C.2. PROPUESTA CIENTÍFICA

C.2.1 Antecedentes y estado del arte

Introduction and Motivation

Energy (electricity, gas, water, etc.) supply networks are large infrastructures, operated by utility companies and controlled by networked instruments and controllers, but governed by social demand (habits, emergent behaviours, etc.) and subject to environmental changes (seasonality, scarcity, etc.). People do not behave like standing smart meters but are alive, moving from on place to another and sometimes as huge crowds. Therefore, the need for a service (e.g. energy) in a spot may change dramatically in a few hours and has to adapt accordingly for an efficient use of it. As a result, these large-scale cyber physical systems (CPS) are continuously affected by the variability (in time and space) of both, user (energy consumers) behaviour and weather conditions. These variations introduce changes on the energy system dynamics, difficult the operation and consequently affects the efficiency. Utilities, energy and facility managers usually take into account weather prediction for the operation but user, or social, behaviour is only considered circumstantially (singular events) because of the difficulties for sensing and predicting it. In this scenario is where CROWDSAVING becomes meaningful and challenging.

Previous results achieved by the consortium

This proposal extends previous results of the consortium (UPM+UdG) achieved in the project MESC (DPI2013-47450-C2-1-R, 2014/16, MESC: Platform for Monitoring and assessing the Efficiency of distribution systems in Smart Cities, http://exit.udg.edu/mesc/) towards the integration in a single platform information from the energy management systems and crowd-sensing. The MESC platform includes the design of a middleware to integrate different data acquisition systems (BMS/BEMS, WSN, Smart meters, weather station, etc.) commonly used for energy management allowing a standardised access to energy data (REFS UPM). MESC already provides some exploitation services designed under the data mining approach to support energy management in two basic steps, adapted to the energy management goals: modelling and monitoring. Machine learning and multivariate statistical methods have been proposed to model energy consumption with respect to independent variables as temperature, occupancy or calendars and have been tested in different scenarios. During monitoring, the reference models can be used for different purposes, among them fault detection, forecasting (when fitted with weather predictions) or energy saving accounting in measure and verification (M&V) procedures ([1],[2],[3]).
The UPM&UdG team has collaborated in the past in previous collaborative projects in the area of smart grids (e.g. IMPONET, ENERGOS) and individually UPM and UdG are currently participating in two H2020 projects that offers complementary views of this proposal. In particular, UPM hosts the CPS (Cyber Physical System) Design centre in Spain, as partner of the CPSELabs project and UdG is partner in the HIT2GAP project devoted to reduce the energy gap between design and real performance of buildings.

New challenges: user behaviour modelling and collaboration

The proposal deals with the challenge of extending capabilities of the MESC framework to integrate in the same middleware classical sensing infrastructures (SCADA, BMS/BEM, WSN, weather stations, etc.) with the crowd-sensing reading from numerous devices carried by different individuals) paradigm. Crowd-sensing is an emerging technology that allows improving observability of large spaces and their interaction with users and activities by exploiting smartphone sensing capabilities and aggregating conveniently [4]. Crowd-sensing imposes new software requirements to the MESC platform to consider new and strong adaptability and variability demands associated with mobile sensing and a reformulation of modelling and monitoring services to deal with the availability of information and caducity of models. Crowd-sensing inherits problems and challenges inherent to big data and mobility.
Users' behaviour (or more specifically social behaviour) modelling and monitoring in bounded areas (buildings, neighbourhoods, cities, etc.) is a keystone to understand the dynamics of energy systems, considered as large cyber physical systems, and to operate them efficiently.

Brief State of the art

Nowadays, software adaptability and flexibility have specially acquired a high relevance due to the change that our society is undergoing with Internet of Things (IoT) or the conception of our systems as smart buildings, grids, cities, spaces and water networks. These systems require the deployment of ICT infrastructures and the design of software architectures using innovative models [5] to provide flexibility and intelligent properties. These systems are known as Cyber-Physical Systems (CPS). CPS are the next generation of embedded ICT systems designed to be aware of the physical environment by using sensor-actuator networks to provide users with a wide range of smart applications and services[6]. These Large-Scale systems are usually *evolutionary* and *decentralized* Systems-of-Systems [7] due to their flexibility and scalability requirements, even in run-time, and the geographical distribution of their resources and services. This fact makes that the components that constitute these systems operate independently requiring interoperability. In addition, these systems requires the support for *"modifications or extensions that were not envisaged at design time"*, and thus should be performed *"without stopping or disturbing the operation of those parts of the system unaffected by the change*" [8], i.e. the systems' behaviour. Hence, these systems require mechanisms to incorporate new software or replace existing software for sensing and acting on systems without being a priori designed to those tasks.

