A Review of Artificial Intelligence in the Internet of Things

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Abstract

Humankind has the ability of learning new things automatically due to the capacities with which we were born. We simply need to have experiences, read, study… live. For these processes, we are capable of acquiring new abilities or modifying those we already have. Another ability we possess is the faculty of thinking, imagine, create our own ideas, and dream. Nevertheless, what occurs when we extrapolate this to machines? Machines can learn. We can teach them. In the last years, considerable advances have been done and we have seen cars that can recognise pedestrians or other cars, systems that distinguish animals, and even, how some artificial intelligences have been able to dream, paint, and compose music by themselves. Despite this, the doubt is the following: Can machines think? Or, in other words, could a machine which is talking to a person and is situated in another room make them believe they are talking with another human? This is a doubt that has been present since Alan Mathison Turing contemplated it and it has not been resolved yet. In this article, we will show the beginnings of what is known as Artificial Intelligence and some branches of it such as Machine Learning, Computer Vision, Fuzzy Logic, and Natural Language Processing. We will talk about each of them, their concepts, how they work, and the related work on the Internet of Things fields.

Keywords

I. Introduction

THIS was the question that was asked by Alan Mathison Turing and to which he responded with the proposal of The Imitation Game [1]. The Imitation Game is played by three people, 'A' who is a man, 'B' who is a woman, and 'C' who is the interrogator and can have any of the genders.

The interrogator is in a room other than 'A' and 'B'. During the game, 'C' can ask them any kind of question to determine who is the man and who is the woman, for example, about the length of the hair. 'C' knows the participants under the labels 'X' and 'Y'. When the game ends, 'C' must say 'X' is 'A' and 'Y' is 'B' or vice versa. In this game, the tone of voice does not help 'C', since 'A' and 'B' must write the answers, preferably using a machine, which are sent by a teletype or through another intermediary to 'C'.

This problem can be thought with a variant that is based on replacing the man 'A' with a machine. In this case, 'C' could ask 'A' and 'B' to write poetry, but the machine could refuse. Given this, 'C' could ask a mathematical operation and see that the machine solved it or ask them if they play chess. However, to avoid undue comparisons in the game, the interrogator is prevented from asking for demonstrations, since in some cases the machine is better and in others, the human being is better, as well as each having different skills. For these reasons, this game is about the machine trying to imitate the behaviour of the human

being, assuming it can give answers just like a human being would do it naturally. From this theory, the well-known Turing Test emerged.

However, the imitation from a machine is very difficult to be given, as Turing says from different points of view, namely: the theological, the reluctant people to know the problem (Head-in-the-sand), the mathematician, the one of the conscience, the one of the different disabilities, from the point of view of the memories of Ada Lovelace [2], from the continuity of the nervous system, from the argument of the familiarity of the behaviour and from the extrasensory perception.

For the reasons expressed from the different points of view, Alan Turing focused on what Ada Lovelace commented when she says that a man can 'inject' an idea into a machine. Thus, based on this, he hypothesised that he could inject knowledge if there was a space large enough for it, or at least, so that the machine could play The Imitation Game and leaving as a problem how to program the machines to overcome the game, because according to Turing, they already had the hardware capacity.

To carry out this idea, he proposed to make a child's brain instead of trying to make an adult brain, and thus educate it to obtain the brain of an adult. In this way, he divides the problem into two parts: the 'child' program and the education process. He explains that we should not expect the first 'child' machine to come out on the first attempt and that we should teach it to see how its learning evolves. Thus, after several attempts, they would be getting better machines (or even worse), something that Turing compared with the process of evolution and that several researchers would later develop under the name of genetic algorithms [3].

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Based on this, Turing talked about different experiments he carried out and the need of machines to simulate a human being, as is the case of the incorporation of random elements to imitate the possibility of failure that human beings have. To conclude, he commented on the thinking of many people that one could start making machines compete with humans in abstract activities, such as playing chess. However, from his point of view, it was better to mount the machines on the better 'organs' that money could buy and teach them to understand and speak English.

II. What is Artificial Intelligence?

Computers can only process zeros and ones. However, years ago, **Artificial Intelligence (AI)** was born to offer the possibility of creating programs that would allow computers to learn. This was the purpose of the first computer scientists, such as Alan Mathison Turing, John von Neumann and Norbert Wiener, among others, who tried to equip computers with programs that contained **intelligence**, the ability to self-copy, learn and control their environment, being, the principle of this, trying to model the human brain, imitate human learning and simulate biological evolution [4].

Research in **Artificial Intelligence** began after World War II, possibly being Alan Mathison Turing the first to investigate in this field in 1947 [5], and publishing an article about whether machines could think in 1950 [1]. This article is where the famous **The Imitation Game** comes from, from which the **Turing Test** emerged. Both serve to know if a machine is intelligent enough to confuse it with a human being. In that article, Turing also explained how an **AI** system should be created, starting with the creation of a child machine that would be learning to be as an adult. Subsequently, in the decade of the 50s, many more researchers joined this field [5].

Later, John McCarthy, Marvin L. Minsky, Nathaniel Rochester and Claude E. Shannon coined the term **Artificial Intelligence** in 1955 in the Dartmouth summer research project [6]-[8]. In this project a stay of two months was proposed to investigate the principles about learning or another type of intelligence and see if the computers could simulate it, or, rather, with the name they coined, to investigate in **Artificial Intelligence**.

But what exactly is **Artificial Intelligence**? According to John McCarthy [5], **Artificial Intelligence** is the science and engineering that tries to make machines intelligent, trying to get them to understand human language and to reach problems and goals as well as a human being. However, there are some authors who affirm that the objective of the **AI** is to put the human mind inside a computer, although they may speak metaphorically. One of the ways to know if a machine is intelligent is the **Turing Test**.

To answer the previous question, one must also understand what is meant by **intelligence**, for which a reference can be made to [5]. **Intelligence** is the computational part of the ability to achieve objectives and has various types and degrees as occurs in humans, many animals and some machines. However, it is not necessary to consider intelligence to answer 'yes' or 'no' to a question, because, although this is sometimes the goal, machines can do much more, such as, for example, solving problems.

