THE ROLE OF ARTIFICIAL INTELLIGENCE AND DISTRIBUTED COMPUTING IN IOT APPLICATIONS

Sara Rodríguez González; Fernando de la Prieta Pintado;
José Alberto García Coria; Roberto Casado Vara

AQUILAFUENTE

Salamanca
University Press

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Ediciones Universidad
Salamanca

AQUILAFUENTE, 287

Motivo de cubierta:
1.ª edición: septiembre, 2020

ISBN:
978-84-1311-294-7 (POD)
978-84-1311-293-0 (pdf)
978-84-1311-309-8 (ePub)
978-84-1311-310-4 (Mobipocket/Kindle)
DOI: https://doi.org/10.14201/0AQ0287

Ediciones Universidad de Salamanca
Plaza de San Benito, 2
37002 – Salamanca (España)

Maquetación:
Gráficas Lope
C/ Laguna Grande, 2, Polígono «El Montalvo II»
www.graficaslope.com
37008 Salamanca. España

Realizado en España – Made in Spain

Ediciones Universidad de Salamanca es miembro de la UNE
Unión de Editoriales Universitarias Españolas
www.une.es

Catalogación de editor en ONIX accesible en https://www.dilve.es/

INDEX

PREFACE

The exchange of ideas between scientists and technicians, from both academic and business areas, is essential in order to ease the development of systems which can meet the demands of today's society. Technology transfer in this field is still a challenge and, for that reason, this type of contributions are notably considered in this compilation. This book brings in discussions and publications concerning the development of innovative techniques of IoT complex problems. The technical program focuses both on high quality and diversity, with contributions in well-established and evolving areas of research. Specifically, 10 chapters were submitted to this book. The editors particularly encouraged and welcomed contributions on AI and distributed computing in IoT applications. The editors are specially grateful for the funding supporting by the project «Virtual-Ledgers-Tecnologías DLT/Blockchain y Cripto-IOT sobre organizaciones virtuales de agentes ligeros y su aplicación en la eficiencia en el transporte de última milla», ID SA267P18, financed by regional government of Castilla y León and FEDER funds.

DOI: http://dx.doi.org/10.14201/0AQ02871124

SPECTRA ROUTING

Zakieh Alizadehsani

BISITE Digital Innovation Hub, University of Salamanca, Edificio Multiusos I+D+I, 37007, Salamanca, Spain
zakieh@usal.es

Abstract: This document describes the architecture and design for the Spectra Routing application that being developed for Smart Personal CO2 free Transport. Routing service is a routing application that provide recommended, shortest and fastest routes in interactive onscreen map. Users simply can route and manage their routes.

Keywords: Routing; Django; MAP APIs; Pelias; Nominatim; ORS.

1 Introduction

Routing is the process of finding the best path between two or more locations with a fixed order in a road. The criterion according to which a path is the best can vary. In Spectra Routing services User can be looking for the shortest path (by distance), the fastest (by travel time), and the recommended path [1-15].

2 Design Goal

There is no absolute measure for distinguishing between good and bad design. The value of a design depends on stakeholder priorities.

The priorities for our design that follows are:
Minimize complexity and development effort.
Use open source components and minimize cost of maintenance.

Use local component rather than requesting to external servers or components to increase performance and decrease cost.

The design shouldn't inhibit reusability. The two previous design goals are more important, but the ability to reuse components is also desirable.

3 Project Technologies

Base on project requirement and design goals following technologies are chosen. Regarding Project goals selection MAP APIs is an important part of project design [15-21]. After days of planning and search following technologies are chosen. The reasons for their selection are explained in next section.

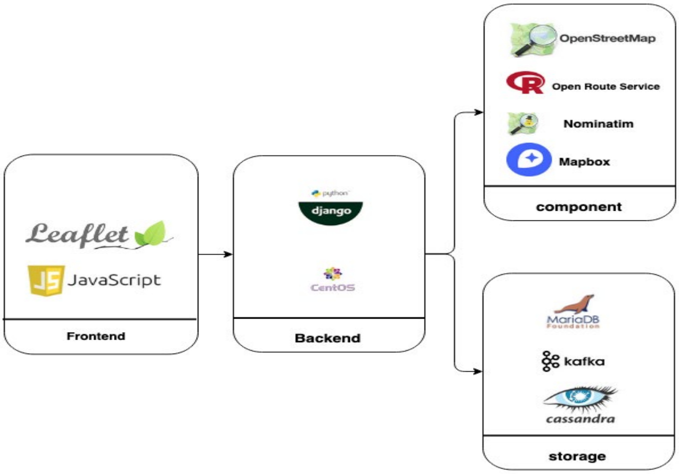

Fig 1. The high-level view to technologies

3.1 Open Street MAP

Main Routing goals is help people get from one place to another and display it on the map. So, first requirement in the routing process is to use proper MAP APIs [21-30]. There are two popular MAP APIs for our purpose:

Open Street Map The free editable map of the whole world. OpenStreetMap is built by a community of mappers that contribute and maintain data about roads, trails, railway stations, and much more, all over the world. On the other hand, OpenStreetMap provides the following key features: Local Installation, community Driven, open data

Google Map Build highly customizable maps with your own content and imagery. Create rich applications and stunning visualizations of your data, leveraging the comprehensiveness, accuracy, and usability of Google Maps and a modern web platform that scales as you grow. Some of the features offered by Google Maps are: Map Image APIs, Place API, Web Services [31-39].

Free is the primary reason that open street map chosen as Map API of Spectra Routing project.

3.2 OpenRouteService

OpenRouteService (ORS) is an open source route planner with plenty of features, it uses a wide range of services based on OSM data which can be consumed in all different kinds of applications and scenarios [40-52]. List of expecting OSM based services features: Open source, Routing /online, Routing /offline, Customizable scale service, Navigation apps be available for Android

There is several software that available for creating routing application. Base on design goals, open source was first priority for choice routing software. Things is there is some limitation for requesting to online routing. So, the local installation feature was the main reason of choice among technologies. Openrouteservice has good documentation and support for using offline routing. In the next sections, openrouteservice will be explain [53-60].

3.3 Leaflet

Leaflet is the leading open-source JavaScript library for mobile-friendly interactive maps. Weighing just about 38 KB of JS, it has all the mapping features most developers ever need. Main requirement for our project was a good user interface for interactive onscreen map. project needs following key features: Familiar, Clear, Responsive, Efficient, Open source, • Customization Features

3.4 Nominatim

To implement interactive map, Project should provide ability of clicking on map to specify source and destination. Friendly interface needs to display address of targeted places. To provide this feature we need Reverse geocoding, reverse geocoding is the process to convert the latitude and longitude coordinates to a readable address.

There are plenty services that provide these features but project needs open source software with local installation ability. Because per routing process at least needs 2 request and it will send huge request to server, so local installation is best option for the project [61-65].

Nominatim is an open source search engine for OpenStreetMap data with local installation ability. It is based around the Postgresql import utility osm2pgsql using the alternative gazetteer output option. Indexing and search are performed using a combination of C, plpgsql and PHP.

In its default setup Nominatim is configured to import the full OSM data set for the entire planet. Such a setup requires a powerful machine with at least 32GB of RAM and around 800GB of SSD hard disks. The good news is Depending on project use case there are various ways to reduce the amount of data imported. In these project Salamanca and Santander OSM data are extracted to save RAM and disk requirement. In Nominatim installation section we will discuss more.

3.5 Pelias

Project needs autocomplete part to users search places, it needs OSM database search engine. The searching of the database is an important step towards routing. So, this is about approaches to search OSM. The good search needs following features: fields Geocoding, autocomplete search, proper filter for country, bbox, OSM Tags, Place type [66-71].

As described in pervious section Nominate is OSM search engine, too. Nominatim reverse geocoding APIs are perfect, but Using Nominatim for Autocompletion might be not the best idea. Auto-complete search not yet supported by Nominatim and we must not implement such a service on the client side using the API. Also, it is not really useful to use Nominatim API for autocompletion, because if you type «Ber» you would expect something like «Berlin» but Nominatim searches for places **exactly** known as «Ber» and suggests «Ber, Tombouctou, Timbuktu, Mali».

So, We choice Pelias APIs, Alternative of Nominatim Search. Pelias is a modular, open-source geocoder built on top of Elasticsearch for fast and accurate global search. Geocoding is the process of taking input text, such as an address or the name of a place, and returning a latitude/longitude location on the Earth's surface for that place. Its online API with proper filter for country, bbox. Below picture is example of Pelias response.

Regarding following address, we used bounding box, country flag, result limitation to enhance geocoding suggestions:

```
http://<IP>:4000/v1/autocomplete?size=8&boundary.country=es&
                    text=p&focus.point.lat=40.977209&
                    focus.point.lon=-5.666977&api_key=xx&
                    boundary.rect.min_lat=40.921745235773&
                    boundary.rect.min_lon=-5.7334899902344&
                    boundary.rect.max_lat=41.021838620757&
                    boundary.rect.max_lon=-5.5872344970703
```

bbox. A bounding box, is an area defined by two longitudes

Country. we filtered search to Spain country.

Language. language of response result.

Limit. limitation of results count.

3.6 Cassandra

Project needs to store all of related routing data in NoSQL database for feature process. When it comes to NoSQL databases, MongoDB and Cassandra are first choice, but according to available resources, Cassandra selected.

Apache Cassandra is a highly scalable, high-performance distributed database designed to handle large amounts of data across many commodity servers, providing high availability with no single point of failure.

4 High-Level Design

The high-level view or architecture consists of 5 major steps:

1. Client specified source and destination on map and request to route.
2. Django application, return specified locations address by requesting to local Nominate.

3. Django application request to local open route service to get recommended / fastest / shortest paths.
4. Django application store OSR response to Cassandra DB.
5. Django application return OSR response to draw them on map.

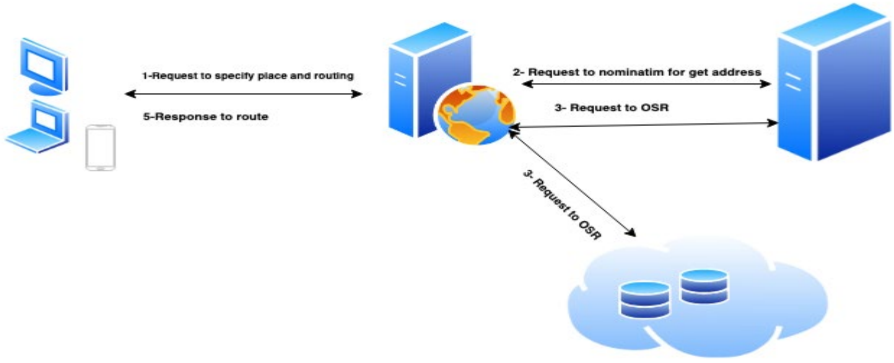

Fig 2. The high-level view to technologies.

5 Platform Overview

Routing service is a routing application that provide recommended, shortest and fastest routes in interactive onscreen map [72-80]. Users simply can route and manage their routes. The application also shows a steepness of routes in chart. This Platform has several services that we described Routing part in this article. is developed by Django framework. Project defines 3 roles for access to the services:

Super user This kind of user is native Django user that has access to every service.

controller user Platform provide limited management services for these kind of user

Regular user Platform provide new That can use limited services.

Routing Interface is available for all type of users.