Flexibility is defined as the ability to deal with changes that can be anticipated or expected [9], [10] i.e., changes that can come or not come with some probability over some period of time. Variability is a means for evolution of component-based architectures, driving flexible and adaptive architectures. *Designing for flexibility* involves the design of an architecture as a set of architectural design decisions implemented through variability implementation [11]. The work of Bachman and Bass [12] is a reference for the management of variability in software architecture, in which variability is supported by modifying the configuration of the architecture by adding or removing components or connections, as the works of Garg et al. [13] or Razavian and Khosravi [14] consider, and that Mae and x.ADL 2.0 [15] provide. There are others works that provide mechanisms to express variability in different architectural views (component, interaction and deployment) [16] or that take advantages of other approaches as Aspect-Oriented Programming or Software Product Lines [17]. In addition, the Koala Component Model [18] and the Plastic Partial Components Model address the need of specifying variability inside components [19].

Adaptability is a step forward to flexibility, it is the ability to deal with changes that cannot be anticipated nor foreseen [20]. Therefore, software architectures of CPS not only require to be flexible, but also require to be adaptive at run-time. CPS should be designed to monitor and respond to the physical environment, enabling fast, effective autonomic control loops between sensing and actuation, possibly with cognitive and learning capabilities [6]. Autonomic computing (AC) [21], [22] emerged as a solution to deal with the increasing complexity of today's computing systems and human management limitations. Horn [21] defines autonomic systems as software systems that mostly operate without human or external involvement according to a set of rules or policies; in other words, the systems are self-managed. Specifically, IBM proposed the MAPE-K loop for supporting autonomic computing [23]. In order to support the mentioned reconfiguration capabilities, two mechanisms are required to be implemented by software architecture: (i) to manage the creation and management of component dependencies at runtime, known as *dependency injection* [24], and (ii) to run programs to examine itself and its software environment and changing what it required from the results of the examination *reflection* [25] approaches emerged.

In addition, these systems require be constructed on scalable solutions that imply the usage of technologies that are loosely coupled and highly distributed. Therefore, it is critical to construct software architectures based on the publish-subscribe paradigm [26] and even implemented on event-driven infrastructures (Service-Oriented Architectures (SOA) [27] or Event-Driven Service-Oriented Architectures (EDSOA) [28]).

But all these state of the art-of is even more challenging in the crowd-sensing, since most of the adaptation will be triggered from mobile devices through applications and services deployed in the Cloud. Currently, there is a movement in the society and software industry and it is the fact that software is being migrated to the Cloud [29]. So, software architecture solutions for CPS that provide flexibility and adaptability require to be also supported by the Cloud Computing or even Fog computing approaches [30],[31].

Crowd-sensing is an emerging sensing paradigm that empowers ordinary citizens to contribute data sensed or generated from their devices (mobile phones, wearable devices, cameras, etc.), aggregates and fuses the data in the cloud for crowd intelligence extraction and human-centric service delivery [32]. Crowd-sensing allows improving observability of large spaces and their