Some of the fields where **Artificial Intelligence** can be applied are, for example, video games, data mining, discourse recognition, natural language understanding, Computer Vision, the creation of expert systems and data classification [5]. Thus, **Artificial Intelligence** can be divided into several branches among which stand out Automatic Learning, Computer Vision, Fuzzy Logic, Natural Language Processing, Heuristics and Intelligent Agents.

III. The Six Rules of Artificial Intelligence

As for robotics, there are the three rules, created by Isaac Asimov in the first literature about robots, Satya Nadella, CEO of Microsoft, offered in an interview to the online magazine Slate[1] an outline of six rules that should be observed by the designers of Artificial Intelligence [9].

1. **AI must be designed to assist humanity**. It needs to respect human autonomy, using collaborative robots to perform dangerous works, such as mining, thus safeguarding human workers.

2. **AI must be transparent, being aware of how the technology works and its rules**. Or as Satya Nadella said: 'Technology will know things about humans, but humans should know about machines'. This would allow humans to understand how technology sees and analyses the world because ethics and design must go hand in hand.

3. **AI must maximise effectiveness without destroying the dignity of the people**. It must preserve cultural commitments, strengthening diversity. A broader, deeper and more diverse commitment to the population is needed because technology should not dictate the values or the virtues of the future.

4. **AI must be designed for intelligent privacy**. Sophisticated methods of protection are needed to ensure personal information to gain trust.

5. **AI must have algorithmic responsibility so that humans can undo the unintended damage**. This is why it is necessary to design AI technology for what was expected and what was not expected.

6. **AI must avoid bias by ensuring adequate and representative research so that an erroneous heuristic cannot be used to discriminate**.

However, Satya Nadella also clarified that humans 'should' prioritise and cultivate a series of characteristics to be able to coexist with AIs, such as:

1. **Empathy** to create relationships with others and perceive their feelings and thoughts because this is something very difficult to replicate in the machines.

2. **Education** that will be necessary to believe and manage innovations that are not understood today. For this, it will be necessary to increase the investment in education that allows developing the knowledge and the necessary skills to implement the new technologies and solve problems that will need much time.

3. **Creativity** because this is the most coveted human skill, that machines will continue to enrich and increase.

4. **Judgment** and **responsibility** to be willing to accept a diagnosis or legal decision made by a machine, but from which we expect that still a human being remains the ultimate responsible for making the final decision.

IV. Machine Learning

Machine Learning, is one of the branches of Artificial Intelligence, and, maybe, one of the most important subfields of AI [10]. It is based on the development of learning techniques to allow machines to learn [11], based on the analysis of data and applying some algorithms for this processing and others for decision making from the data already analysed.

One of the goals of **machine learning** is to facilitate the process of analyzing data intelligently, examples of which are spam filters

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1 http://www.slate.com/

[11], **Optical Character Recognition** (OCR) techniques [12], quantification of data relationships [12], recommendation systems [13], [14], computer-aided medical diagnostics [12], search engines [15], **Computer Vision** [16], [17] or **Data Mining** [18]–[20].

A. Taxonomy of Techniques According to the Type of Learning

Machine Learning algorithms can be classified based on the type of **feedback** received. In this subsection, we present a total of six categories: supervised learning, unsupervised learning, semi-supervised learning, reinforcement learning, transduction learning and multitasking learning.

The first is **supervised learning**. These algorithms infer a function by means of labelled training data that they receive as input [12], [21], [22]. An example of them is the algorithms used to classify images by using Computer Vision techniques. These algorithms must be fed with images labelled, for example, as correct or incorrect. In this way, the algorithm is fed so that it learns to classify the images according to the previously labelled images supplied. Therefore, it can be said that the algorithm learns for itself [23]. Some of the algorithms found in this group are some of those belonging to **Artificial Neural Networks**, **Bayesian Networks**, **Support Vectors Machines** and **Decision Trees**.

Another taxonomy is **unsupervised learning** [22], [23]. The difference with the previous one is that the input data is not labelled, and it is the system itself that must infer algorithms or patterns to recognise and label the same type of data. In this group, we find some types of **Artificial Neural Networks**, the **Association Rules** and some **Grouping Algorithms**.

In contrast, in **semi-supervised learning**, a combination of the two previous algorithms is performed [24]. In this way, the system must consider both the tagged elements and the untagged elements.

Another type of learning is **reinforcement learning** [25]. This is based on the algorithm learning based on the world that surrounds it. In this case, the algorithm learns from the answers given by the outside world based on its actions, criticizing them if they were good or bad. Therefore, this is an algorithm based on the classic trial-error learning.

An algorithm similar to the supervised learning is **transduction learning**, presented in [26]. The difference is that, in this case, the function is not created explicitly, but rather the idea is to predict the categories of future examples based on the input examples. In this way, this learning tries to create groups by labelling the elements of the received inputs. An algorithm found in this category is the **Transductive Support Vector Machine** (TSVM) [27], [28].

The last taxonomy is **multitasking learning**. These algorithms use previously learned knowledge in similar problems already experienced to improve the learning of the problem to be solved [29].

B. Taxonomy of Algorithms Used in Machine Learning

There are different types of algorithms to perform the learning that can be grouped according to the type of output of the same. In this subsection, we will talk about **decision trees, association rules, genetic algorithms, Artificial Neural Networks, Deep Learning, Support Vector Machines, clustering algorithms and Bayesian networks.**

The first is the use of **decision trees** [19], [20], of which information on their use in Artificial Intelligence can be found since 1986 in [30]. **Decision trees** are a set of nodes arranged like a binary tree. In the intermediate nodes, there are the necessary conditions to reach the leaves, where these conditions or predicates may imply one or more characteristics of the element. Meanwhile, at the end of each branch, what is known as a leaf, there is the output that the object must return after analyzing the different possibilities obtained in the input and traversing the tree, that is, the leaves contain the decision to be

made. Based on this, these algorithms map possible entries and the possibilities of such entries that the object can contain. The operation of the decision trees to classify an element consists of beginning to analyse that element by the root of the tree and, based on whether it fulfils or not the predicate of the node in which it is found, move that element to the left or right child of the current node, repeating the process until it reaches a leaf that returns the result of the tree.