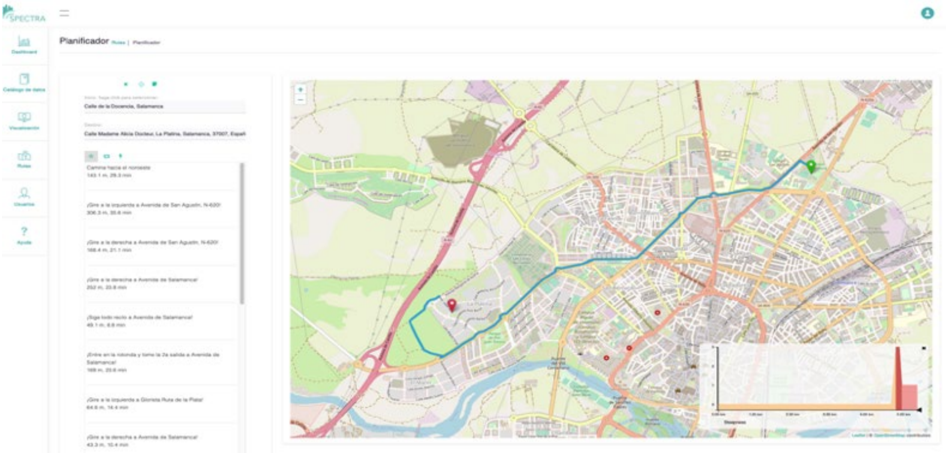

Fig. 3. Routing Interface

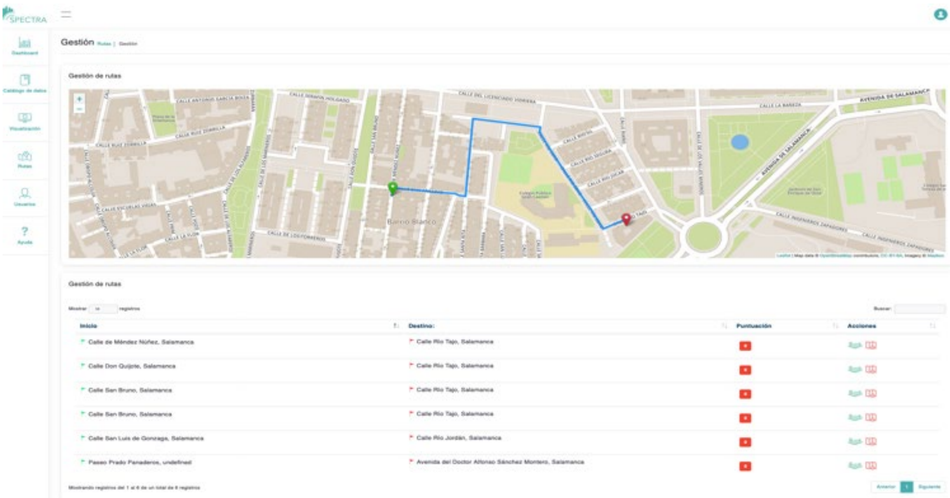

Fig. 4. Routing Management

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DOI: http://dx.doi.org/10.14201/0AQ02872539

DESIGN OF PLATFORMS BASED ON BLOCKCHAIN TECHNOLOGY APPLIED TO DIFFERENT USE CASES

Yeray Mezquita

BISITE Digital Innovation Hub, University of Salamanca, Edificio Multiusos I+D+I, 37007, Salamanca, Spain
ORCID: 0000-0003-4813-4043
yeraymm@usal.es

Abstract: The developments of my PhD in this past year are shown in this article. It is studied thoroughly the possibilities and limits of the blockchain protocols when used in IoT platforms. It is commented how the scalability limits of blockchain technology affects the performance of the systems that make use of it. Also, a review of the state of the art has been carried out, pointing out how some solutions make use of a centralization process to improve response time and security of the blockchain. As future remarks, it should be studying the possibility of creating a public blockchain network with the IoT devices of the platform.

Keywords: Blockchain; IoT platform; Multi-agent system; Review.

1 Introduction

Our society is evolving into a digitally interconnected world by attaching sensors and actuators to everyday objects used in people's daily lives. Those devices are capable to read their surroundings and interact with them in an automatic manner, optimizing activities of the daily life of people [1-12].

Different real objects can interact between themselves through internet, creating a network of interconnected devices defined as Internet of Things (IoT) [13-27]. The concept of IoT is very popular in resource optimization problems and highly demanded in today's industry due to its cost savings (Smart Grids, Smart Home, Smart Farming, Smart City) [28-32].

Although these possibilities make the use of this technology very attractive, they also bring with them some disadvantages [33-41]:

- **Privacy**: With devices that monitor virtually all of people's activities, companies that have access to that information also have access to the routine of our daily lives.
- **Security**: The continuous exchange of information between the devices, problems with the integrity of these data may arise, due to potential attacks from malicious actors.

The previously mentioned problems could be tackled by designing this type of systems with technology capable of ensuring the privacy of the users and the integrity of the generated data. Thanks to the data encryption protocol end-to-end, Blockchain Technology (BT) have the potential to cover the issues IoT platforms have [42-50].

The blockchain is an incorruptible digital distributed ledger of economic transactions that can be programmed to record not just financial transactions but virtually everything of value. This ledger consists of a peer-to-peer (P2P) network of nodes that keeps the information stored in a redundant way. In an IoT system, BT can be used instead of traditional databases, helping on getting rid of centralized controllers such as banks, accountants and governments [51-59].

The benefits BT brings with itself in IoT systems comes with some downsides that limits their performance:

- **Storage capacity**. In BT the size of the data stored in the chain is continually growing. This means that, as time passes and size grows up, the nodes require more resources.
- **Consensus.** The nodes of the blockchain network need to reach a consensus in order to add the next block of information to the blockchain. The common consensus protocol used in the most famous blockchains (Bitcoin and Ethereum) needs time and consumes a great quantity of resources, something that does not match the nature of IoT platforms, essentially composed of devices with low computational power and near real time responsiveness.

- **Scalability**. The resources needed to get consensus in the network increase with the number of transactions carried out within the platform. A globally used platform needs a lot of time to handle that increase of activity.

Within the spectrum of blockchain technologies, there always exist an alternative that, with greater or lesser difficulty, can be implemented satisfactorily in the majority of the use cases. This article shows and discuss some of the solutions proposed for different IoT platforms of the literature, emphasizing what is proposed within the scope of my PhD thesis.

2 Blockchain Technology: background

BT has been created with the intention of replacing the current, centralized financial system. In [60-65] it is claimed that BT is capable of replacing intermediaries while ensuring the security of platforms. But, although BT offer resistance to traditional cyberattacks, as it gains widespread adoption, they are being developed new attacks specifically for hacking it [66].

Distributed Denial Of Services (DDOS) attacks are the most common. A kind of DDOS attack is the Malleability attack, produced when an attacker creates a copy of a transaction but with another ID, which makes the user spend double for it [71]. This attack occurs when a system that make use of a blockchain, like a bitcoin exchange, have flaws in the implementation of the code that allows the trading of cryptocurrencies.

The eclipse and sybil attacks have similar bases. In both, the attacker gains control of a large number of IP addresses of the network and surrounds the victim with them. In Eclipse attacks, the victim is not allowed to obtain transactions they are interested in. This kind of attacks has been successfully carried out in the Ethereum blockchain by Researchers from the University of Boston. In a Sybil attack, the victim is influenced by the voting power of the attacker nodes and the information they send to it, which makes the victim vulnerable to double spend attacks.

A 51% or majority attack occurred when a single entity owns the majority of the voting power of a network. An attacker who wants to take advantage of this condition can create a fork of the main chain with the transactions it wants to be done. The cryptocurrencies with a small network behind them are at risk, because it's easier for an attacker to gain that 51% of the network voting power.

The more proven a BT-based platform is against the attacks previously mentioned, the more trust the users give in the cryptocurrency it underlies. As a result of that trust its economic ecosystem will grow, which will translate into an increment of the cryptocurrency value and its market capitalization [72].

Some of the differential aspects of a BT based platform are: the consensus algorithm that the peers of the network use to add new blocks to the blockchain; the way in which the network is governed; and its capability to execute code that does or does not allow to deploy Turing-complete Smart Contracts in the blockchain.

Relating to the consensus algorithm, there is an increasing number of them and their own variations. The most widespread algorithms are the most proved, that's why they, or any of their variations, are shared by the vast majority of the cryptocurrencies [73].

In the Proof-of-Work (PoW) algorithm, to add a new block to the blockchain a cryptographic problem must be solved. The computational cost and the difficulty of solving the problem, the energy spent on searching for its solution (work) and the simplicity of verifying it, are enough reasons to encourage the nodes that wants to add new blocks (miners) not to cheat by adding illegal transactions.

Proof-of-Stake (PoS) is a consensus algorithm, in which miners take turns at adding new blocks. The probability of a miner to receive the turn to add a new block depends on the amount of coins deposited as escrow (Stake). This algorithm assumes that a node is going to be honest in order to avoid losing the escrow.

In the Practical Byzantine Fault Tolerance (PBFT) algorithm, the process of adding a new block is called a round. In each round a node is selected to propose a new block, the block needs to receive 2/3 of the votes of all the nodes in the network in order to be valid.

Currently, every consensus algorithm has its own risks and vulnerabilities. For example, PoW wastes a massive amount of energy to produce new blocks. That algorithm is very limited in terms of scalability and its mining pools are centralized [23]. In the case of the PoS algorithm, its Nothing at a Stake theory causes to occur forks of the blockchain more frequently than with other consensus algorithms [3]. In the case of PBFT the main risk is that it is a permissioned protocol and not a truly decentralized.

Another feature allowed by many BTs, is the possibility to use self-enforcing programs that can control and supervise, in an automatic way, the conditions of non-trusted parties that interact between themselves and need to reach agreements. These programs are called smart contracts and their use, is allowed in most of the blockchain protocols, in a Turing Complete or non-Turing complete way.

In [71] it is shown a thorough study of the smart contracts limits when used in real world applications: the data sources where smart contracts get the data from and make their clauses work with. That's why it is needed a reliable data source that allows smart contracts to interact with the outside world without losing the trust that users have placed in them.

To allow users trust the external data used in a smart contract, it arises the term oracles. Oracles are external agents that observe and validate external data of the real world. Oracles are centralized and can be black boxes, which makes them a new trusted intermediary betraying the security and reduced-trust model of blockchain applications.

Regarding on how an oracle interacts with the Smart Contracts of a blockchain, there can be classified in [68]:

- **Software Oracles:** This kind of oracles gather the information from sources like web sites or public databases. By doing that they can provide to Smart Contracts the most up-to-date information from Internet. Examples of their use is in temperature readings, current price of financial assets or public transport information.
- **Hardware Oracles:** This kind of oracles provides the Smart Contract with data directly from the physical world. These readings come from sensors that takes measurements from their environment.
- **Outbound Oracles:** These oracles do not provide the Smart Contract with data from outside, instead they provide another Smart contract with data from a previous one. For example, it can tell a wallet provider that the balance of a user has changed due to some conditions.

- **Consensus based oracles:** A possible solution to a centralized oracle model is to make use of a set of oracles and giving them the capacity of reach a consensus, deciding the solution of a task in a decentralized way:
  - The oracles provide a deposit in the smart contract.
  - After that they send a vote with the result they have achieved independently.
  - The result with the most votes is the one used in the execution of the Smart Contract.
  - If a result given is not between acceptable and previously defined margins, the oracle in question loses the deposit.

In [76] it is also shown why the current legislation is not fully adapted to the evolution of blockchain technology. In addition, it is commented the necessity of the apparition of an audit system for the IoT devices and smart contracts that operates and control any BT-based platform.

3 Solutions Review

In [34] it has been reviewed some relevant works in the field of blockchain-based IoT systems. In that work, it has carried out a review of the papers that appeared first while making a search by the keywords «blockchain» and «IoT» in Google Scholar.

In [47] it is shown how BT can be applied to a supply chain in order to strengthen the security of the IoT devices that operates in it. In the case of supply chains, it is used BT to provide transparency and visibility to the transactions of assets made between actors within the supply chain.

In the case of any kind of IoT system, control and configuration of IoT devices can be made through a blockchain. By making use of RSA public key crypto-systems and signatures in the platform communications, it is possible to avoid attacks such as man-in-the-middle. Thanks to the use of the cryptographic mechanism of the BT, messages IoT devices exchange are encrypted and signed with the private key of those who send them. In this use case, the public key of an IoT device is stored in the blockchain, while the private one is kept inside the device itself [32-50].

The most used approach in this kind of systems is the one in which the blockchain is not stored inside the IoT devices, rather used as a service from outside the IoT network. This is due to IoT devices being resources-constrained, while the use of a blockchain normally involves the use of many computational resources and bandwidth [51-63].

On the contrary presents a smart home use case scenario based on a permissioned blockchain. In that work, for each smart home of the platform is used a local private blockchain, in which registered devices of the smart home read and write data in it. There also exist an IoT device for each home, called Home Miner, that manage the addition or deletion of new devices and the public key cryptosystem. The Home Miner also is the one in charge of the interactions between different Smart Homes [64-71].

Following a similar blockchain approach as the previous one, in [70] it has been proposed a MAS that manage and control an agri-food supply chain. In that work, a permissioned blockchain based on the Ethereum protocol is deployed within the platform. The IoT devices make use of it when exchanging data, encrypting and signing it with the services provided by the blockchain platform.

4 Current Works

To continue the research shown in section 3, a study called Multi-Agent Architecture for Peer-to-Peer Electricity Trading based on Blockchain Technology, has been defended in the special session Blockchain Technology and its Application (BCTA) of the International Conference on Information, Communication and Automation Technologies (ICAT). In that work has been proposed a MAS-based architecture that makes use as a Service of the BT provided by the public network of Ethereum to allow peer-to-peer transactions of energy in a microgrid. The MAS is in charge of automating and optimizing the interactions between entities in this platform, following a Game-Theory model. While the BT used, have more proven security than any of the permissioned solutions proposed in the literature, at the cost of losing global scalability [72-73].