interaction with users and activities [4]. The most extended crowd-sensing approach takes benefit of computing and sensing capabilities of smartphones and wearables and commonly is referred as Mobile Crowd-sensing and Computing (MCSC) [32].
Several application domains can benefit from mobile crowd-sensing, such as smart cities, road transportation, healthcare, marketing, etc. In the field of smart cities, research efforts are currently underway to exploit the full potential of the sensing data to improve city efficiency by deploying smarter grids and water management systems [33] and MCSC seems a significant technological solution for enhancing energy monitoring and management [34]. Energy management (EM) systems integrated with home automation systems and BEMS (Building energy management systems), play an important role in the control of home and facility energy consumption and enable increased consumer participation [35]. One of the key requirements for EM systems is the information integration from different sources, such as energy meters, sensors, weather stations, etc. and mobile devices, such as smart phones, can be included. Then, the system is able to interact with its users through their devices, providing sensory data and receiving feedback.
[36] categorizes crowd-sensing applications into (1) Environmental (2) Infrastructural (3) Social. An example of environmental application is to measure pollution levels in a city. Infrastructure sensing involves measurement of large-scale phenomena involving public infrastructure, such as traffic conditions, road conditions, parking availability, etc. Social applications are those where individuals share sensed information amongst themselves (e.g. sharing exercise/health biomarker levels). In this project, effectiveness of crowd-sensing to assist energy efficiency is proposed. This is very new topic where only few examples exist. In this sense [37] develops a smart luminance scenario where the luminance units are adjusted creating live luminance maps and aggregating user preferences. In [38] a platform to achieve energy saving considering user behaviour aspects (interaction with the system, identity, location and activity) in the management of the buildings' infrastructures is deployed. Also, crowd-sensing techniques that adapt the ambient conditions to the crowd presence and behaviour and improve energy efficiency are included in a testbed in [39]. In the presented scenario, measurements from the user's smartphones (e.g. temperature) are sent to the energy optimization/automation server, phone's sensor hints (e.g., accelerometer and gyroscope) are used to extract the user's status (lying, moving, etc.), and the user selects a desired energy/comfort trade-off/preferences; then, the actuation is triggered according to the inputs.
Standardisation of data gathering is still a challenge, although some dedicated examples and middleware have been created. Thus, [40] proposes a crowd-sensing architecture to gather and processing events affecting citizens. These events can come from mobile application (images, audio, location), SMS, Web-based forms, and social media feeds. Since a key challenge is the veracity of data, this paper proposes various methods for data validation, such as correlations and a challenge-response protocol based on the requiring participation of citizens through the sending of tasks to a phone. USense[41] is a cloud-based coordination middleware to which data consumers can execute queries that send out sensing tasks to individual smartphones to collect data. The platform build data models and responds to the queries.
As a conclusion, it can stated that crowd-sensing is still an immature discipline. A lot of effort has been focused on supporting crowd-sensing itself, but not so much on transformation and enabling the overall infrastructure to provide better services to citizens. There are many open issues that have to be covered before reaching a standardised operation mode. Data quality, reliability and soundness are clear examples, but also architecture issues related to variability and adaptability are open and depends on the application domain and nature of data. Thus, data model definition, data validation, processing and analytics, development of domain-specific policies, security/privacy issues or communication are some of the active research areas. Moreover, crowd-sensing inherits common challenges from big data.

Links with other research groups (national and international)
To achieve the proposed goals the CROWDSAVING team will collaborate with other groups At Spanish level several Universities and research groups have activity in topics related or close to this project. We consider contacting The "Plataforma Tecnológica Española de Eficiencia Energética" (http://www.pte-ee.org), E2TIC a cluster promoted by five University Chairs (Universidad Politécnica de Catalunya, Universidad de Oviedo, Universidad Politécnica de Valencia, Universidad de Extremadura and Universidad de Sevilla) that aims promoting TIC initiatives, in Spain, oriented to achieve the 20-20-20 UE goals, the "Grupo de Ciudades

Inteligentes (GICI)" a group ccreated to aligned the strategy related to smart cities in Spain and the includes all the Spanish ETPs concened with Smart Cities.
At individual level some universities have active groups working on areas of interest to the project, combining parking places management and crowd-sensing. An example is the group of Prof. Juan Carlos Lopez, at UCLM. At European level, most the effort is being focused on supporting crowd-sensing, as it was discussed in the State of Art Section. From this perspective, the project RADICAL (2013/16) will enable the development of interoperable pervasive multisensory and socially-aware services. UPM-SYST is in regular contact with European research centers working on software architectures, not mentioned here for the lack of space.
The CPSElabs projects, in which SYST-UPM is involved, is one opportunity to be in contact with partners that are making experiments related to the city, and where social networks can be present. The SYST-UPM and eXiT UdG have been partners in the predecessor project MESC it will possible for them to use the network of contacts develop in the MESC project.