Association rules contain those algorithms that try to discover associations between variables of the same group [19]. In this way, they allow you to discover facts that occur in a certain set of data. A possible example of these is that, if someone publishes a tweet with a photo and the hashtag 'selfie', then the photo was made with his mobile. A real case is the one studied by [31], where they discovered that 90% of the purchases that contained bread and butter also had milk.

Another type of algorithms are **genetic algorithms**. These are nothing more than a heuristic search process that attempts to simulate natural selection following a process of evolution of individuals through random actions. Thus, these algorithms contain methods such as mutation, crossing and selection to find the best solution to a given problem. Some examples of the use of these algorithms are in the field of automated designs of equipment and machinery, in game theory, in the learning of Fuzzy Logic rules, natural language processing and prediction, among others. The creation of genetic algorithms is due to John Holland and his students at the University of Michigan, who developed them between the 60s and 70s and presented them theoretically in [3]. In this way, his goal was not to search for algorithms to solve a specific problem, but to import into computers the phenomenon that occurs in nature by which it adapts to what happens around it [4].

Another case is the **Artificial Neural Networks** (ANN) [22], [32]. ANNs allow automatic learning by simulating the neuron system of the nervous system of animals. Within this system, the neurons collaborate with each other to produce the output, considering that each connection between neurons has a weight, which is adapted according to the experience collected throughout its use. ANNs consist of an input layer, one or more hidden layers and a final output layer, all composed of neurons. Therefore, neural networks can learn and are used for a variety of tasks such as translation of languages or learning patterns.

Deep Learning is a set of algorithms that are based on modelling high-level abstractions composed of multiple non-linear transformations [33], [34]. The use of Deep Learning allows learning data representations. For example, an image can be represented in many ways, but not all of them facilitate the task of face recognition, so, what it does is try to define which is the best representation method to perform this task. Some examples of its use are in **Computer Vision** and in the recognition of speech and music [34]. The algorithms used can be both **supervised learning** algorithms and **unsupervised learning** algorithms [35]. The deep learning algorithms have different internal transformations between the input of the data and the output response, each transformation consisting of different weights and thresholds that can be trained [35]. However, according to [35], there is no definition that exactly says the limits between **Deep Learning**, **Shallow Learning** and **Very Deep Learning**, but they propose that it should be considered Very Deep Learning when it exceeds 10 levels of depth.

Support Vector Machines (SVMs) [36], also used in similar investigations such as **Support Vector Networks** (SVN) [37] and **Support Vector Regression** (SVR) [38], are a set of supervised methods that are used to solve problems of classification and regression, producing non-linear limits by using linear limits and transforming the feature space version [18], [22]. The operation of this type of algorithm is based on the selection of a small number of critical limit cases, known as support vectors, to build the discriminant function to separate existing cases as much as possible [18], [20]. For example, by

using SVM you can classify a set of images from a previous training with tagged images to teach the algorithm how to classify. An example of this is the optical character recognition presented in the first article that dealt with them [36].

Clustering algorithms are those that classify similar data based on certain criteria in subgroups, also called clusters [18], [20], [39], [40]. The success of **clustering** is measured based on how useful this clustering is for humans [18]. There are many different algorithms to perform this task because the notion of 'cluster' is not defined very precisely [41]. To do this, it looks for the distance or similarity of the data according to the defined function. These types of algorithms are commonly used in data mining [18], [20], [42], as well as in other cases of statistical analysis [43]. These algorithms are **unsupervised learning** algorithms.

Another type of algorithm is **Bayesian networks** [8], [44]. Bayesian networks are probabilistic models that represent random variables and their unconditional independencies in a directed acyclic graph. That is useful, for example, to represent probabilistic relationships between diseases and symptoms. In this way, we can calculate the probability that a disease is present or not in the body.

V. Computer Vision

Within Artificial Intelligence, one of the fields is **Computer Vision**. It is the field that allows computers to 'learn' to recognise an image and the characteristics of this image. The goal that Computer Vision seeks is that machines can understand the world [45]. Getting the machines to be able to recognise elements by their image and discern what they are, calculate how far they are and their place, and all this in a quick way. However, performing this task presents many challenges.

The first challenge is how to model the objects so that the computer can discern the different types of objects to differentiate what is a person or what is a car, for example. However, these can be viewed from many different positions. Here comes another problem that is to recognise or differentiate if a person is sitting, standing, behind a vehicle or crouched, or even if the car is in front or profile. In addition, there are different light stages throughout the day, not only day and night, but also cloudy or sunny. This creates another problem that is that the same object may be in the same position that the computer recognises but that it is not able to recognise it due to light changes.

Another challenge is the one that arises about how to process the image. Related tasks must be quick and efficient searches of the image should be performed, which must be processed in different ways to normalise it and to avoid some problems previously discussed.

Currently, one of the most important fields in Computer Vision is the detection of people [46]. This is due to the boom to create intelligent systems, mostly for cars, to detect pedestrians to try to avoid or at least to reduce the severity of an accident. Some even try to recognise human movement [47].

A. General Concepts

Every part of the image counts. We must work with the colour, the size of the window that we will use to analyse the image and the intensity of the image. Therefore, the same image can be differentiated in the colour of the light and the sensitivity of the camera. Any variant will make the same take a different image, although they are the same components in it. It must also be borne in mind that the material of the surface of the different elements affects the refraction of light, which also affects the images made. All this is because the cameras we use are based on the human eye because they have three types of sensors, one for each cone existing in the human eye. The cones are photoreceptors found in the retina and there is one for each wavelength: Cones-S

(short), Cones-M (middle), Cones-L (long) [46]. Thus, the sensors equivalent to these cones are the red, green and blue sensors (RGB).