In the previous work it has been done an analysis of the costs that the users should pay to use that platform. A similar analysis has been done in another proposal: Beneficios de la incorporación de la tecnología blockchain en el proceso de registro de la propiedad. That work has been accepted in the International Conference on Blockchain Technology in Contracting Impact on Financial, Notary, Registry and Judicial Systems. In that work, it is shown the reduction in costs that the Spanish property register would receive if the country adapts that process to allow the use of BT within it.

Like in the articles [54] it is possible to take advantage of the distribution of task a MAS provide and optimize any BT-based system. The next step that will be taken, will be to implement a negotiation algorithm that can improve payoffs and performance of the platform proposed in the ICAT paper.

Another good way to improve the performance of BT-based systems is to make use of a blockchain deployed within the IoT devices. With that approach, it is possible to stop depending on the latency of the network to read the data stored in the blockchain, but it is needed to take into account the losing security and decentralization of similar approaches. It has been analyzed the possibility of implementing this kind of platforms in [62]. In that work it has numerated and detailed some of the problems and challenges that this kind of platforms currently have, like scalability, data privacy, latency times, and some legal aspects.

5 Conclusions

In this paper it has been pointed out the advantages and limitations of the use of BT in any IoT platform. Although it can be increased the security of those platforms, it also reduces their performance.

In addition, it has been studied some representative IoT platforms based on BT from the literature. In those solutions, it has been shown that the trend they follow is to make use of the blockchain as a service from outside the IoT network of devices.

In future works it will be studied the possibility of creating the blockchain network with the IoT devices of the platform. The aim of that solution will be to stop relying in the internet latency and try to make cheaper the use of the blockchain protocols within that platform.

Acknowledgments

The research of Yeray Mezquita is supported by the pre-doctoral fellowship from the University of Salamanca and Banco Santander. Also, this work has been partially supported by the Salamanca Ciudad de Cultura y Saberes Foundation under the Talent Attraction Program (CHROMOSOME project).

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DOI: http://dx.doi.org/10.14201/0AQ02874154

A DEEP TECH ARCHITECTURE FOR INTELLIGENT IOT SYSTEMS

Mehmet Ozturk

BISITE Digital Innovation Hub, University of Salamanca,
Edificio Multiusos I+D+I, 37007, Salamanca, Spain
mehmet@usal.es

Abstract: The increase in the number of connected devices on the Internet of Things (IoT), interactions and the amount of data raises a number of issues. Two major problems are limitations in terms of network latency and bandwidth. While cloud-based infrastructures give us access to scalable, on-demand storage and processing services that can scale to the requirements of the Internet of Things (IoT), these centralized resources can create unacceptable delays and performance problems for devices that have latency-sensitive applications, such as health monitoring and emergency response applications. This article has been created for the PhD thesis that aims to create a deep tech architecture for intelligent IoT systems.

Keywords: Edge Computing; Machine Learning; Deep Tech; Internet of Things (IoT).

1 Introducción

The recent increase in the number of devices and applications has led to a rapid increase in data storage and processing requirements. Cloud computing offers many options that can meet the demands in this context. Therefore, Cloud Computing has caused a big change in the way we live and work [1-12].

But we are now at a point where Cloud Computing alone is not enough to provide the necessary services. The increase in the number of connected devices on the Internet of Things (IoT), the interactions and the amount of data raises several issues. Two major problems are limitations in terms of network latency and bandwidth. While cloud-based infrastructures give us access to scalable, on-demand computing and processing services that can scale to IoT requirements, these centralized resources can create unacceptable delays and performance problems for devices that have latency-sensitive applications such as health monitoring and emergency response applications.

The term Internet of Things (IoT) is one of the emerging technologies of recent years and is the basis of many trends such as smart cities, smart homes and e-healthcare [13-20]. Now, with IoT, a new era begins with a post-cloud name, where there will be a large amount of data generated by things that are immersed in our daily lives, and many applications will also be implemented on the edge of these devices to consume these data [21-27]. By 2015-2020, 26.3 billion of these nodes will be connected to the Internet [27-38]. This will cause problems with latency and network bandwith.

The problem of network bandwith can cause damage, as IoT devices will produce so much data that existing networks will not be able to send it all to cloud services in time for processing. This can result in a loss of important information for decision making. Data are increasingly produced at the edge of the network, so it would be more efficient to process data at the edge of the network as well. The process of handling data at the edge is now known as «Edge Computing». Cisco has created the term «Fog Computing» which implies the computation performed at gateways, routers, etc. Fog computing is a distributed model that provides cloud services to peripheral devices on the network. In the following sections of this article, several definitions and descriptions of these two terms will be explained.

Edge Computing also has a strong influence on how Machine Learning methods are implemented. Cloud Computing has enabled a revolution in the scalability of artificial intelligence by allowing model training to be conducted in an affordable and sustainable manner. Since model training generally requires a lot of CPU power, it is estimated that training will still be done in the Cloud computing, but the inference (which is the application of a trained algorithm to a real world) will be done at the edge. The large-scale characteristics of these systems and the complexity of the applications suggest that rethinking both the application model and the development process. As can be seen in the name of Distributed Artificial Intelligence (DAI), the advances in both distributed systems and artificial intelligence are the main fields of driving. Edge Computing provides an excellent way to use autonomous software or hardware intelligence agents in a distributed manner [39-47]. This comes with a question: How far will artificial intelligence eventually go?

The objective of this paper is to provide an analysis of edge computing, the shift of computing models from centralized to edge computing, and to share the state of the art on edge computing and models of artificial intelligence distribution. This article is carried out with the aim of continuing the doctoral thesis to create a deep tech architecture for intelligent Internet of Things (IoT) systems.

2 Edge Computing & Fog Computing

Cloud computing has played an important role in the last decade to perform massive and complex data computation, taking advantage of virtualized resources and parallel processing with scalable data storage. However, due to the explosive growth of lightweight connected devices that are driving the entire information society into the Internet of Things (IoT) era, the Cloud is facing increasing challenges in supporting lightweight IoT devices, especially for delay sensitive IoT applications.

Data is increasingly produced at the edge of the network; therefore it would be more efficient to process data at the edge of the network as well. But, compared to the rapid development of data processing speed, the network bandwidth has become a problem. As an example, for the delay-sensitive case, a Boeing 787 will generate about 5 Gigabytes of data every second, but the bandwidth between the aircraft and the satellite or the ground base station is not large enough for data transmission. Another example is that an autonomous car will generate one gigabyte of data every second and requires real-time processing for the vehicle to make the right decisions. If all the data has to be sent to the cloud for processing, the response time would be too long. Not to mention that the bandwidth and reliability of the current network would be threatened by its ability to support a large number of vehicles in a single area. In this case, data needs to be processed at the edge for shorter response time, more efficient processing and less network pressure [48-55].

Internet of Things (IoT) refers to the interaction and communication between billions of devices that produce, and exchange data related to real-world objects (co-sas). The characteristics of IoT, which include a large-scale network of things, heterogeneity at the level of devices and networks and the large number of data and events generated by these things, will make the development of various applications and services a very complicated task. Internet of Things (IoT) applications need to handle a variety of information from a large number of heterogeneous devices. In relation to this issue, the Edge Computing (EC) paradigm, with the idea of supporting devices with a cloud closer to the edge of the network, appears as an attractive solution. However, adding Edge resources complicates network management, as several devices will face them [56-63].

Another term that is also a step of cloud-based services through which data is produced is «Fog Computing». Cisco defined the concept of «Fog computing» as an extension of cloud computing to harness the full potential of the IoT. The fog is a layer between the edge and the cloud, which extends the cloud closer to the nodes that produce and act on the IoT data. Industrial gateways, routers and other devices with the necessary processing power, storage capabilities and network connection may be fog nodes. By analyzing and pre-processing the data at these nodes, fog computing can minimize latency and reduce bandwidth usage. In addition to Fog Computing, Edge Computing aims at the same objective. However, additional computing power and device storage at the edge are used [64-70].

Fog computing allows for seamless integration of edge and cloud resources. It supports intelligent, decentralized processing of unprecedented data volumes generated by implemented IoT sensors for seamless integration of physical and virtual environments. This could generate many benefits for society, for example, by enabling intelligent healthcare applications. The further development of fog computing could help the IoT to reach its vast potential [71].

3 Deep Tech

Deep tech is a new term introduced by Swati Chaturvedi, co-founder and CEO of the investment company Propel (x). Deep tech projects are, in principle, more socially relevant. By its definition, deep tech refers to «companies founded on the basis of scientific discovery or significant engineering innovation» and which also seek to make the world a better place. She describes deep tech: «We define deep tech as companies founded on a scientific discovery or significant engineering innovation. This is where they ask: «Not all technology companies are based on these principles. Most technology companies today are based on business model innovation or on the transition from the offline to the online business model using existing technology. Take the example of Uber: Uber is based on the concept of a «shared economy», an innovative business model that allows individuals to share existing resources.

On the other hand, deep tech companies rely on tangible scientific discoveries or engineering innovations. They are trying to solve big problems that really affect the world around them. For example, a new medical device or technique to fight cancer, data analysis to help farmers grow more food, or a clean energy solution to try to reduce human impact on climate change. Continuing Uber's reference, companies with deep technology in the transport business would include autonomous vehicles, flying cars or other similar transformation technologies [72-74].

There are several examples of deep tech technological innovations in the published article [75]. What makes a deep tech technological project different from the usual technological products is that it aims to solve real life problems through scientific discovery or real technological innovation. For example, in the life sciences, «We will not cure cancer by investing in a health monitoring application. We will not grow more food, improve our energy efficiency or perform more efficient surgery by investing in internet companies or mobile applications. To achieve these goals, we will have to invest in real things – in cancer drugs, new energy sources and storage, new medical devices... That is why it is important to invest in deep technologies – because without these technologies, humanity does not move forward [76].

Deep tech projects/companies promise solutions in a wide range of fields, using techniques such as Big Data, artificial intelligence or deep learning, with a more scientific approach than what is normally seen in media-covered technology companies. They are not the digital companies that have grown the most in recent years (like Facebook or Spotify), and they are not based on innovative business models (like Airbnb). Instead, they solve problems through significant scientific or technological developments.

4 Distributed Artificial Inteligence

Machine Learning (ML) is becoming a part of our lives. There are several main reasons for this:

- The increasing capacity of the computers used to build and train ML models.
- More data capture capability throughout the computing environment, often in the form of low-cost sensors integrated into everyday consumer, business and industrial products.
- The development of new algorithms and approaches that improve the accuracy of ML applications.
- The creation of software toolkits that make the creation and training of ML applications much easier and therefore less expensive.

In addition to these four reasons, there are two other often overlooked factors that are equally important in bringing AI (artificial intelligence) into our lives. These factors are not about where AI is built and trained, but where it is implemented and used:

- A reduction in the cost and an increase in the performance of the chips that make IA «on the edge».
- Middleware development allows a wider range of applications to run smoothly.
- on a wider variety of chips.

This leads to a new model of IA that fits what is to come: construction and training, which will continue mainly on increasingly powerful cloud-based computers, and inference that is the implementation of the trained ML model.

Cloud computing has enabled a revolution in AI scalability; supporting ML by allowing model training to be conducted in an affordable and sustainable manner. If you had a large data set and had to study it, you could spin a thousand virtual machines to force your way through it. ML basically consists of two main steps:

Training is when a data set is studied and the results are incorporated into an algorithm of some kind. For example, you must study one million pictures of cats to learn how to identify future cat images. This process requires massive data and is computationally intensive.

Inference is the application of a learned algorithm to a real-world problem. Algorithm training is about the past, inference is about the present. Teaching the model to identify a cat is training while taking a single picture and using that algorithm to decide if it is a cat or not is an inference.

Where should the calculations be made to make the inference? The short answer is that for many – if not most – applications, inference in the future will be made at the edge, that is, where the data is collected. This will have a big impact on the way the LMA will be developed. The Edge is the next stage in the evolution of AI technology. The applications that people use in real world products, such as controlling devices in the home or assisting the driver in a car, are all running on the edge and many will require real-time responses. Any delay from bouncing information to the cloud and back could be a problem.

There are many popular research topics related to the ML, including multi-agent systems, intelligent transport systems, multi-robot systems, wireless sensor networks and intelligent network systems. The technology behind this is called distributed artificial intelligence (DAI) or distributed intelligence (DI). As the term DAI implies, advances in both distributed systems and artificial intelligence are its main driving forces. There are many ID applications such as Smart Grid, Intelligent Surveillance, Industrial Control and Automation, Wireless Sensor Networks, Multi-Robots, etc. How to train a high accuracy model and how to use the inference model on distributed architecture are two important topics of AI research. At work, there are two ways to do this:

1. Training on distributed architecture
2. Inference about distributed architecture.

This work proposes three layers of architecture: Sensor Layer, Fog Layer, Cloud Layer and Actuator Layer.