C.2.2 Hipótesis de partida y objetivos generales

Initial hypothesis
Actual energy monitoring systems have a reduced observation capacity of the user behaviour and their interaction with energy infrastructures. Moreover, dynamics of these interactions are completely unknown and the use of standard monitoring equipment is not enough to capture and model it. The cost of instrumentation at consumer premises, allowing load disaggregation, was the principal barrier to deal with. Consequently, new low-cost broad-sensing paradigms are needed, and crowd--sensing is offering this possibility, not only at premises level but, at different community and aggregation levels. On the other hand actual software architectures and middleware used for data acquisition and management at utility or facility level does not contemplate the integration of such new sensing approaches. Data volume and variability are not affordable by traditional monitoring architectures as it has been demonstrated in MESC and the variability studies performed in it.

General Objectives of the coordinated Project
The general objective of the CROWDSAVING project is to provide a software infrastructure levering to monitor impact of user behaviour on the dynamics of energy/water distribution networks and energy intensive facilities. Crowd-sensing enables the observation of social behaviour at different aggregation levels and requires specific methods and adapt variability of data streams to existing energy management solutions. This general objective comprises two complementary objectives, addressing the challenge from two complementary points of view, software architecture and energy monitoring:

- O1: To enable software architectures to support dynamic distribution networks, as an evolution from existing distribution networks
- O2: To identify and define the mechanisms needed monitor the impact of social behaviour on energy efficiency of power networks and facilities.

Subproject 1 will expand on the objective O1 exploring software architecture issues to provide support for crowd-sensing in changing environments. In addition, **Subproject 2** will go through the objective O2 to adapt or define methods to analyse data provided by crowd sensors.
CROWDSAVING aims to improve energy management of distribution networks and facilities based on ICT technologies through the integration of people acting as dynamic sensors (mobile and intermittent) with existing sensing infrastructures. CROWDSAVING project implies transformations at different levels, energy managers need to adapt the system architecture to integrate crowd-sensing capabilities, society needs to understand and accept its new role as source of information and benefits for efficient energy management, and finally institutions need to regulate crowd-sensing to protect people rights (including privacy and security).
Both subprojects aim to share the objective of transforming MESC (DPI2013-47450-C2-1-R, 2014/16, previous collaborative RETOS project started in 2014) by extending its capabilities towards a common framework to integrate information from classical sensing infrastructures (SCADA, BMS/BEM, WSN, weather stations, etc.) and crowd-sensing information, providing a standardised access to the modelling and monitoring services. This new framework will enable new capabilities to sense variability of energy demand and levering the deployment of adaptive mechanism for a more efficient management. Thus, the project proposal has been conceived to:

- To make the existing framework (MESC) evolve towards the demands from crowd-sensing by enabling new capabilities
- To improve energy modelling and monitoring capabilities with crowd-sensing information including users' behaviour and context sensing.

The scope of this main objective has been extended in section C2.3 according to particular objectives of the subprojects.

Adequacy to the Spanish and European research strategy and societal challenges:
The CROWDSAVING project is aligned with the Spanish societal challenge "Reto 7: Economía y Sociedad digital", addressing the sub-challenge "IV APLICACIONES Y SOLUCIONES TIC". CROWDSAVING project covers topic "(iii) materia de eficiencia y la gestión energética", through the improvement of efficiency of energy distribution infrastructures based on ICT technologies levering the participation of people as dynamic sensors and exploiting this information on the energy management systems. From this perspective the project will also contribute to the societal challenge "Reto 3: ENERGIA Segura eficiente y limpia"
At European level, CROWDSAVING project tackles three focus areas of the third societal European challenge "Secure, clean and efficient energy" that maps the spanish strategy: energy efficiency, smart cities and water; and fits with the objective of developing ICT based energy management tools to enable the development of Energy efficient and smart buildings and neighbourhoods.
The proposal has taken into account the **SET-Plan Roadmap** on energy efficient policies and the directives on energy efficiency (ED2012/27) and energy performacne of buildings (ED 2010/31) and embraces on the **Energy Efficiency WP 2016/17 empowering consumers** (topics EE6, EE7,EE8) and **demand side response deploying using smart technologies** (EE12). Moreover, the topic of the project is aligned with topics of the industrial leadership pillar on **LEITs (Leadership in Enabling and Industrial Technologies)**, particularly those on **big data** (ICT-15), **IoT** (EUB-2). Also, achievements in the projecte will contribute to leverage of the **societal challenge 5 (Climate action, environment, resource efficiency and raw materials)** looking for **intelligent, user-driven and demand-oriented city infrastructure and services, integrating smart buildings, smart grids,** energy storage, electric vehicles and smart charging and latest generation **ICT platforms based on open specifications** addressed in SCC-2, SCC-3 and SCC-4.