Sometimes we also work with other types of images such as near-infrared images (RGB-NIR), which add a non-visible channel in the shortest wavelength of the infrared spectrum. In other cases, thermal images can be used, which reproduce the correlation between temperature and infrared emission of objects. Another type of image is depth images (RGBD) that allow the devices to measure, for example, a Kinect II, the depth of the scene with respect to the sensor.

The process of **Computer Vision** consists of several steps to be performed [16], [46], [48]. In Figure 1, a possible diagram corresponding to these processes is shown. The first step to create a computer vision system is to perform the **features extraction** to build the descriptors of the objects in the images. An example of a descriptor is the colour of the pixel, which would allow defining the object as a region of connected pixels that have the same colour. However, the descriptors usually contain tens or hundreds of different characteristics to be more stable and better. This leads to performance problems and slow scanning of the images.
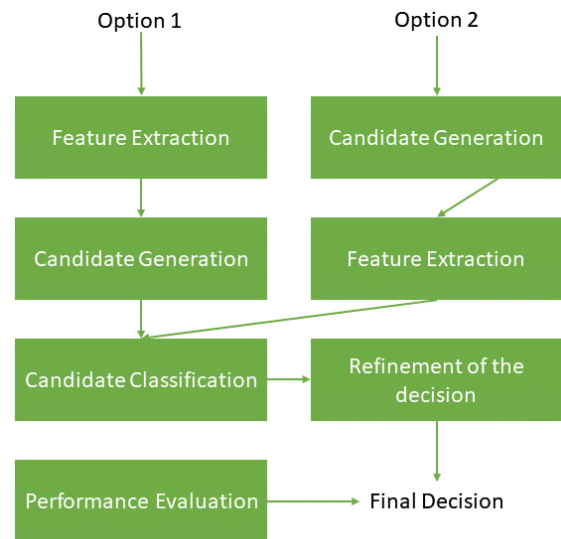

Fig. 1. Cycle diagram of creation of a Computer Vision module.

One of the problems that arise is when there are changes in the intensity of the images to process since a minimum change in it will make the colour different and difficult to be recognised. Therefore, the first step should be to process the images to eliminate the effects of intensity and colour changes and create **descriptors** using a colour invariant to the intensity and the effects of colour. This prevents an image taken with a different intensity or colour changes due to light or camera from being different for the computer vision system's **classifier**.

The second step is the **generation of candidates**. In this step, the regions of interest in the image are defined to solve the problem of the location of the object within it. To do this, the image will be analysed in search of the previously defined objects and will be boxed with a window within the step known as **window generation**. In this generation, there are multiple ways to create windows and how to apply them, such as the **sliding window** and the **sliding window pyramid** (**multiscale**). This helps to solve one of the problems that must be solved: different size that objects can have and the depth of which they can be found.

The next step is the **classification of candidates**. In this phase, we must study and verify that the descriptor is effective for the different instances of the object that we want to detect and verify that it is

different from the objects that we do not want to. Thus, we must also create the border that will define what our object is and what is not the object we want. The problems encountered in this phase range from possible variances in the tonalities to the translation, since it can happen that the windows generated in the **phase of window generation** cut objects, transfer them or cut them and detect half of an object and half of a second object as a unique object. Some of the algorithms used in this phase of candidate classification are **Histogram of Oriented Gradients** (HOG) [48], **Local Binary Patterns** (LBP) [49]–[51], **HOG-LBP** [52], **Scale-Invariant Feature Transform** (SIFT) [53] and **Speeded-Up Robust Features** (SURF) [54] as descriptors, and **Logistic Regression** [55], [56], and **Support Vector Machine** (SVM) [36] as classification methods. In addition, one of the learning methods used is **supervised learning**.

In the phase of **refinement of the decision**, the best scoring images must be chosen to avoid duplicates due to the overlap of the created windows and to remain with the best identification of the desired object.

In the **performance evaluation** phase, we must check how the classifier works and assess how accurate it is and the faults it produces, that is, whether they can be ignored or not. One way to do this is by using a confusion matrix. This matrix contains the true positives, true negatives, false positives and false negatives that were identified by the Computer Vision module. This gives us the measurement of the quality of the classifier using four parameters. The first is its accuracy, which helps us to know the distance to the perfect classification. The following is its precision, which indicates the quality of the response of the classifier. The third is the sensitivity that indicates the efficiency in the classification of all the elements that are of the kind that we are looking for. Finally, the specificity indicates the efficiency of the classifier in the classification of the elements that are not of the class for which it was trained.

However, the task of obtaining a good model to recognise a given object is very difficult. It is important to use many and very good images and try to validate it with other different images assuring that the model works correctly. In addition, there is a need to create a model to solve a specific problem, because if a generic model is created, this may have a low accuracy, due to the difficulty to recognise images. To all this, it is important to take into account the different existing problems such as the quality of the images, the different ways of training it and the time it takes to process an image.

B. Work Related to Internet of Things, the Recognition of Faces and Movements

Regarding the work related to the combination of the **Internet of Things** and **Computer Vision**, hardly anything was found. However, there is a lot of related work that focuses on the recognition of people, faces and heads. This work is mainly oriented to vehicles, to prevent outrages or reduce the damage of these, and health, by creating alarms to notify quickly and effectively when older people fall at home.

One of the first works about vehicles is that of [17]. Authors are investigating automatic driving systems that can detect pedestrians or other vehicles and thus avoid collisions, either by notifying the driver or taking control of the vehicle before the accident occurs. This system is based on the recognition of objects that move and on the recognition of pedestrians. This is not only useful for **IIoT** but also in **Smart Cities**, to create a safer city.

In contrast, in [16], they present a framework to detect faces in an extremely fast way while maintaining a good hit rate. In addition, this article presents a new way of representing images that can be computed much faster, a new classifier based on AdaBoost [57] and a new method of combining classifiers using 'waterfall'.

Other authors focus more on the low level, as it is the case of the improvement of the analysis of RGB photos to help the classification of images. These improvements are useful in the classification of images in general, even though they present their idea using the recognition of people [46]. Specifically, they focus on the colours that are opposite, that is, they consider the red-green and yellow-blue tuples and the luminosity.