5 Conclusion

In this article, we discuss the current state of Cloud Computing, Edge & Fog Computing and its relationship to Machine Learning. We can conclude that thanks to IoT and many other developments, most of the calculations will be done at the edge, there is a big movement from centralized cloud services to distributed edge models. As the price of computing continues to fall, the number of computing devices will continue to increase exponentially. While that cannot persist indefinitely, one thing seems certain: computational devices powered by artificial intelligence will touch our lives in almost every conceivable way. The power, safety, and speed requirements of these devices require inference at the edge, where data is collected. This will allow for an increasingly common way of identifying the digital devices that will play a role in our lives.

6 Future work

The next phase of this work is to investigate deep tech architectures that focus on an artificial intelligence distribution model and, after analyzing them, to propose and create a deep tech architecture for intelligent IoT systems.

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DOI: http://dx.doi.org/10.14201/0AQ02875568

THE IMPORTANCE OF DIGITAL TRANSFORMATION. INCIDENCE OF THE DIGITAL ECONOMY AND SOCIETY INDEX (DESI) IN THE GDP OF THE EUROZONE ECONOMIES

Javier Parra; Eugenia Pérez; Jorge González & Juan Manuel Corchado

BISITE Digital Innovation Hub, University of Salamanca,
Edificio Multiusos I+D+I, 37007, Salamanca, Spain
javierparra@usal.es

Abstract: In recent years, numerous researches have studied the relationship between the so-called technological indicators and the social development of different countries.

The main motivation of this study has been to find out whether there is a relationship between the variables of the DESI technological indicator and this year's GDP per capita. The existence of such a relationship has been identified and it has been discovered that it is directly related to the use of internet services by citizens and to the implementation of technology in companies.

Keywords: DESI; GDP; technology; digital transformation.

1 Introduction

Over the past few years, companies in almost every industry have carried out a series of initiatives to develop new digital technologies and explore their benefits [1-12]. *Information and Communication Technologies* (ICT) are the merger between new digital technologies and traditional industrial production, leading to the emergence of what we know today as Industry 4.0 [13-20].

The concept of industry 4.0 has allowed to transform factories into intelligent environments where information, objects, and people are connected thanks to the convergence between the physical and the virtual world through cyber-physical systems [21-29].

Advanced economies have experienced significant technological change. The developments that were made since the twentieth century onward eventually led to the emergence of Industry 4.0. The scientific progress that has been made over the years, has allowed for a significant fall in the price of technological capital [30-41].

Unlike the largest economies, such as Germany or the United States, some countries in the European Union have not been able to take advantage of all the benefits offered by the so-called digital revolution. The crisis in 2008 made governments implement austere fiscal policies which reduced spending on research and development [42-50] and business investment. Nevertheless, the situation changed noticeably in 2014. In that year, the digitalization became the driver of several economies [51-56], in the case of Spain, it was responsible for a 30% increase in added value in 2015 [57-60].

In recent years, digital transformation has become an engine of growth for the entire Eurozone. For this reason, the current work focuses on the study of the relationship between the GDP per capita of the Eurozone countries and The Digital Economy and Society Index (DESI) during the period 2015 – 2018.

1.1 Digital transformation. A global concept

Digital native companies are the ones that have best responded to digital transformation, they increased their profits and have been able to implement new business models more efficiently [61]. Despite the fact that technological and digital advances have enabled interconnectivity, digital transformation has not spread uniformly around the world and not all countries benefited from it equally. One of the main reasons for which this inequality exists is the digital divide. This is a term used to describe the unequal opportunity to access technology and it focuses especially on the varying conditions of Internet access [62-68] in different parts of the world.

Given the possibilities offered by digital transformation and the technological inequality between countries, at the last G20 summit, digital transformation has been included in the global agenda. It is hoped that thanks to this, more inclusive and sustainable growth will be achieved for all countries worldwide [69-70].

1.2 The Digital Economy and Society Index (DESI)

The Digital Economy and Society Index, DESI, is a composite indicator that measures the digital performance of Europe. DESI is also responsible for investigating the digital competitiveness of the member states of the European Union. This index is elaborated annually by the European Commission [71].

The indicator of digital competitiveness is broken down into 5 components and their main implications:

- Connectivity: Measures the deployment of broadband infrastructure and its quality. It is measured according to 5 variables: Fixed ADSL, Mobile ADSL, fast broadband, ultra-fast broadband, broadband price index. For example, access to fast and ultrafast broadband services is a necessary condition for competitiveness.
- Human Capital: Measures the skills that are needed in order to take advantage of the possibilities offered by digital technology. It is measured according to 2 variables: Internet users' skills, advanced skills and development.
- Use of internet services by citizens: It represents a variety of online activities, such as the consumption of online content (videos, music, games, etc.), as well as online shopping and banking.
- Integration of digital technology by businesses: Measures the digitalization of companies and e-commerce. By adopting digital technologies, companies can improve efficiency, reduce costs and improve customer and business services.
- Digital public services: Measures the digitalization of public services, focusing on electronic administration and health. The modernization and digitalization of public services can generate efficiency gains for public administration, citizens and businesses alike (such as e-health and e-Government).

2 Methodology

2.1 Population and sample

Data on the GDP per capita and The Digital Economy and Society Index (DESI), have been obtained for 19 countries in the Eurozone, for the following time period 2015-2018.

GDP per capita data comes from Eurostat [72] and is expressed in millions of euros at current prices, for each time period and country separately.

The Digital Economy and Society Index (DESI) data have been obtained from the reports of the European Commission that analyze the ranking of each country according to the DESI index [73-78].

2.2 Variables

The following variables have been selected for the analysis, so it is possible to observe, as anticipated, the incidence of DESI disaggregation in GDP:

PIBPC = GDP per capita
PIBAN = GDP per capita for the previous year
desia = Connectivity
desib = Human Capital
desic = Use of internet services by citizens
desid = Integration of digital technology by businesses
desie = Digital public services

2.3 Estimation techniques

For the estimation of the model we have used panel data, combining cross sections for several periods of time.

Specifically, we have followed the methodology of applying fixed effects, this is the most elementary and consistent methodology and the model to be estimated is:

$$\log(PIBPC) = \beta_1 \log(PIBAN) + \beta_2 \log(desia) + \beta_3 \log(desib) + \beta_4 \log(desic) + \beta_5 \log(desid) + \beta_6 \log(desie) + u_{i,t}$$

We have elaborated the expression of the model and we have chosen to adopt logarithms because they facilitate the comprehension of results. In the model, we take into account this year's and last year's GDP per capita of each country, considering the 2015-2018 period and all the disaggregated components of the DESI index during this time period.

We have used the R software to estimate the model, a free programming software, oriented to statistical analysis, which allows to design econometric models and analyze them statistically by means of different libraries.

3 Results

Prior to the development of the study, a correlation analysis has been carried out, as shown in Table 1. As it can be seen, there is a clear relationship between last year's GDP per capita and this year's GDP per capita.

The rest of the correlations are not considered to be as strong, nevertheless, the most significant relationship is between this year's GDP per capita and the *desib* variable, which stands at 0.624592.

Strong correlation would imply multicollinearity between the explanatory variables of our model. Given that it is not the case, as the correlation between the chosen set of variables is not strong, it has been possible to continue with the estimation of the proposed model.

Table 2 illustrates the developed model, where it is possible to see that this year, there is a clear implication of the *desic* and *desid* variables in the GDP per capita indicator. In addition, last year's GDP per capita has had a logical impact on this year's GDP per capita, which is positive.

It is important to note that the implication of the variables of the DESI index is positive, and it occurs due to the use of internet services by citizens and due to the implementation of digital technology in businesses.

Table 1. Correlation analysis.

	PIBPC	PIBAN	desia	desib	desic	desid	desie
PIBPC	1.000000	0.994836	0.481729	0.624592	0.299778	0.292481	-0.004682
PIBAN	0.994836	1.000000	0.482999	0.621272	0.298734	0.270716	-0.024390
desia	0.481729	0.482999	1.000000	0.577137	0.714044	0.485058	0.371132
desib	0.624592	0.621272	0.577137	1.000000	0.511841	0.432595	0.438125
desic	0.299778	0.298734	0.714044	0.511841	1.000000	0.259130	0.387760
desid	0.292481	0.270716	0.485058	0.432595	0.259130	1.000000	0.487801
desie	-0.004682	-0.024390	0.371132	0.438125	0.387760	0.487801	1.000000

Table 2. Regression analysis.

```
Call:
plm(formula = log(PIBPC) ~ log(PIBAN) + log(desia) + log(desib) +
    log(desic) + log(desid) + log(desie), data = datest)

Balanced Panel: n = 19, T = 4, N = 76

Residuals:
       Min.     1st Qu.      Median     3rd Qu.        Max.
-0.06844738 -0.01367687  0.00052004  0.01000381  0.06409087

Coefficients:
             Estimate  Std. Error t-value  Pr(>|t|)
log(PIBAN)  1.3769e-01  4.8934e-02  2.8138  0.006938 **
log(desia) -2.1885e-02  6.9281e-02 -0.3159  0.753376
log(desib)  4.9375e-02  6.1260e-02  0.8060  0.423989
log(desic)  2.9505e-01  5.7769e-02  5.1073 4.918e-06 ***
log(desid)  2.7161e-01  4.3985e-02  6.1750 1.090e-07 ***
log(desie)  8.1522e-05  3.6255e-02  0.0022  0.998215
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Total Sum of Squares:    0.20228
Residual Sum of Squares: 0.038294
R-Squared:      0.81069
Adj. R-Squared: 0.7216
F-statistic: 36.4002 on 6 and 51 DF, p-value: < 2.22e-16
```

4 Conclusions

In developed economies, specifically in the economies whose main driver is technology, different studies have aimed to determine the implication that technological development has in the labor market. However, not many studies have associated GDP per capita with technological development indicators.

According to the results of the conducted study, there is a close relationship between technological indicators and the GDP per capita, especially in terms of the use of Internet services by citizens and the digitalization of businesses.

This result makes one think about the importance of technological development for a country, given that an increase in technology in different fields implies growth in GDP per capita.

Future lines of research will focus on determining why developed countries have better technology and it will look at the percentage of technological investment in different countries. In addition, it will be analyzed whether the implementation of high-tech in Europe's less developed countries will foster a process of convergence among all European regions.

Acknowledgement

This article has been funded under the EP - INTERREG V operating program

To Spain Portugal (POCTEP) with the DISRUPTIVE project «Dynamization of the Digital Innovation Hubs within the PocTep region for the promotion of disruptive and next-generation ICTs through cooperation in the cross-border region», in call 2, with the identifier (2291).

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DOI: http://dx.doi.org/10.14201/0AQ02876983

DISTRIBUTION OF QUANTUM KEYS OVER COMMERCIAL NETWORKS

Iván García-Cobo

Universidad de Salamanca. Salamanca, Spain
ORCID: 0000-0002-9472-5613
ivangarciacobo@usal.es

Abstract: Modern cryptography – as it was conceived – is under a threat by the development of quantum mechanics applications. The abilities of quantum computers for solving complex mathematical problems, as a strong computational novelty, is the root of that risk. The main challenge is to find commercial exploits of quantum properties and developments, following these directions for both, theoretic and test tube environments.

This work proposes a pilot experiment that implements a quantum communication system on a commercial fiber optic network, covering an area of almost 100,000 km^2.

Keywords: modern cryptography; quantum cryptography; quantum key exchange; quantum key distribution; QKD.

1 Introducción

We can place the origins of computing as a modern discipline in the works of Sir Alan Turing. The exercise of mathematical and algorithmic abstraction led him to design knowledge as Turing's Machine: a formal device capable of solving any mathematical problem that could be represented by an algorithm [1-10].

One of the main theoretical challenges facing modern cryptography is its vulnerability to future quantum computers. According to Shor's algorithm [11-18], once quantum computers exist, most public key encryption algorithms can be compromised in linear time. This is a major problem, not only in terms of secure communication, but also in terms of protecting data – both future and present –.

To address the threats that quantum computing poses to classic cryptography, we can use applications of quantum mechanics itself to implement new solutions. Talking about encrypted communication, quantum cryptography allows us to design algorithms that, on the one hand, manage to overcome the limitations of classical physics and on the other hand, are not vulnerable to attacks from quantum computers. However, one of the main problems associated with such algorithms is the distribution of so-called quantum keys, given their physical properties.

There are numerous successful experiments on quantum communication over distances of up to 100 km^2 on fibre optic channels (e.g. [19-27]). However, trying to put a necessary realistic approach in a commercial implementation, distances below 50 km^2 ([28-35][1]).

