servers, polices and several management components. VM replication is a method for managing which workloads and combining capabilities. It allows research scholars to easily design, develop and estimate dynamic resource management methodologies. It includes new technologies not found in other simulators, such as a multi- tier application model. With the expansion of computing power, data center costs and operating expenses are increasingly rising. Data centers are becoming more well-known for the provisioning of computational services [40].

3.11 ICANCLOUD

SIMCAN is used to create ICanCloud, which is a kind of simulator. It is a device modelling platform for massive storage networks. ICanCloudprovides a complete graphical user interface (GUI) for performing and executing tests, but available software systems can only be demonstrated manually. It enables the concurrent execution of a single experiment through several devices [31]. ICanCloud can predict the cost and performance of different applications on different hardware's and notify users about the cost. On huge storage networks, it is basically used for simulating high level MPI applications [30]. In this tool, there is no need to change the code to examine numerous applications or architectures. This can be accomplished by merely generating anew configuration file [32].

3.12 NETWORKCLOUDSIM

S.K. Garg and Rajkumar suggested it as an expanded version of CloudSim. It is a generalized application model and scalable network. To enhance performance of cloud framework, it permits more precise calculation of scheduling. NetworkCloudSim makes use of the network topology class, which runs the CloudSim network layer, reads a BRITE disc and produces topological based network. In network CloudSim, file holds nodes, no of objects in the simulation and without changing the topology file, it allow users to increase scale of simulation. At any given time, each BRITE node can only be plotted to one object (entity). For the designing of the real cloud sim data centers and plotting d/f strategies, NetworkCloudSim structure provide support. In network traffic of CloudSim, network CloudSim info utilized for simulating latency. In the NetworkCloudSim, there are 3 main entities: NetworkDatacenterBroker, Network Datacenterand Switch. NetworkCloudSim aids in the production of more efficient and advantageous resource management strategies in theconstruction of network systems and complexsoftware that works within cloud datacenters. NetworkCloudSim helps in the modeling of cloud datacenters for the fast simulations [14].

3.13 OCT

Grossman suggested Open Cloud Testbed (OCT). It provides standards to examine d/f cloud computing systems and their interoperability. Cloudcomputing applications and networks are modelled using OCT. OCT framework comprises of 4 datacenters located at the Uni of Illinois (Chicago), John Hopkins Uni (Baltimore), Starlight(Chicago) and the Uni of California. Every rack contains thirty two vertices. Every node comprises of dual-dual core. 2 Cisco switches connect the 32 nodes. At all levels, the framework of OCT contains infrastructure, services and high performance protocols. Rather than using the internet, it employs a high-performance 10 GB network that is built on fast transport protocols. To make OCT more user-friendly, to research requirements, and to build network libraries and monitoring systems to support the experimental studies and development of CC stacks, d/f cloud services and systems are fixed containing CloudStore, Hadoop, Thrift and Sector [15].

3.14 FTCLOUDSIM

It is a CloudSim based framework for estimating and designing cloud services reliability improvement apparatus. To support scholars in executing new methodologies easily, an expandable interface is provided in FTCloudSim. FTCloudSim can examine failures to analyze the behavior of every mechanism. After implementation, it will create statistics and data to highlight the advantages of the mechanism. Replication and check pointing are the 2 mostly used mechanisms. FTCloudSim study the performance of new planned technologies. FTCloudSim has been added new six segments into CloudSim: results generation, fat-tree data center network construction, checkpoint based cloudlet recovery, checkpoint image storage and generation, failure and repair event triggering [43].

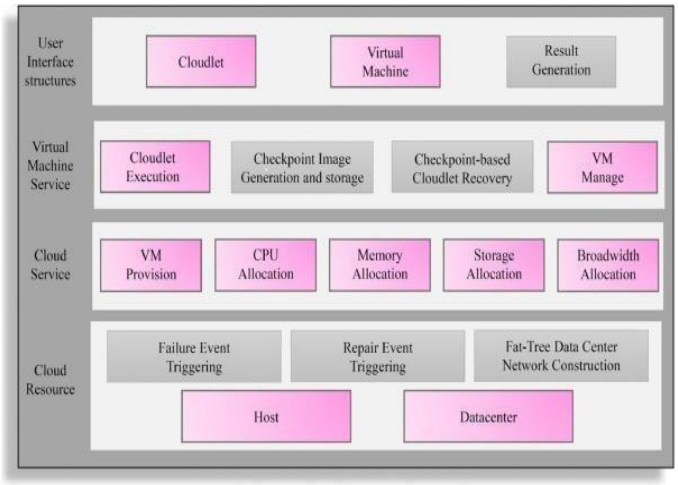

Fig. 11. FTCloudSim Framework.