Other research uses Computer Vision in Robotics, to allow robots to recognise objects or people to be able to perform actions based on it, such as dodging objects, collecting the desired objects among several recognised objects or recognizing a person. For example, in [58] they conducted a survey of the use of Computer Vision in cognitive robots, which are those that are designed based on imitating human cognition, in order that robots can recognise objects, but in such a way that robots do not get saturated with the information of an image, because even if it is small it contains a lot of information. On the other hand, in the 'survey' of [59], they deal with the state of the art of Computer Vision in unmanned aerial vehicles (UAVs), because with their use, autonomy can be extended by improving control during flight and the perception of the environment that surrounds them.

Related to health we have the work of [60]. They did a study on different systems used for the detection of falls to help the elderly. That work collects different 'wearables' device systems that capture environmental data and vision-based systems. According to the authors of the survey, vision-based systems must be better than the other approaches. Likewise, authors classify the field in three types: space-time, inactivity or change of form and movement and 3D position of the head. Among these is the proposal of [61], which proposes a fall detection system based on the combination of moving images with its own vector, so that it takes spatiotemporal data of the movement and its occurrence into account. In contrast, authors of [62] used a detection method based on recognizing the background pixels and using different algorithms to distinguish a fall from other normal movements. The authors of [63] presented a system by which they recognised the person and surrounded them with an oval in order to base their system of recognition of falls based on the change of shape of the oval and comparing this with the previous ovals by means of the histograms that were created. As an example of the third type of Computer Vision applied to falls, this corresponds to the 3D position of the head, which is described in this work [64], and which presents a system that combines 3D cameras with models of the head of the person obtained at times when it is inactive and thus provide in conjunction with the different characteristics of the movements, such as the location and duration of the movement, whether it is a fall or not.

One of the works that integrates vision by computer and IoT is the one carried out in [65], where they integrated a computer vision module in an existing IoT network, called Midgar [66], [67], to allow automation for actions and objects of different intelligence [68], based on what it is recognised in a sequence of photos. For example, if it is recognised that the sequence contains a person then the system is able to send an automatic warning, thus doing the work of a guard or places that need security much easier and automatic.

VI. Fuzzy Logic

The Fuzzy Logic term was introduced in 1965 by Lotfi Asker Zadeh [69], Professor at the University of Berkeley, as a way to deal with the problems of common sense. **Fuzzy Logic** emerged to solve problems that classical logic could not solve because classical logic can only deal with binary values (zeros or ones), while some problems require dealing with more values because these problems use expressions that they are not totally true or false, as shown in Figure 2. Thus, by having more than two values, one can have more states, that decisions can be

made with more information and allow them to be represented by an intermediate value that is between absolute truth and total falsehood. Normally these states are known as *linguistic variables*, which can represent characteristics of type 'size', which in this case could have three possible values or even more, such as 'big', 'medium' or 'small'.
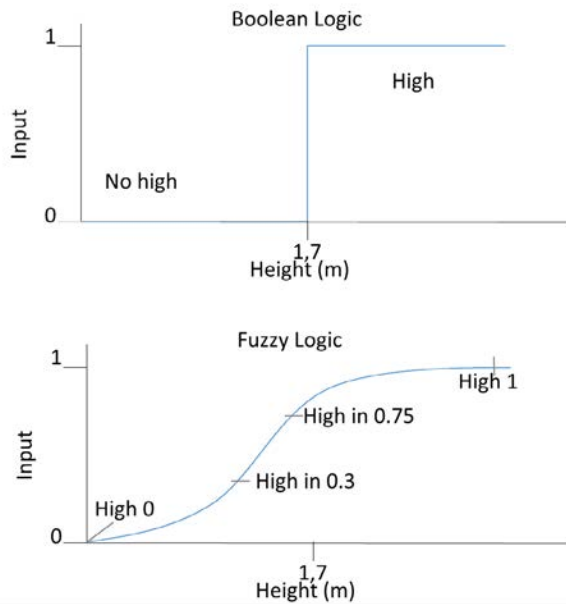

Fig. 2. Comparison between a Boolean Logic system and a Fuzzy Logic system.

Therefore, this approach to the problem is questions of the type: How big is this? The answer to this type of questions depends on individual cognition, therefore, not everyone responds to the same, because, not all of us have the same opinion and perception of reality. It is medium, or even large. An example of this perception could be the place where each person lives, because, if a person lives in a city with a lot of skyscrapers like New York, possibly these people think that a building of 8 plants is small, but in the case of that a second person lives in a town, is possible that the second person thinks that this building is very big.

A. General Concepts

The first thing that emerged in the field of **Fuzzy Logic** was the **fuzzy sets** in [70], presented by Zadeh in 1965. **Fuzzy sets** are set with 'not very well-defined' limits that have a scale between 0 and 1 and serve to measure the **degree of belief**, also known as the **degree of truth** [8], of a certain element in that set. Then, in **Fuzzy Logic**, an element can belong to a set with a certain percentage and to another set with another percentage. Therefore, these serve to represent mathematically the intrinsic imprecision of certain categories of objects and with these, to model the human representation of knowledge, and thus, improve decision systems and Artificial Intelligence. Figure 3 shows an example of the definition of two possible fuzzy sets, the left one defines the temperature and the right one defines the humidity.