The aim of this work is to propose a new way of creating a quantum key distribution network that allows providing service over a fibre optic network in a de-terminated territory. For this purpose, the fibre optic network of a commercial operator over the territory of Castilla y León has been studied. With this information, a methodology is proposed, based on grouping algorithms, that tries to minimize the number of quantum key repeaters over that specific territory, so that not only the distribution network is created, but also it is optimized.

In the case of a maximum distance of 35 km^2, it would be sufficient to use the available network by coupling 100 repeaters on it. This would guarantee secure communications using quantum encryption in Castilla y León, a territory that currently occupies 100.000 km^2.

2 Quantum communication protocol

For the explanation of the protocol, we will then use the traditional actors: Bob, Alice and Eve.

[1] Este dispositivo [4] permite intercambiar del orden de 20000 claves cuánticas en una hora

2.1 BB84

The BB84 protocol is considered the first quantum key distribution protocol. It was proposed by Bennett and Brassard in 1984 [36-45]. It uses quantum properties. This protocol uses four states and two alphabets, each with two states.

After the execution of the algorithm and once the key has been generated by BB84, Alice will use this key to encrypt her message. Later Bob will be able to decrypt the message with the shared key. The guarantee of the security of the use of the key lies in the fact that both its creation and transmission are based on the fundamentals of quantum mechanics.

The presence of a potential spy –Eve– could compromise the exchange of the key. However, the security of the protocol is that it uses two alphabets with non-orthogonal states – Eve cannot simultaneously measure the x and z polarization for the same qbit.

2.2 Practical example of protocol use BB84

By using modern cryptography and quantum we can apply this algorithm to an exchange of messages between Alice and Bob. We will use the Vernam cipher applied to the encoding and decoding of the message; while the BB84 protocol will be used for the creation and exchange of the secure key.

Alice will locate the clear message she wants to transmit and transcribe it as a sequence of 0 and 1. BB84 is used to generate a key the same size (or larger) as the message to be transmitted. To do this, Alice generates a random sequence of 0 and 1. They follow the rest of the steps of the BB84 protocol to exchange the key. Remember that the last step of the BB84 algorithm discards the values that have not matched [46-53].

Once both share a secure one-time key, the message is encrypted with that key by Alice and sent to Bob, who, upon receiving it, will perform the binary addition with the key previously transferred to him by Alice and will be able to discover the sent clear text.

3 Quantum Key Distribution

To build a network that connects all municipalities, a distributed network of repeaters must be designed. To make the distribution, a methodology based on grouping municipalities, through a k-medoids algorithm, is used. This algorithm will help, given a set of municipalities, to select those that are physically close to each other. Then, the algorithm will facilitate the selection of the most central municipality, within the set of nearby municipalities. This municipality will be considered as a candidate, within the set, to host a repeater. Finally, the methodology will try to connect the possible repeaters to each other to generate a distribution network.

This type of problem is similar to the problem of the traveller, where the optimal route has to be selected for a traveller who intends to travel to a certain set of places. In this case, «the traveller» would correspond to the set of quantum keys, and «the places» would correspond to the municipalities. The problem of the traveller is NP-complete [54-62], and it requires approximation methods in order to find local solutions.

3.1 Basic Network of Municipalities

When selecting municipalities as potential candidates for placing repeaters, it is important to take into account two factors: the selected municipality must have all the other municipalities in its group within the range of distances required in the quantum distribution, and the municipality representative of the group must have at least one other representative municipality within the distance limit in order to generate the distribution network.

3.2 Identification of Representative Municipalities

The way to address the problem of distributing quantum keys over a given population implies not only knowing the physical limits that communication between nodes establishes, but also specific methodologies that allow for the optimal placement of repeaters. For this second part, clustering is used, a technique known within unsupervised machine learning [63-70].

3.3 Repeater Network

In order to ensure that any municipality within the network can communicate with any other, it is necessary to establish a repeater network based on the representative municipalities selected in the previous step. This network will be defined as follows:

1. Each representative municipality shall be connected with all the municipalities in its cluster. In this way, all municipalities in the same cluster will be able to exchange quantum keys using the repeater. In the previous step it is guaranteed that the repeater is at a distance less than D from each municipality in its cluster.
2. Each repeater will connect to all repeaters in its environment within a distance of D. Thus, if more than one repeater is close to another, different routing can be used.

These criteria when creating the network not only facilitate better routing, but also make it easy to identify possible isolated regions of the network. In order to find these regions, it is sufficient to calculate the number of related network components. Formally, the network is a non-directed G network, divided into V-points, representing the municipalities, and E-points, representing those municipalities that are either within a cluster and connected to its repeater, or are repeaters at a distance less than D from each other. The number of related network components is calculated by estimation using random paths [71-81].

4 Experimentation

The experiment shown below measures the quality of the networks with respect to the number of repeaters. The limiting distance is considered as a parameter and is manipulated together with the number of repeaters.

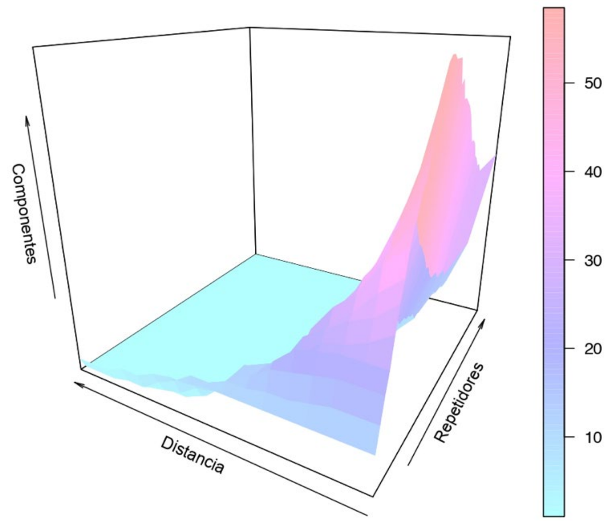

Figure 1. Display of the experimental results considering the two variables of the experiment: the limit distance of the repeaters (D) and the number of repeaters (k). The graph shows the number of connected components that the network has for different values of these parameters. It can be seen that the predominant value is 1 component in most cases, so the network would be connected.

Figure 1 shows the result of the experiment. It establishes a range of distances and a number of repeaters that varies between 20 and 100 km for the distances and between 10 and 250 for the repeaters [82-89]. The main goal of the experiment is to check at which points the complete network is reached. The lighter blue of the figures represents the lowest number of components, in these results, a single component. This means that the service can be provided to all municipalities without leaving any isolated ones. As you can see, the optimal distance values should be from 80 km in order to place the least number of repeaters possible (between 10 and 20), however, for distances around 40 km, about 100 repeaters should be enough to create the connected network.

5 Conclusion

The application of quantum to computing involves a paradigm shift. The move from classical computing to quantum computing is the starting point for finding solutions to historical problems that have long been unsolvable. It is necessary to strengthen the current communication systems by implementing algorithms resistant to such possible attacks while designing new applications of quantum to achieve secure communications faster and more efficient.

After showing the BB84 quantum key distribution (QKD) algorithm and referencing different tests in researchers' laboratories, it was found that it was necessary to implement a quantum key repetition system, since the maximum distance in practice at which the system could be made to work was relatively low. Together with this, we found the need for the designed system to be able to operate over a commercial (general purpose) fiber optic network.

An experiment has been designed to find the optimal way to distribute the repeaters to cover a wide area. Specifically, we have considered the area occupied by Castilla y León, an Autonomous Community of Spain. The municipalities that are the object of this experiment are those with 1000 or more inhabitants within the selected territory. The experimentation has served to show how the number of repeaters required varies according to the distance as well as the minimums necessary to cover the entire territory, interconnecting it in its entirety.

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DOI: http://dx.doi.org/10.14201/0AQ02878596

GECA: A GLOBAL EDGE COMPUTING ARCHITECTURE

Inés Sittón-Candanedo

BISITE Research Group, University of Salamanca, Edificio Multiusos I+D+i, Calle Espejo 2, 37007 Salamanca, Spain
ORCID: 0000-0001-8953-7848
isittonc@usal.es

Abstract: The smart scenarios are in continuous advance thanks to the group of devices that are always connected to Internet. In the last 10 years this phenomenon has been called Internet of Things (IoT). The adoption of the IoT to generate these intelligent scenarios or smart has motivated that governments, universities, research centers or companies are in constant evolution to face the challenges brought by the deployment of IoT platforms. Its disruption in all environments generates large volumes of data, requirements by users for their applications to respond in real time, but with low bandwidth or power consumption, and without delays. The challenges presented by the development of applications for the IoT has occasioned the emergence of technologies such as Edge Computing. This paper presents GECA: A Global Edge Computing Architecture, an architecture based on Edge Computing, which has been deployed in smart farming and smart energy scenarios, with the aim of demonstrating that it is possible to reduce latency, energy consumption and bandwidth costs and integrate Edge computing in IoT platforms.

Keywords: Edge Computing; Reference Architecture; Internet of Things; Industry 4.0; Smart Energy; Smart Farming.

1 Introduction

The term Edge Computing is not new, its origin dates back to the 1990s, when Akami Technologies coined it to refer to content delivery networks

(CDNs) [1]. After Akamai, it is again in 2016 when the term begins to arouse the interest of organizations, governments, universities and researchers for its potential to facilitate the deployment of the Internet of Things.

The Internet of Things, has been defined by various authors as the interaction and communication carried out between the connected devices that generate and exchange data with things or objects of the real world [2-15].

The IoT has extended to a wide variety of environments and disciplines, including solutions for the development of intelligent cities, intelligent farms, smart energy, smart health, logistics and transport. The number of heterogeneous «things» such as buildings, machines, vehicles, homes, people connected to the Internet or to each other through electronic devices that communicate using a set of standard protocols, form a set of networks that can generate, process, store and obtain useful information for organizations. The EC allows the optimization of computing processes as it does not depend on cloud computing for the execution of these processes [16-30].

One of the first scenarios in which the usefulness of Edge Computing has been validated has been Industry 4.0., where it has been presented as an alternative to solve the problems generated by the large data flows generated by IoT devices. In the context of Industry 4.0, A state-of-the-art review have conducted of the main references architectures that include EC technology [31-42].

2 A Global Edge Computing Architecture

The revision carried out of the reference architectures that are focus on the use of Edge Computing as a method to reinforce the capabilities of IoT and Cloud Computing, identified a gap in the development of architectures that integrating edge computing, it is possible to deploy in environments other than Industry 4.0. This motivated the design of a new Edge Computing Architecture, with the following purposes:

- Facilitate a real-time analysis of data at the level of local devices and edge nodes, without dependence on the Cloud.
- Reduce operational and management costs by reducing traffic and data transfer between the Edge and the cloud.

- Improve application performance by achieving lower latency levels at the edge of the network compared to the cloud.
- Enhancing security to through the block chain technologies that will be incorporate to the architecture from the lower layers of IOT to the upper layers of the cloud.

The Global Edge Computing Architecture was proposed by Sittón-Candanedo *et al.*, in [43]. The architecture is made up of three layers (see Figure 1):

- **IoT:** it is integrated by IoT devices mainly used to monitor services, activities or equipment in operation, such as: sensors, actuators, smartphones, controllers. The communication is done through wireless standards (Wi-Fi, BLE, ZigBee, LoRa or SigFox). The main function of this layer is the management and storage of the computing resources of IoT devices. The security in the architecture starts in this layer by incorporating Blockchain for the protection of the data generated.
- **Edge:** this layer integrates edge computing for hardware management, represented by the IoT devices of the lower layer. The data filtering and processing processes are carried out in the Edge layer, which, unlike the existing reference architectures, allows the deployment of low-cost solutions such as the micro-controllers incorporated in Raspberry Pi or Orange Pi. The characteristics of these equipment's allow the processing of a much greater amount of data than the ones that are currently incorporated in the IoT devices. The purpose of integrating them into the architecture is to minimize energy consumption and at the same time allow the execution of logic programs and reading control, as well as filtering and preprocessing data using machine learning models and algorithms (e.g.: TensorFlow Lite) on a server based on Node.js that collects data from IoT sensors. Therefore, data filtering running on this layer reduces latency and bandwidth costs by limiting data traffic to the cloud on the platform on which the architecture is deployed [44-50].
- **Business Solution Layer:** The architecture is designed to integrate the Edge with the Cloud, by including in this third layer the set of services and applications needed today for any business. It can be deployed as an online platform that can run on public or private cloud servers. Calls are made individually to each API and are activated when the user demands

the use of interactive interfaces of the applications that are part of their business intelligence [50-63].