3.15 GDCSIM

Green Data Center (GCD) Simulator is a type of simulator, under several data center graphs, scheduling algorithms and resource management strategies, it is use for the study of energy effectiveness of datacenters. GDCSIM is efficient to model green datacenters. It is appropriate for online data analysis. GDCSIM consists of different components like BlueSim, resource management and Simulator. Modularization guarantees that d/f constituents of GDCSIM can be used freely (independently) [17].

3.16 CDOSIM

CDOSim stands for cloud deployment option simulator. It simulates SLA contraventions, response times and CDO costs. CDO is considered to be a decision based simulator and takes decision regarding cloud provider selection, precise runtime adaptation tactics, and modules deployment of VM and configuration of its instances. Module deployment of VM instances contains probability of developing new modules of already present modules. It is a simulator which permits incorporation of fine grained models. It is a good illustration for relating runtime reconfiguration policies and for defining trade off among performance and costs. CDO simulator made to address main deficiencies of other simulators like: for simulating CDO's, from production monitoring data, workload outline should be utilized to rerun real consumer conduct; alleviates cloud consumers deficiency of knowledge and control relating structure of cloud platform and accordingly oriented to cloud user viewpoint rather than revealing fine grained internals of cloud platform [11].

3.17 EMUSIM

EMUSIM (integrated emulation and simulation) [18] integrates simulation and emulation to automatically excerpt info from application conduct via emulation and

Table 3. Comparison of different Cloud Simulators.

Cloud Simulators	Platform	ogramming Language	GUI Support	Open Source	TCP/IP Support	H/W orS/W
CloudSim	GridSim	Java	Limited	√	None	S/W
Network CloudSim	CloudSim	Java	None	√	None	S/W
GreenCloud	NS2	OTCL/C++	Limited	√	ull TCP/IP support	S/W
EMUSIM	AEF	Java	Limited	√	None	S/W
CloudAnalys	t CloudSim	Java	√	√	None	S/W
CDOSIM	CloudSim	Java	None	NA	No TCP/IP support	S/W
MDCSIM	CSIM	Java/C++	No	Commercial	None	S/W
GDCSIM	BlueTool	XML/C++	No	√	None	S/W
TeachCloud	CloudSim	NA	√	√	None	S/W
ICanCloud	SIMCAN	MPL,C++, OMNet	√	√	None	S/W
DCSIM	NA	Java	None	√	No TCP/IP support	S/W
GroudSim	NA	Java	None	NA	Full TCP/IP support	S/W
SPECI	Simkit	Java	Limited	√	None	S/W
OCT	Four data centers make up a geographically dispersed cloud testbed	NA	Limited	Limited	NA	Both S/W and H/W

utilizes this info to create simulation model. In request patterns and application computing resources, simulation model utilized to body a simulated state which is near to real target manufacture atmosphere. EMUSIM is a software framework built on top of two software systems: CloudSim for simulation and AEF (automated simulation framework) for emulation [25]. EMUSIM is suitable when tester unaware on the performance of software below various stages of parallelism and adequacy that obstruct use of simulation [7, 16, 36].

4 Comparison of CloudSimulator Tools

For simulation and modeling of cloud computing (CC) virtualized domain hosts, data centers and data center network topologies, cloud simulator are beneficial to use. The table below illustrates some of the most significant variations among simulators, which will be very useful fore searchers when choosing best simulator for their project.

5 Conclusion

In the IT (information technology) sector, cloud computing has been the fastest growing domain. It is compulsory to evaluate security risks and performance that are integral part of CC, as consumers are concerned about encryption and other cost-related concerns that come with widespread cloud computing adoption. For performance analysis of cloud computing environments, numerous simulators designed such as CloudSim, GroudSim, GreenCloud, EMUSIM, OCT, SPECI, ICANCLOUD, MDCSIM and CDOSIM etc.

In this review paper, different cloud simulation tools were discussed. Every simulation tool has limitations and advantages over the other. Thus, users can choose tools according to their needs.

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