Later, **Fuzzy Logic** was defined and presented in [69]. Since then, **Fuzzy Logic** has been linked in many investigations. A common problem where **Fuzzy Logic** is applied is in energy saving. However, there are a lot of examples where **Fuzzy Logic** is applied. The reason for this is that all of these need more than two values to represent the states. In the case of Grant [71], he used **Fuzzy Logic** to propose a diabetic control. In this way, he allows managing with fuzzy and ambiguous data and thus the diabetic control makes decisions as a person would do.
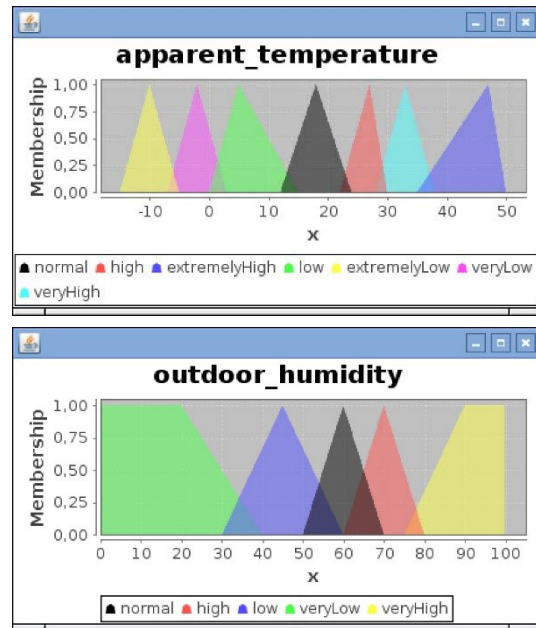

Fig. 3. Fuzzy sets defined to represent the temperature and the humidity.

To make decisions, **Fuzzy Logic** uses controllers called '**adaptative controllers**' [71] or '**expert systems**' [8]. These controllers are based on 'If X and Y then Z' rules to mimic human fuzzy thinking. These rules represent the knowledge that guides these controllers or systems to make the optimal decision. The definition of these rules is complex and requires the use of **linguistic variables** because the human representation of knowledge is fuzzy. The process of taking a **linguistic variable,** for example, in the previous case of the 'size', input, and processing it by a function to say that it is the linguistic variable with the 'small', value, is known as *fuzzification* [72]. Thus, a **linguistic variable** is the assignment to a numerical value a word or sentence of the natural language.

Figure 4 shows the life cycle of some data in a Fuzzy Logic system. In this figure, you can see the data entry, with two values, 18 and 85 respectively. These data are 'fuzzified' to transform them through **membership functions** [70], [73]. The difference between Boolean logic and Fuzzy Logic at this point is that, while the Boolean logic can only be 0 or 1 and belong to a set, in Fuzzy Logic this value can belong to several sets since the value can be any between 0 and 1, being a case that the value can belong in 0.3 to one set and in 0.7 to another [70]. The *membership functions* are executed both in the 'fuzzification' and in the 'defuzzification'. In this way, by means of **membership functions** it can be established to which or which fuzzy sets a value belongs. The **membership functions** can have different forms, such as triangular, trapezoidal, gamma, sigmoidal, Gaussian, or pseudo-exponential functions.
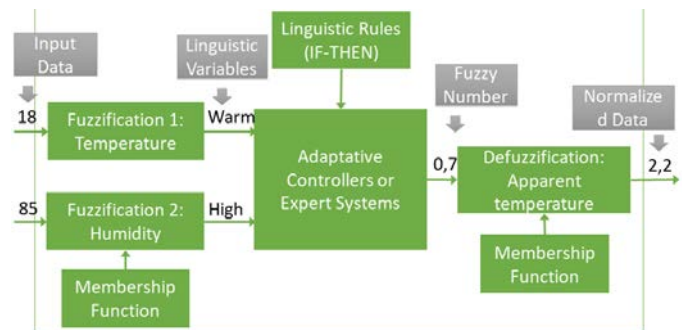

Fig. 4. Cycle diagram through a Fuzzy Logic system.

Thus, from the received values, which are 18 and 85, the corresponding **linguistic variables** are obtained, which in our example are 'small' and 'large' The next step is to apply the linguistic rules, of type IF-THEN, which are found in the controller called '**expert system**', to these variables to obtain the **fuzzy number** or **fuzzy variable**. These **linguistic rules** are responsible for obtaining the fuzzy number from the combination of linguistic variables. They are defined by hand and applying a bit of common sense [73], which implies that a test-error system may have to be made until the rules that best suit our system are found. On the contrary, if the **Fuzzy Logic** system had a training mechanism with which to learn and evolve over time, it would be said that it is an **Adaptative Fuzzy Logic System** [74].

Fuzzy numbers have a value between 0 and 1 and are the result of joining several values. The **fuzzy number** obtained is passed through the 'defuzzifier', phase in which one of the many existing methods is chosen to perform this operation in order to transform the **fuzzy number** into the normalised data that we will use to make the decision.

B. Related Work on the Internet of Things

Below are some examples of using **Fuzzy Logic**. Larios et al. in [75] locate a device avoiding many localisation errors and, therefore, achieve better accuracy. In this case, the authors also achieved savings in the energy consumption of different elements such as the Global Positioning System (GPS). On the other hand, Chamodrakas and Martakos in [76] proposed using **fuzzy set** representation methods to select a network and connect to it in an efficient way, with low power consumption, a good quality of service (QoS) and with a good performance.

In contrast, in the proposal of Bagchi [77], **Fuzzy Logic** was used to maintain streaming playback quality and achieve improvements in energy consumption. However, there are also proposals for the improvement of vehicle systems, such as the cases of [78]–[80]. In the first, the authors proposed improvements in the exchange of information between vehicles and servers in order to save energy. Meanwhile, in the second, the authors proposed a system to create applications through the use of voice. Meanwhile, others focus on energy saving in homes, as in [81], where they use **Fuzzy Logic** to make decisions based on outdoor temperature and humidity and the interior temperature of the house using two IoT networks and to know if it is necessary to turn on or to turn off the heating and/or air conditioning.

VII. NATURAL LANGUAGE PROCESSING

Natural Language Processing or *NLP*, sometimes called **computational linguistics** [8], is a branch of Artificial Intelligence that tries to solve the problem of understanding natural language using machines, or in other words, allowing users to communicate with the machines in a faster and more effective way using natural language [82], [83], as if they were communicating with other humans [84]. El **NLP** requires understanding the structure of sentences, but, in addition, it also requires knowledge of the subject matter and the context in which it is found [8]. This seeks to make applications that can analyse, understand, alter and/or generate natural language according to help with tasks ranging from writing using computers to doing more human tasks through robots. For this reason, **NLP** is a field that seeks to close the existing gap in communication between humans and machines [85].