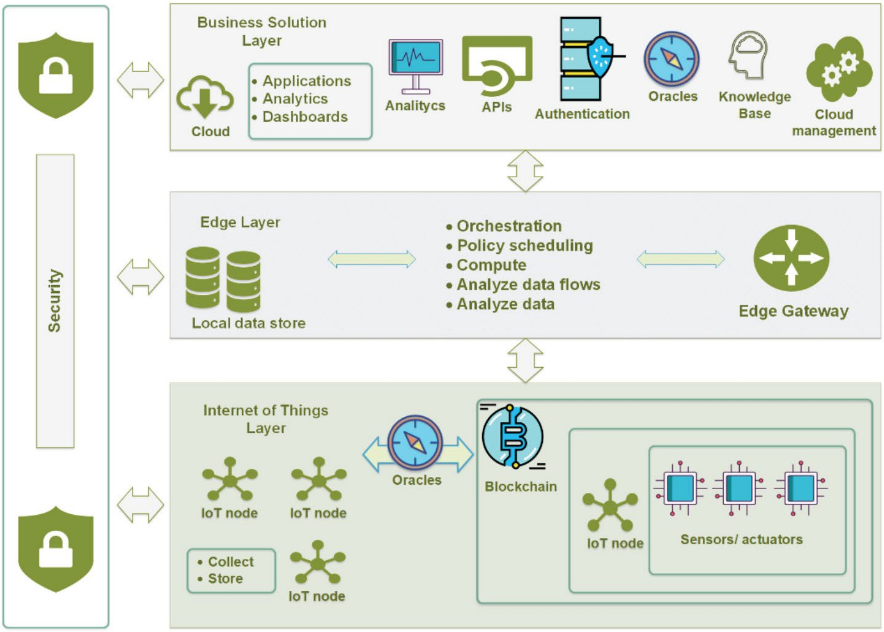

Figure 1. Global Edge Computing Architecture.

So far, the architecture has been deployed in two cases of use:

- **Smart Farming:** with a platform designed to monitor and optimize the management of agricultural and livestock farms in a mixed dairy farm in Castilla y León, Spain. The aim is to reduce time, bandwidth and storage costs through efficient management. The deployment of GECA made it possible to locate the animals and monitor their health conditions in real time in less time and in a more economical way. On the other hand, the application of the data analytics techniques of the Business Solution layer helped to detect in a timely manner the presence of specific diseases in cows thanks to the association and analysis of the parameters obtained.
- **Smart Energy:** To validate GECA functionality in a Smart Energy scenario with IoT applications, the architecture was deployed in CAFCLA, a framework to encourage energy consumption efficiency in public

buildings by applying social computing. CAFCLA was developed and evaluated by [64-70]. When integrated with GECA, two tests of four weeks each were carried out, resulting in a reduction of the data sent to CLOUD. In this scenario the reduction in energy consumption was considerably greater than in Smart Farming [71-75].

To analyze the disruption of Edge Computing in other environments, a state-of-the-art study is conducted to identify existing solutions to the problem posed and present a new solution. In this regard, the Systematic Mapping Study methodology was used to identify existing solutions in which EC is applied to Smart Energy environments [76-80].

The papers analyzed in the SMS were classified according to the type of solutions they offer for a Smart Energy environment. On the other hand, it is a complex scenario with development requirements and proposals aimed at reducing the cost and energy consumption, contributing to obtain operational efficiency, through the intelligent management of infrastructure, make decisions based on data analysis and access to information in real time [81].

3 Conclusion

The demand for applications capable of responding in real time regardless of the scenario or the environment variables in which they run is growing.

This demand has contributed to the interruption of increasingly accessible technologies such as large data, the Internet of objects, artificial intelligence, automatic learning models, business intelligence techniques, to mention just a few, which are adopted by large companies to continue operating efficiently and effectively in an increasingly competitive digital market.

Small and medium enterprises seek to access this type of market through cheaper platforms, but at the same time are adequate to ensure their competitiveness and the extraction of the knowledge needed to keep a current company.

This paper presents GECA and its deployment in two smart scenarios in which there are Internet of Things devices. The results obtained in both scenarios demonstrate that it is feasible to provide small organizations or companies with more accessible and economical platforms. GECA allows the reduction of costs for hardware, energy consumption, transfer and storage of data to the cloud (whether public or private) and to balance the burden of computing processes.

As future lines of research, GECA will be deployed in other experimental scenarios in which it is also possible to evaluate the reduction of latency, comparison of the reduction of data transfer and costs when using a cloud or another, even evaluating the providers of these services.

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DOI: http://dx.doi.org/10.14201/0AQ028797108

WINDY RURAL COLLABORATIVE POSTMEN PROBLEM USING ROS AS MULTI-AGENT SYSTEM ARCHITECTURE

Francisco Lecumberri de Alba

BISITE Research Group, University of Salamanca, Edificio Multiusos I+D+i, Calle Espejo 2, 37007, Salamanca, Spain
fcolecumberri@usal.es

Abstract: In the last decades the urban areas have grown and as a result the transportation has become an important problem. We are exploring a potential solution for the last mile delivery problem in urban areas in a similar way that internet solves the delivery of information problem.

Keywords: Last Mile Problem; Multi-Agent System; ROS; Graph Theory; Routing Tables; Postman Problem.

1 Introduction

In the last decades, the number of people living in urban areas has grown dramatically throughout the world and this trend continues to grow. According to data from The World Bank, in 1960, 61% of people in the European Union lived in urban areas and in 2015 this number increased to 75%. In Spain, where industrialization has taken place later than in other countries, this increase is even more pronounced, from 57% to 80%.

The increase in urban population has led to a drastic rise in transportation necessities [1-15]. As a result, traffic and environmental problems (CO_2 emissions, air pollution, noise, etc.) have increased, and such problems have a direct impact on the quality of life in cities. Among the main challenges that big cities face nowadays is that of managing the mobility of both people and goods.

The «classic» way of dealing with these problems has been the encouragement of public transport and placement of restrictions on the use of private vehicles. Although these measures have helped to ease these problems, traffic and pollution due to transport, continue to persist. There are several reasons for which these measures have not provided real solutions to traffic and pollution. On the one hand, modern life requires us to get to places «anytime» and «anywhere» [16-24]. The ability to travel to any place at any time has become a basic necessity and traditional public transport systems have some limitations in this regard. Perhaps, this is the reason for which private vehicles have become the main means of urban transport in many countries in Europe and North America, while public transport finds it increasingly difficult to attract and retain passengers [25-31]. On the other hand, the emergence of e-businesses has triggered a change in the habits of consumers: globalized purchasing services provided by technological platforms allow consumers to acquire goods and services from both, the local and international markets and the public and private spheres. This change entails increased freight transport and the need for new freight transport methods, since this aspect affects urban mobility and in which traditional public transport systems are not very helpful.

The way citizens demand services, as well as the way services are established, offered and executed has changed with the evolving environment. Technological advances have contributed to this change, especially the increase in connectivity, between both «things» and people. Along with an increase in connectivity, areas such as the Internet of Things, Cloud Computing or Artificial Intelligence facilitate new ways of offering, distributing and regulating existing services or generating new services, also in the field of urban mobility [32-40].

This article aims to define and develop the ICT services that will facilitate the transition to a more sustainable and individual-centered mobility model. Such a model will reduce the global costs related to mobility but will satisfy the transportation needs of today's society. The term cost here is rather general. It refers to the energy costs, the costs of the infrastructure (streets, parking spaces, etc.), the «environmental costs», the cost derived from occupying or using public space, etc. In our opinion, in order to achieve more sustainable mobility, the system should be based on I) an efficient coordination of shared infrastructure resources II) prioritization of the use of transportation infrastructure resources to favor and thereby encourage the use of more sustainable means of transport III) collaborative transport solutions [41-49], based on transport sharing or perform several transportation tasks on a single trip. A proposal for an integrated solution will be developed, as well as techniques, methods and tools to proceed in this direction.

This article main approach is to solve the last mile delivery problem in a cooperative environment. The last mile delivery problem is a problem known in math and graph theory as the rural postman problem (which is a variation of the classic postman problem where the postman just needs to travel certain places, not everyplace). The rural postman problem is about finding the optimal route inside a graph to pass by every connection inside the graph [50-59]. However if we consider the fact that the delivery will be affected by traffic and that traffic asymmetrically affects routs (A route may have lots of traffic in a direction but few in the opposite direction) and the fact that streets may or may not be bidirectional, we are dealing with the «windy» version of the problem. In summary the last mile delivery problem may also be referred in the academia as the «windy rural postman problem». In this particular case, it is intended to solve the problem where collaboration may exist among several postmen. It is also important to note that the postmen problem and every other variant here described are NP-problems, so the approach is going to be mainly in reduce the complexity of the problem as much as possible to get efficient results (not necessarily optimum) in affordable time [60-67].

Since this thesis work started two months ago, everything mentioned here are non-proven ideas, conjectures and results can not be provided.

2 Proposal

The proposal presented is propound the graph as a multi-agent system where each node of the graph is an individual agent that communicates with the adjacent nodes and uses Routing tables in a similar manner as internet routers (which are designed to manage graphs with 4,294,967,296 nodes which are graphs bigger than any city graph).

The routing tables algorithm is about each node has a list of the nodes that it can reach, the edge that must be taken to reach that node, the associated cost. when a node gets connected with another node (or the connection information change), this nodes exchange information of their routing tables and update the information (if necessary) and the new information. The routing tables algorithm has advantages and disadvantages that will be exposed below [68-71].

The fist advantage is that since each node only depends on the node it is communicating with the algorithm may run in parallel (even if two nodes are connected, if this are not communicating, the execution is independent). This allow to consider cluster systems to accelerate the computing process in certain cases.

In contrast, a disadvantage of this algorithm may not be run in GPU technology since each node needs to execute different parts of the algorithm at the same time.

Another disadvantage of this algorithm is that the system initialization may be computationally expensive. This disadvantage only suppose a problem in the first initialization since once the initialization is done the configuration may be saved in disc.

The main advantage of this algorithm in this particular problem is that once each node have knowledge of the best route to the other nodes, you may just ask any node about how to reach another node and get the optimal direction in an instant time (technically is in a logarithm time since the search inside a table is logarithmic at best).

Once the graph is initialized with this system the next proposed step is to make an agent to represent each postman (In the multi-agent system) and assume the postmen are not collaborating so each postman should form the best route [72-80].

To generate the best route each postman will list all the nodes that it should attend and will ask every node in that list about how much does it cost to go to the other nodes in the list and from there the postman will generate a reduced graph in which the postman should travel every node transforming this problem into the Hamiltonian Traveling Salesman Problem (TSP). The TSP is also a NP-Problem

This problem conversion can be seen in the figure \ref{graph} where we have a 10 city with 10 nodes where we need to deliver packages to the nodes 1, 7, 9 and 10 so the graph get transformed into a graph with just 4 nodes. In this example the reduction may seems small, but in real examples a city may have ~ 5,000 nodes and a very busy postman may have ~100 packages so the reduction is quite significant [81].

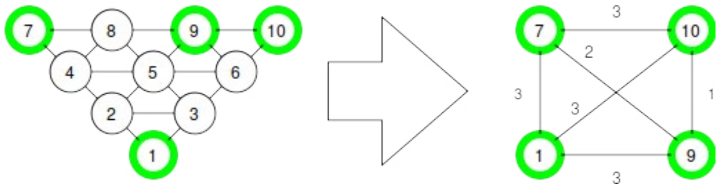

Figure 2. Transformation from Postman problem to Traveller problem.

The way to solve this problem is still to be analyzed since we may find a way to merge the graphs of each traveller in order to make a collaborative solution or to solve each graph in an independent way and then try to merge each path to generate a collaborative solution.

The way to implement this will be using the ROS framework. Robot Operating System (ROS) is a development framework (not an operating system despite the name) made to communicate multiple process developed to make reusable software independent of programming language. ROS currently fully supports C++ and python and have as a main advantage that makes the communication transparent to the network so once a development is working in a computer, migrate the multi-agent system to a cluster where the process run in different computers should be trivial. Furthermore, given the fact that the delivery task is gradually becoming a robot driven task, ROS also represents an advantage since ROS Have become the standard of development in the robotic development field.

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DOI: http://dx.doi.org/10.14201/0AQ0287109119

DESIGN AND DEVELOPMENT OF SOLUTIONS FOR RESEARCH PROJECTS: UPPER, CITYCHAIN AND PULSE GENERATOR

Domingo Hernández Gómez

BISITE Research Group, University of Salamanca, Edificio Multiusos I+D+i, Calle Espejo 2, 37007 Salamanca, Spain
domihg@usal.es

Abstract: This paper describes the research work done in several projects. These projects have a different scope, from the monitoring of a city to the safety of workers in their workplaces. The solutions provided in these projects are focused on custom electronics and IoT technology.

Keywords: Electronic.