Economic relevance
CROWDSAVING results could be directly applied to energy efficiency and to improve the management of power distribution networks helping distribution companies to adapt demand and response. Simply focusing on energy efficiency on buildings, in EU there are 25 millions of square meters of buildings (including Switzerland and Norge), half in noth Europe, 36% in the central Europe and 14% in South Europe with an annual growth of 1%. At City levels, the majority of municipalities have signed the Covenant of Mayors compromising to reduce emissions and energy consumption according to ED2012. This a huge market, mainly governed by Energy Services Companies (ESCOs) and facility managing companies.

C.2.3 Objetivos de cada subproyecto

This general objective (already defined in section C2.2) comprises the following two objectives:

- O1: To enable software architectures to support dynamic distribution networks, as an evolution from existing distribution networks
- O2: To identify and define the mechanisms needed monitor the impact of social behaviour on energy efficiency of power networks and facilities.

Subproject 1 will expand on the objective O1 exploring and then enabling software architecture issues to provide support for crowd-sensing in changing environments. In addition, **Subproject 2** will go through the objective O2 to adapt or define methods to analyse data provided by crowd sensors. The next subsections describe the specific objectives of each subproject.

C.2.3.1 Subproject 1: UPM
This subproject is focused on the implications of crowd-sensing over the software architecture of distribution networks (energy, water or any other type). Subproject 1 will evolve results obtained in MESC to provide support to crowd-sensing needs and to integrate services and

methods obtained in Subproject 2 to provide an architectural framework adaptable to changing environments. Subproject 1 presents the following sub-objectives:

- **O1.1 UPM: To study data acquisition in crowd-sensing environments.** (Resp. Juan Garbajosa) This objective pursuits understanding the specific characteristics of data coming from users. In crowd-sensing environments data could have different sources such as existing sensors (static), mobile devices (smartphones or tables) or any other software for pattern recognition (person counters or movement detection). Therefore, research on the analysis of these heterogeneous sources and their modelling is required.
- **O1.2 UPM: To integrate crowd-sensing capabilities to existing distribution networks software architecture.** (Resp. Jennifer Pérez) The integration of crowd-sensing capabilities into existing software architectures is key to achieve the major goal of this proposal that is to have support for dynamic (adaptive, flexible and mobile) distribution network. Software architecture should provide flexibility because people is login-In and login-out in the system, and therefore the number of sensors is rapidly changing. In addition, as people is moving around places, sensors are not statically allocated. Finally, software architecture should be adaptive because crowd-sensing systems changes their structure, behaviour or resources according to demand.
- **O1.3 UPM: Validate the crowd-sensing architecture to energy efficient operation of infrastructures and buildings.** (Resp. Jennifer Pérez) The last objective of this subproject is to validate the crowd-sensing software architecture through testbeds in real scenarios related to energy efficient operation of infrastructures and buildings. These testbed enables a twofold validation of the architecture; on one side to validate the obtained software architecture in changing environments and; on the other side the capability to integrate models and services provided by Subproject 2.

C.2.3.2 Subproject 2: UdG

The objective of this subproject is the improvement of data driven methods and services for energy monitoring, developed in MESC, with the integration of crowd-sensing information and user behaviour modelling capabilities. With this aim the following sub-objectives have been identified:

- **O2.1 UdG: To Develop new services to model user/social and context behaviour based on crowd-sensing** (Resp. Joaquim Melendez) This objective pursuits understanding the influence of users in energy intensive spaces (buildings, neighbourhoods) and implies the development and integration of specific services to systematically model and analyse crowd-sensing data to infer significant information directly influencing energy consumption. To achieve this objective the following partial goals have been defined:
  - Identification of occupancy patterns (time-space distribution) in bounded areas.
  - To develop new methods for modelling and discovering social behaviour based on crowd-sensing information.
  - To understand the influence of users/social behaviour on the energy consumption of bounded communities.
- **O2.2 UdG: Adaptation of existing energy monitoring services to incorporate influence of user behaviour** (Resp. Joan Colomer). Variability and availability of crowd-sensing supposes a new challenge to machine learning approaches that will be afforded in this project. The goal is to adapt the already developed energy modelling and monitoring services to include information inferred from crowd-sensing sources attending these new challenges. Sub-objectives to be achieved include:
  - Adaptation of the energy monitoring data model to incorporate the crowdsesing data model in order to integrate the services to the new architecture
  - Analysis, study and redesign of existing modelling methods to deal with variability of behavioural patterns and adapt the existing energy monitoring services to include user behaviour models.
  - Exploitation of data driven models to detect emergent energy behaviours influenced by social behaviour.
- **O2.3 UdG: Validate the exploitability of the proposed methods to support a more energy efficient operation of infrastructures and buildings** (Resp. Joaquim

Melendez). We fix as objective to have an integrated solution ready for testing in real scenarios.