However, **NLP** is a complicated field, since it requires a linguistic corpus, a model of the domain, knowledge of the domain in which you want to work and linguistic knowledge of the language in which you are going to work, plus, of course, the software tools and necessary hardware [86]. This implies that different disciplines must work together such as computer science for methods and creation of software, linguistics to create processes and linguistic models, mathematics to identify formal models and methods, and neuroscience to explore the mechanisms of the brain and other physical activities [83].

Natural language processing has existed since the 1940s and since then it has contributed significantly in the fields of interaction with the computer, both theoretically and practically [85]. It all started in 1946 when Warren Weaver and Andrew Donal Booth discussed the feasibility of machine translation to break enemy codes in World War II. However, it was not until 1957 when it was found that solving this problem could be much more complex than it seemed [8]. Since then, this field has improved from using dictionary-based translations to what is now known as NLP. An example is NLP in medicine, where it began to be published in the year 1960 [86].

Note that NLP is very important not only in the branch of computer science but for many other areas. For example, in healthcare, it is very important because there is a lot of relevant information in the text that can be processed by a machine in order to help improve patient care and advance in medicine [86]. An example of this importance is the one that occurred in 2012, when the National Library of Medicine of the United States of America sponsored a workshop on April 24 and 25 to review the current state of the art, the challenges, the obstacles and the effective use and best practices of NLP focused on texts in English, both in language in general and in biomedical texts [86].

A. Application Areas

NLP has many application areas [82], [83], [85], [87]. Among these, some of those that can be highlighted are in the **recognition and generation of speech, natural language interfaces, speech management, understanding of history and text generation, machine translation**, and **intelligent writing assistants**.

In **speech recognition,** the goal is to convert the words spoken by a person through a microphone to represent them written on a machine. Thus, **speech understanding** systems try to improve the 'understanding' of the machine about what the user is saying while acting and/ or making decisions based on that context.

On the other hand, the **speech generation** seeks to improve the speech process of the machine by means of looking for the ideal sound representation of the written words that the machine must 'say'.

The research in **natural language interfaces** tries to close the gap between the different existing languages in order to internationalise correctly the user interfaces due to the differences between the different languages. Another example within this category is to facilitate the work with the interfaces through voice commands.

On the other hand, **NLP** is also used to index and classify text, perform summaries, index search engines, Data Mining, make question-answer dialogue systems, extract content, among other similar applications. In these cases, we are talking about **speech management**, **understanding of history**, and **text generation**.

A case similar to the previous one, where the system must have a minimum knowledge of what it reads, is that of **machine translation**, the oldest application of **NLP**. This type of application tries to translate a text from a given language into its equivalent in another required language [8].

Smart Writing Assistants is another **NLP** area. These include various types of applications such as spell-checkers, word-splitting agents, format/separation/text selection wizards, automatic thesauri, and automated document creation or maintenance or document classification environments [88], between some examples. As we can see, all these types of applications are those that try to give a smart help when are working with documents.

B. Linguistic Knowledge Models

To perform **NLP**, different **linguistic knowledge models** can be applied [83], [85], [86], [88], [89]. These models can be classified

into five different types: **symbolic or knowledge-based, statisticians**, among which are **stochastic or probabilistic** and **connectionist**, **hybrid approaches** and **Artificial Intelligence.** Each approach has its advantages and disadvantages, which makes each one adapts better or worse depending on the type of **NLP** problem that you wish to solve.

Symbolic or knowledge-based models are based on the explicit representation of facts about language through schemes of representation of knowledge understood, by marking the linguistic corpus used to train it, and associated algorithms [85], [86]. [85], [86]. These types of techniques are the most studied in NLP, however, they have many deficient in comparison with stochastic and connectionist techniques. Symbolic techniques are especially used in cases where the linguistic domain is small or very well defined [85].

Stochastic or probabilistic models use several probabilistic techniques to develop approximate generalised models of the linguistic phenomenon, which are based on real examples of these phenomena. These types of techniques are very effective in those domains where symbolic techniques fail [85], [86], trying to compensate for the difficulty of creating a grammar that fits the whole language and is prepared for reasoning and uncertainty [86].

Connectionist models also use examples of linguistic phenomena to develop generalised models. However, being made from connectionist architectures, these models are less restrictive than stochastics, which is more difficult to develop than connectionists. Being based on stochastic models, connectionist techniques are used in scenarios where symbolic techniques fail [85].

Hybrid approaches use the combination of different architectures and previous models in order to find the best approach. An example of a hybrid approach is that carried out by Miikkulainen in [90], where he combines symbolic techniques with connectionist techniques to process short stories and make summaries and possible answers to questions. Hybrid techniques take the strengths of symbolic, stochastic and connectionist techniques to try to minimise the effort required to construct linguistic models and maximise their flexibility, effectiveness and robustness [85], [86]. This type of approach is the most used in recent years [86].

The methods based on **Artificial Intelligence** are very varied. These can use different types of learning as shown in [88], this work shows some examples where supervised or semi-supervised learning algorithms, based on decision trees, support vector machines, artificial neural networks, Bayesian networks or genetic algorithms were used.

C. Internal Knowledge Levels of Natural Language

NLP is a very extensive field that needs the analysis of different points of view to get to process a speech correctly. Thus, from the linguistic point of view, **NLP** has many aspects that must be studied [91].

- **Phonetics**: studies the sound of human speech from the point of view of its production and perception.
- **Phonology**: study the structure of sound and how it works.
- **Morphology**: studies the internal structure of words to delimit, define and classify words and the formation of new words.
- **Syntax**: studies the structure of the sentence by means of the combinatorial rules and principles of the words and the relationships between them.
- **Semantic**: studies the meaning and denotation of symbols, words, expressions and formal representations.
- **Linguistic variation:** study the different styles of expressing the same meaning and the dialects of a language.
- **The evolution of language:** it studies how the current language emerged and evolved.

- **Pragmatic:** studies the use and communication of language in a specific context.
- **Psycholinguistics**: it is a branch of psychology that studies the production and understanding of language by human beings to see how they acquire and use it.
- **Linguistic acquisition:** studies how language is acquired during childhood.
- **Neurolinguistics:** studies the mechanisms of the brain that facilitate knowledge, compression and language acquisition, both written and spoken.