1 Introduction

In this document my contributions to the different projects of the Bisite Group will be presented and developed. These participations have been in the projects of:

- Pulse generator for the stimulation of peripheral nerves in experimental animals
- Citychain
- Upper

1.1 Problem description

According to the Project, the problem to face is different:

a) Pulse generator for the stimulation of peripheral nerves in experimental animals

Vagus nerve stimulation (VNS) has been applied in the clinic for more than two decades, but even so, the fundamental mechanisms underlying the improvement that the procedure induces in epilepsy are not entirely clear, so it is essential to continue research on the subject [1-14].

b) Citychain

The concept of Smart Cities has emerged with great intensity in recent years and its influence on our lives will continue to be increasingly evident. Some cities have begun to promote themselves as intelligent, to demonstrate their technological adaptation, attract new citizens and external investments, as well as retain those who already live there and the investments that have already been made [15-23].

Under this idea, cities play an important role, both as large data generators and as places where new services can be deployed and shown to all citizens, which impacts on their ability to generate income. Although several case studies have already demonstrated these benefits, a very low percentage of cities in the world, mainly large cities, have joined this trend and in most cases use proprietary software. The fact that this software is proprietary prevents an evolution of these management platforms, the community can develop external modules that can be coupled to the system to extend the existing functionality [24-37].

c) Upper

Safety and health in the workplace is one of the challenges that generate most concern within the business world and especially in the industrial sector. In this sense, the strategies of organizations and their teams dedicated to safety and health in the workplace, focus on training and making available to workers, the means necessary to reduce risks, which otherwise could lead to an occupational disease or an accident [38-43].

Nowadays, the available technology makes it possible to approach these problems from a similar approach, but abandoning traditional training actions and obsolete personal protective equipment (PPE), disconnected from the real environment where the working day takes place and lacking in personalization and adaptation to the particular needs of each worker.

1.2 Reasons

Motivation has been common in all three projects, where the focus of progress has been on improving and making cheaper products and ways of using current technology, in an equally effective but more economical way, while at the same time trying to find a new approach to its use that provides features that are not exploited as much as possible or in a different way. Likewise, the use of new elements and technologies in all these projects has meant the need to understand and implement these technologies in the elements to be created, which has been a constant challenge that has given the team a continuous impulse to advance in the project [44-58].

1.3 Brief description of solution

a) Pulse generator for the stimulation of peripheral nerves in experimental animals

A PCB has been designed and created, whose function is to generate electrical impulses that are programmable, and that allows its implantation in a chronic way in the GASH/Sal. This board has been designed with connections both for the battery or power battery and for the connection of the electrodes that will be in contact with the vagus nerve.

b) Citychain

The hardware team has overseen the design and production of the plates that will be incorporated in the Citychain project. Modular plates have been created different plates with different functionalities each one, which can be joined, obtaining the combined functions of them as required.

c) Upper

Different devices have been created: a helmet, a bracelet and a belt, which have different sensors and elements incorporated, in such a way that each one of them is in charge both of collecting data from different variables and of acting in the prevention of occupational risks, depending on the values captured.

2 Materials and methods

a) Pulse generator for the stimulation of peripheral nerves in experimental animals

With regard to the decision whether or not to use rechargeable batteries, it was finally decided that they would be non-rechargeable, as rechargeable batteries increased in size and price, and the estimated lifetime of certain non-rechargeable batteries (such as the one finally chosen as the best option) is sufficient for the purpose of the project.

We have tried to create the smallest possible size, whose main limitation has been the size of the battery, which is greater than desired and what could have been the PCB itself, in addition to its thickness is considerable with respect to the plate and the ideally sought [59-63].

Even so, we have created a plate of reduced size, with circular form, whose activation is carried out with a magnetic switch of which it is provided.

b) Citychain

The hardware team has overseen the design and production of the plates that will be incorporated in the Citychain project. Modular plates have been created different plates with different functionalities each one, which can be joined, obtaining the combined functions of them as required [64-68].

c) Upper

Different devices have been created: a helmet, a bracelet and a belt, which have different sensors and elements incorporated, in such a way that each one of them is in charge both of collecting data from different variables and of acting in the prevention of occupational risks, depending on the values captured [68-71].

3 Conclusions

Based on the results obtained so far, we can say that progress in these projects is taking shape, and the proposed objectives have been achieved satisfactorily. The Upper prototypes are almost finished, the Citychain plates are already functional, and the electric impulse generation plates are already being tested with the mice. Teamwork has been key to solving the problems that have arisen throughout the different processes of design, testing, creation and other phases of development.

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DOI: http://dx.doi.org/10.14201/0AQ0287121133

A RECOMMENDATION-BASED PROPOSAL FOR IMPROVING ENERGY EFFICIENCY IN HOUSING

David García Retuerta

BISITE Digital Innovation Hub, University of Salamanca, Edificio Multiusos I+D+i, Calle Espejo 2, 37007 Salamanca, Spain
dvid@usal.es

Abstract: 75% of buildings in the EU are not designed according to any energy efficiency code and around 45%of the world's energy is used in the residential sector. This is why one of Europe's biggest energy challenges is to include consumers at the heart of the energy system. The aim of this work is to develop a solution to a problem of such magnitude: to create a system of personalised recommendations to each consumer that contributes to improving the energy efficiency of their home.

The data will be obtained from sensorized homes in Salamanca. Some examples of possible recommendations are reducing the temperature of the thermostat, change the time at which the house is ventilated and raise the blinds at a certain time. The system developed is capable of providing these recommendations correctly an-d efficiently.

Keywords: Artificial Intelligence; Energy Efficiency; Machine Learning; Recommending System.

1 Introduction

For retrieving energy consumption-related data, everything that surrounds the targeted house has to be linked to a data source and every aspect of the environment must be captured digitally. When a constant dataflow is obtained, an in-depth analysis must be carried out in order to capture the valuable information. We live in the era of big data and even bigger analytics.

However, a new method for transforming the obtained insights into real actions had to be developed. The proposed technique is based upon previous studies for modelling social behaviour. Previous studies have shown that environmentally friendly behaviours were most effective when they were accompanied by a provincial norm, as opposed to when they were accompanied by standard environmental messages [1-13]. The statistical capabilities of Artificial Intelligence for modelling group behaviours will be used for rewarding the most eco-friendly members of the group, and criticising the most wasteful ones.

In this work we propose a technique based on hybrid algorithms which combine machine learning methods with mathematical and statistical techniques for obtaining insights out of the raw data. Those algorithms will be used to change consumer behaviours and result in a decrease in energy consumption, without the need of altering the structure of the building or making construction works. Furthermore, consumer comfort will be taken into account by the recommender system which will increase the likelihood of changing the consumer habits in the long term [14-25]. Our main contributions are: Generating energy-related recommendations based on sensor's data automatically, providing the recommendation in the most effective way, maximising the likelihood of consumer's behaviour changes, and creating a public Python library for deep sensor's data preprocessing.

The main goal of this master's thesis is to provide some useful recommendations which are personalised for each user. The performance of the developed programs will be tested in the town of Salamanca (Spain) in the year 2020, as the city council of Salamanca has agreed to implement it in some of its social housings [26-31].

2 Objectives and Methodology

The **main goal** of this project is to **promote energy-efficient behaviours among its users**. In addition, the **secondary objectives** (sorted by importance) are:

- Useful insights must be obtained from the retrieved data.

- Users current energy-related behaviour must be correctly modelled.
- Basic energy demand predictions must be achieved.
- Gather data of sensors which are reliable and useful.
- Measure the level of satisfaction of the users and take them into account for the recommendations.
- Make an in-depth research into social behaviour modelling in order to deliver the recommendation in the most effective way.
- Provide a easy-to-use program which can be handily implemented in a real-life case.
- Find the relationship between certain changes in sensors' data and an increase/decrease in energy consumption.

The following **methodology** has been used: firstly a features selection is made, and a clustering algorithm selection is carried out. Afterwards, the results are validated and interpreted. Eventually, an output is produced (Figure).

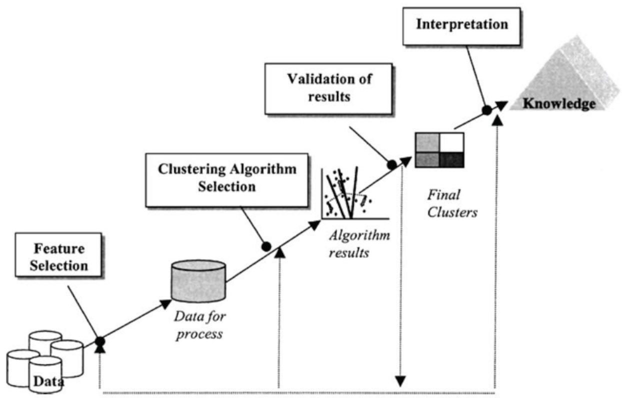

Figure 1. Steps of the clustering process.

2.1 Contribution

The **innovative part** of this work is the use of hybrid algorithms which combine machine learning methods with mathematical and statistical techniques for obtaining insights out of the raw data. Those algorithms will be used to **change consumer behaviours** and result in a **decrease in energy**

consumption, without the need of altering the structure of the building or making construction works. Furthermore, consumer comfort will be taken into account by the recommendation system which will increase the likelihood of changing the consumer habits in the long term [32-43].

The following **recommendations** can be delivered to the users:

- **Comparison of energy expenditure (weekly)**. The data is collected from the sensor established as the main one and compared with the rest of the neighbours, eliminating from the calculation those installations that do not have data or are not sufficient.
- **Comparison of energy expenditure (weekly intervals)**. The data is collected from the sensor established as the main one and compared with the rest of the neighbours. For each installation, data from the meter is received grouped every 8 hours and compared with the data of the other installations.
- **Thermostat survey and alert**. The values of the thermostat are collected and those users that exceed a recommended value (22ºC) are sent a consumption recommendation and a percentage reduction (4-7%).
- **Ventilation recommendation**. The indoor temperature and the weather forecast (OpenWeatherMap) of the following 24 hours are measured. It is recommended to ventilate in the hour with the smaller difference between the interior temperature and the prediction, also it warns if at that hour it is possible that it rains.

Furthermore, if the indoors temperature exceeds the Tukey's Fences, a recommendation for ventilation is sent [44-51].

- **Recommendation by humidity value**. The humidity value is measured for each installation and, if it exceeds the Tukey's Fences, a recommendation is sent.

Furthermore, a **public Python library** has been developed and shared, it is available in *PyPi*. More details can be found in the **¡Error! No se encuentra el origen de la referencia.**

3 Results Analysis

A recommender system has been successfully developed in this work. The user must place certain IoT sensors, which will collect the data for the system, and will receive recommendations for increasing the **energy efficiency** of the house. The recommendations are inspired in the **system of Singapore**, which proved this idea to be a valid method [3]. Furthermore, this program broadens the scope of Singapore's method as, in addition to providing monthly recommendations, it delivers weekly and real-time recommendations [52-60].

- **Monthly recommendations** target the long-term habits of the user, promoting the consumer used to a eco-friendlier lifestyle.
- **Weekly recommendations** target long-term habits, as well as medium-term routines.
- On the other side, **real-time recommendations**' main goal is to end user's obsessions which are known to be a waste of energy, e.g., airing out the house at first time in the morning (the temperature difference indoors-outdoors is at its peak, which produces a big temperature drop inside of the house).

I believe such a complete system will be capable of improving the energy performance of dwells in Salamanca due to its wide range of recommendations. The real-life tests will show who recommendations are more useful for users and which recommendations are ignored. The program will then be fine-tuned, and the most useful recommendations will be presented in a more relevant context to the users. I consider that a raking system of «best users» could also be integrated for creating an attachment to users [61-75].

4 Conclusion

Energy saving or energy efficiency consists of using energy in a better way. That is, with the same amount of energy or with less, get the same results. Furthermore, saving money is important for many households, but finding the habits that will save energy at home is not always easy. Getting used to doing certain tasks on a daily basis can be complicated at first.

With the purpose of finding a powerful and economic solution that provides the tools necessary for changing consumer habits, it was proposed the design and implementation of a recommender system of low cost and lower cost of implementation. In addition, recommendations had to be personalised by user so that the consumer gets engaged with the program for a time long enough to change their habits.

The designed system successfully provides personalised recommendations based on IoT sensors. The raw data was very unstructured due to several factors: failing sensors, different refresh times, etc. As a result, a public Python library has been developed and publicly published, so that people facing a similar problem can find a solution easily. The resulting data made it possible to create some testing recommendations which impact will be measured in the near future. Long-term recommendations are known to be effective based on the experiments carried out in Singapore, medium-term and real-time recommendations are believed to affect medium-term behaviours as well but no previous experiment has been made about this topic. Performance of the algorithms is satisfactory as real-time recommendations can be sent instantly and weekly analysis can be processed in a few seconds.

Real-world tests will be carried out in Salamanca (Spain) in order to fine-tune the recommendations for increasing the user's energy efficiency. The used data already provided useful information about the problem, but the user's reaction to the provided recommendations will also be taken into account.