- Functional validation of a set of the energy monitoring services integrated in the platform
- Exhibit the benefits of the proposed solution to third parties for evaluation.

C.2.4 Metodología

Basic methodological issues

This project will start with the basic principles observed about crowd sensing and will study how they can be integrated in energy management systems. The goal is to have the technology validated in a pilot at the end of the project. This entails usage of different methodologies for different activities of three knowledge areas: software engineering, computation sciences and control engineering. This implies a collaborative work that merges methodological issues inherited from these areas. Basic methodological issues, reflecting this condition, to be followed during the execution of the project are briefly described below:

Research methodology:

Specific research methodologies in software engineering are consistent with the principles of *design science* [42], as well as specific techniques such as the use of pilot/case studies for specific issues such as validation. Design science is essentially a problem-solving paradigm that seeks to create and validate artifacts intended to solve identified problems [42]. The design-science's guidelines are the following: (i) Research must provide solutions to important and relevant problems. (ii) Research must provide verifiable contributions. (iii) Research must produce a viable artifact resulting from a search process. (iv) Design artifacts must be rigorously validated. (v) Research must be communicated. The most common kind of validation is evaluation through empirical research methods: observational methods (e.g. case studies or field studies) or experimental methods (e.g. controlled experiments or simulation). A pilot/case study is an empirical method that investigates contemporary phenomena in its natural context [43] in order to search evidence, gain understanding, or test theories by using primarily qualitative analysis [44].

Data mining & Knowledge discovery: Data mining is a methodological approach to extract hidden patterns from data and transform data into valuable information or knowledge (knowledge discovery). Methodological principles of data mining can be summarised in the following steps: *Preprocessing* (Data filtering, Elimination of outliers, blanks and corrupted data) *Exploratory Data Analysis* (Feature selection, MANOVA, covariance analysis, etc. to identify significant variables and redundant variables), *Transformations and Feature extraction* (Extract significant information from raw data according to goals, data transformation and dimensionality reduction), *Data modelling* (Different typologies of models can be obtained -classification, clustering, regression, associative rule learning- according to exploitation objectives) and *Model Exploitation* (projection of new data to the model to achieve proposed goals: detection, diagnosis and prediction in this project). Data mining methodology will be used for building energy consumption models and their exploitation during monitoring.

Monitoring. Fault Detection and Diagnosis: Basic principles of Fault detection implies the exploitation of analytical redundancy given by models in order to detect inconsistencies on real data. Decisions on such deviations (residuals) are used to generate alarms associated to abnormal behaviours and signatures described by such residuals are used in the identification and isolation of possible causes (diagnosis). Definition of appropriate metrics and search strategies are key issues in the diagnosis process. Models used for this purpose, will be learned from data (following data mining approaches) in this project. Well known strategies operating with multivariate statistical models based on principal component analysis (PCA) also follows these strategies. Performance of both, multivariate statistical and transient models, will be evaluated for detecting and diagnosing energy efficiency misbehaviours the project.

Evaluation of architectures: methods for architectural evaluation such as ATAM will be used for early validation of the proposed software architecture. In later development stages, the software architecture will be evaluated by pilots and experiments.

Software development methodologies: all tasks that will involve software development will follow an iterative methodology due to this methodologies are suitable for projects where

Comentado [CF1]: Hace falta una metodología de investigación, las que tenemos son muy de ingeniería, son las mismas que cualquier empresa usaría para realizar un proyecto, nos falta añadir más peso al research.

Comentado [CF2R1]: Cierto!!. Debesmos reducir lo que hay e incluir algo de metodológica de ivnestigacion en Computer science

Comentado [CF3]: Si estás de acuerdo con algo así, añado las referencias.