A future research line is making predictions based on the current data. The preprocessing phase of the program provided many datasets which can be used for predicting future values of the sensors. A possible application is warning the user that they should be careful on the following day about a certain event.

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DOI: http://dx.doi.org/10.14201/0AQ0287135148

RECOMMENDER SYSTEMS BASED ON HYBRID MODELS

Alberto Rivas; Pablo Chamoso; Alfonso González-Briones

BISITE Research Group, University of Salamanca. Edificio I+D+i, Calle Espejo 2, 37007. Salamanca, Spain.
Air Institute, IoT Digital Innovation Hub (Spain), Calle Segunda 4, 37188, Salamanca, Spain.
rivis@usal.es; chamoso@usal.es; alfonsogb@usal.es

Abstract: Recommender Systems (RSs) play a very important role in web navigation, ensuring that the users easily find the information they are looking for. Today's social networks contain a large amount of information and it is necessary that they employ mechanism that will guide users to the information they are interested in. However, to be able to recommend content according to user preferences, it is necessary to analyse their profiles and determine their preferences. The present study presents the work related to different recommender systems focused on two different hybrid models. Both of them are using a Case-Based Reasoning (CBR) system combined with the training of an Artificial Intelligence (AI) algorithm. First, some information is analyzed and trained with an AI algorithm in order to determine relevant patters hidden on the information. Then, the CBR system extends the system using a series of metrics and similar past cases to decide whether the recommendation is likely to be recommended to a user. Finally, the last step on the CBR is to propose recommendations to the final user, whose job is to validate or reject the proposal feeding the cases database.

Keywords: Recommender Systems; Artificial Intelligence; Case-Based Reasoning; Social Networks.

1 Introduction

The role social networks play in our daily lives is probably greater than we realize. We often see them as simple communication and content-sharing tools, those, of course, are their main functions. However, social networks have come to be much more than that; they customize advertisements to suit our tastes and they even help us find a job [4]. Social networks provide such advanced features thanks to the collection and analysis of the data users generate on the Internet [1] [5]. Career-oriented social networks enjoy a particularly high success rate, some well-known platforms include Monster, XING, LinkedIn or beBee [2]. Following a different approach, a recommender system can be designed and developed using the information obtained from Virtual Learning Environments (VLEs). According to the information gathered, a platform like Moodle can be modified in order to give recommendations to their students [10-21]. In the next sections two case studies are described. The first case is a work related to social networks in which individual job recommendations are given based on the preferences and the profile of a particular user on social networks. The second case is using data from a VLE platformm, and the main goal is study the variables to determine the principal factors that affect to the final results of students [22-33].

2 Job offer recommender system

The research presented in this case study focuses on a relationship recommendation system for a business and employment-related social network called beBee [6]. On beBee, companies and users share content, and users search for and apply to the published job offers. Therefore, in the case of this social network, the recommender system will not only serve for connecting similar user profiles but also for providing work related suggestions to users and companies.

For this purpose, we identify different factors that could be extracted from the information provided by users and we analyzed the information found in the published job offers. One of the challenges that we had to address was the extraction of information, since the required information is often not available or it is not properly structured. Thus, it was necessary to apply text mining and information extraction techniques in order to evaluate possible ties between users as well as users and job offers [34-47].

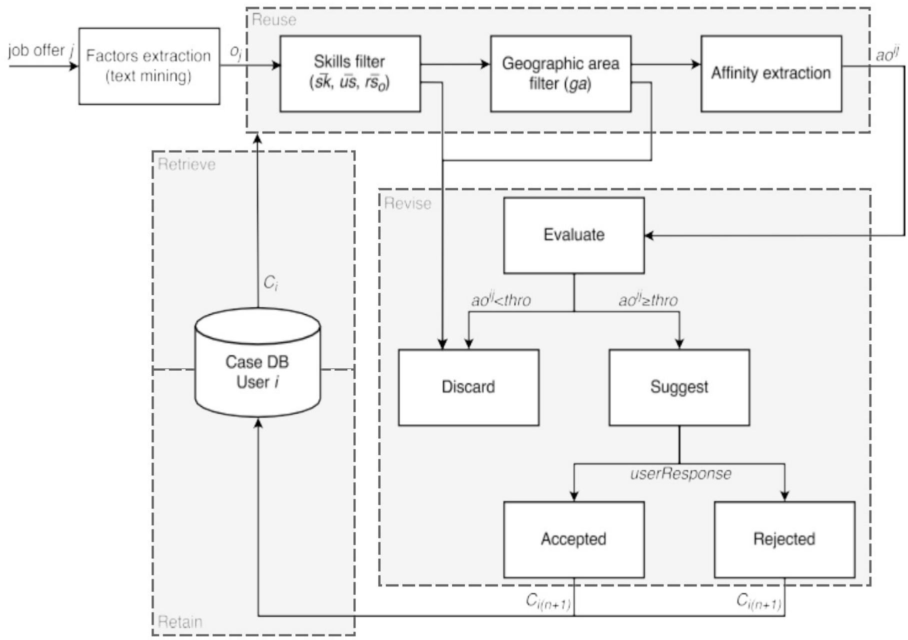

Figure 1. Job offer recommendation system flowchart and CBR parts.

These techniques ensure that the job offers recommended to users, correspond to the information provided in their profile; they possess the skills required by the offer, they have been previously interested in similar offers, etc. However, the use of these techniques does not guarantee that the offer suggested by the system, satisfies all user expectations.

To provide accurate suggestions, it is important to analyze the reasons for which a particular user could reject or accept a suggestion. To do such an analysis, it is necessary to employ techniques such as case-based reasoning (CBR), which allows to feedback the system with information on previous cases [7]. CBR is a problem solving methodology and its use in this project is essential since it will allow the recommender system to learn and improve over time by re-using similar past experiences which are stored in cases. The one proposed in the case study follows the flow described in the Figure 1.

To evaluate the proposed system it has been divided into two parts: user-user relationships and user-job offer relationships. Different subsets of real and active users, as well as recently published job offers, have been selected to gather information for this evaluation. The results obtained in this evaluation are satisfactory [48-56].

3 Resources recommender system based on the students performance

The objective of this case of study is to give some recommendations to the students aiming for increase exam pass rate through the evaluation of an automatic learning model and its subsequent improvement. The system proposed in Figure 2 has been designed for this purpose; an Artificial Neural Network (ANN) is trained with data in order to make it capable of identifying patterns of behaviour. Subsequently, the initial data set is analyzed and the parameters that contribute to students failing their exams are minimized to increase the pass rate. Finally, the already trained network is used in order to predict if with the modifications made in the parameters are going to help students to pass their exams.

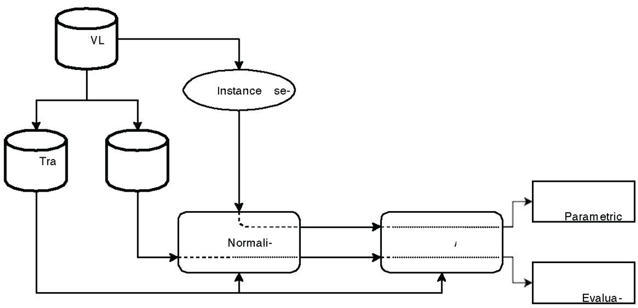

Figure 2. System workflow.

Due to data protection, the processing of data may be a complicated process, as a result, it was decided to work and apply a set of public data that can be accessed at [3]. The dataset contains a group of students who have participated in a series of four online courses, resulting in a total of 32, 593 students. It includes the students' personal data such as their identification code, the students' gender, region, educational level, age range, neighborhood crime rate (IMD), number of times they have previously participated in the course, enrolled credits, disability and the final exams result (passed/failed) [57-67]. In addition, the number of times the student clicked on any of the online course contents has been counted throughout the course.

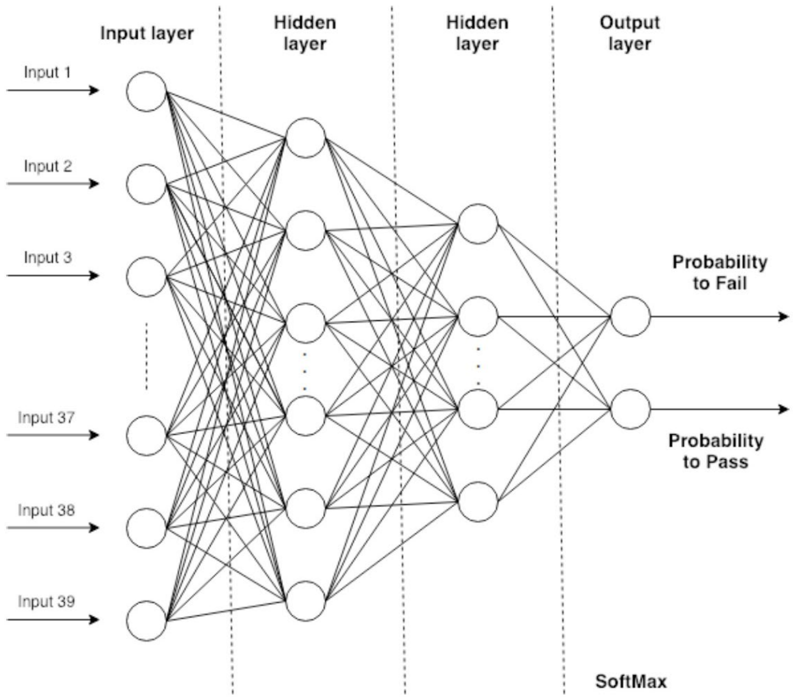

Figure 3. Design of the multilayer perceptron.

About the ANN, the proposed system architecture is based on a multilayer perceptron (MLP) with up to two hidden layers with a previously fixed size, as shown in Figure 3. The activation function of the neurons in the hidden layer is selected among three choices: the Rectified Linear Unit function,

$$relu(z) = \max(0, z) \tag{1}$$

the logistic sigmoid function, and the hyperbolic tangent function, tanh. The procedure for choosing these hyperparameters of the network, such as the number of neurons in the hidden layers or the activation function, a 5-fold cross validation procedure was carried in the training set. The mean accuracy is then used to compare the different network topologies [68-75].

Apart from those hidden layers, the input layer has as many neurons as there are inputs in the data set, while the output layer has 2 neurons with a SoftMax activation function, ideal for classification problems as it scales actual values in the range of [76-86]. The first neuron in the output layer is the probability that a student is going to fail, while the second is the probability that a student is going to pass the course.

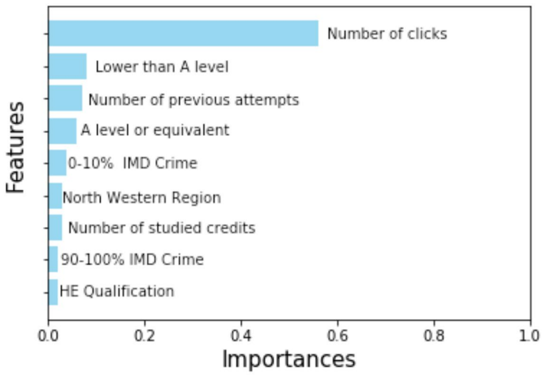

Figure 4. Weight of parameters

The logarithmic loss has been used to optimize the weights of the network, providing a more nuanced view into its performance than the accuracy. To minimize the processing costs of the algorithm, an optimization method has been leveraged. Specifically, the Adam optimizer [8] designed to train Deep Neural Networks, has been used with 500 epochs and a batch size of 30.

Regarding the results, it can be seen that the user intersection with the contents displayed in the VLE is really significant as Figure 4 shows, being the number of click the most important feature amongst the other ones. Based on this study, next step will be to study the resources available in the platform in order to figure out the most relevant ones for each user []76. Once this study will be done, the most interesting aspect to include is to display better positioned in the VLE the most important resources to facilitate the final user the interaction with them.

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AQUILAFUENTE, 287

The exchange of ideas between scientists and technicians, from both academic and business areas, is essential in order to ease the development of systems which can meet the demands of today's society. Technology transfer in this field is still a challenge and, for that reason, this type of contributions are notably considered in this compilation. This book brings in discussions and publications concerning the development of innovative techniques of IoT complex problems. The technical program focuses both on high quality and diversity, with contributions in well-established and evolving areas of research. Specifically, 10 chapters were submitted to this book. The editors particularly encouraged and welcomed contributions on AI and distributed computing in IoT applications. The editors are specially grateful for the funding supporting by the project "Virtual-Ledgers-Tecnologías DLT/Blockchain y Cripto-IOT sobre organizaciones virtuales de agentes ligeros y su aplicación en la eficiencia en el transporte de última milla", ID SA267P18, financed by regional government of Castilla y León and FEDER funds.

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ISBN: 978-84-1311-293-0
9 788413 112930