Based on this, **NLP** is composed of different levels. These vary according to the authors and the time, since some consider four [82] [82] in 1993, another six [92] in 1995, other authors eight [83] in 1996, but which were updated to nine later [85] in 1998, but in general all agree that they can be subdivided mainly into lexical, syntactic, semantic, and pragmatic [85].

Each of these levels offers a different kind of information about the same data. Some tell us the sound of the word, others tell us its meaning, others its gender and number, another level tells us that it means depending on the context, among many other data that we can obtain depending on the way of analysing the text. Thus, architectures that add more levels, get more data and different than architectures with fewer levels. The architectures with more levels add, among other characteristics, the phonetics and knowledge of the world, maintaining the levels of the previous ones.

Next, all the levels found in the literature will be explained, showing in parenthesis what kind of classification they belong to. An example of the different levels can be seen in Figure 5, which shows an example of processing the text 'The wise dragon imitates a duck' that needs levels 4 to 6 because its lexical, syntactic and semantic composition is studied. In case you had to recognise the sentence through a microphone when it was dictated by someone, then you would need levels 1 to 3. If, on the other hand, you wanted to recognise the situation where that sentence was written in order to keep a conversation, then you would also need levels 7 to 9. If, on the other hand, you want to have a conversation with someone, you would need all the levels.

1. **Acoustic or prosody** (8, 9): study the rhythm and intonation of language and how to form their phonemes.
2. **Phonologic** (6, 8, 9): study the relationship between words and the sound that they make and how they work, as well as the formation of morphemes.
3. **Morphologic** (6, 8, 9): studies how words are constructed from their morphemes, which are the smallest unit of the language that has the lexical or grammatical meaning of its own and cannot be divided into smaller units. Thanks to this, you can know and create the gender and number of a word and thus also be able to form them. However, some authors put together the morphologic and the lexical [82].
4. **Lexical** (4, 8, 9): works with words, by means of lexemes and the meaning of words. In the event that the morphologic level does not exist, its constituents are treated at this level as morphemes and their inflectional forms. In addition, it works with the derivation of units of meaning.
5. **Syntactic** (4, 6, 8, 9): works with the combination of words that form a sentence. In this step, each word has a different category such as name, verb and adjective, which makes each word also have specific rules of combination in the given language. He also works on how to form sentences. Figure 5 shows an example of a syntactic analysis of a sentence formed by a subject (first noun phrase) and a predicate (VP) which contains the verb, and the second nominal phrase (NP). Within both nominal phrases are the

analysis of each word that is classified as a determinant (det.), adjective (adj.), noun, and preposition (prep.).

6. **Semantic** (4, 6, 8, 9): deals with the individual meaning of words, the meaning of words according to the sentence and the meaning of the whole sentence. Thus, study the meaning of the sentence independent of the context. For this, he works on how to derive meaning from sentences.

7. **Discourse** (8, 9): deals with the structural roles of the sentence or collections of sentences and how to form dialogues.

8. **Pragmatic** (4, 6, 8, 9): works with the monitoring of the context and the interpretation of sentences within this context. This affects later sentences because it influences the meaning of the interpretation of pronouns.

9. **Knowledge of the world** (6, 9): this includes information about the structure of the world of language users, thus including the beliefs and goals of the other user according to maintain, for example, a conversation.
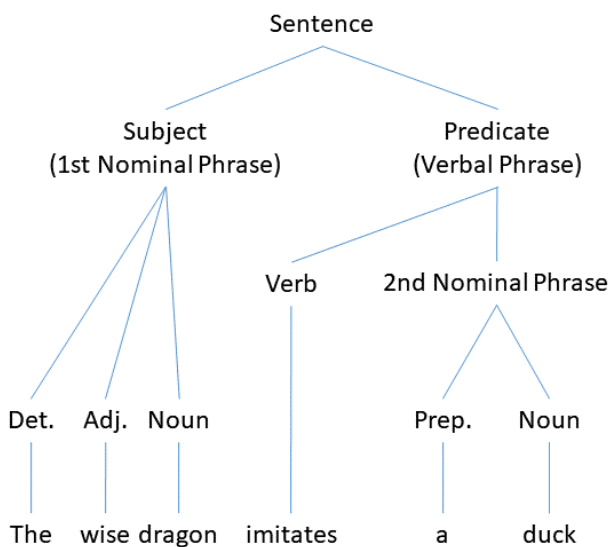

Fig. 5. Syntactic analysis of NLP.

It must have to in mind that the different levels of abstraction necessary among all these, or even a new one, will depend entirely on the domain of the application to be developed or the problem to be solved [85], since it may not be possible to they need all of them or only a few are needed. For example, a text translator will probably need only levels 3-7 or 3-8, for a speech recognition application levels 1-5 will be used, for an intelligent writing assistant levels 3-8 or 3-9 will probably be needed and a dictation system will need levels 1-5.

D. Related Work on NLP

In relation to related works in the field of **natural language processing**, there is a very large variety of these. As shows the 2012 congressional 'survey' [86], there has been much research with **NLP** in the field of medicine to improve the service provided to patients and help doctors in their task.

A first example of NLP in medicine is the work of [93], where they use **NLP** to detect problems of misuse of opioid prescriptions in order to prevent and control their measurements, since problems were detected in traditional clinics that contain documents or incomplete information or in cases in which the patient's information is obscured due to the large number of documents from the clinics. To solve this, they proposed a method that combined **NLP** and manual computer help to review the notes and detect problems with opioid misuse.

Other uses of the **NLP** are those applied to linguistics to help translate or create tools to process certain languages. In this first article [94], the authors developed a framework to promote collaboration between linguists and non-linguists in the use of **NLP** applications for the Arabic language. On the other hand, in [84] they presented a simulation of the parser for Bahasa Indonesia, which is the language of Indonesia, due to the lack of research in this area for this language.

NLP can also be used to give orders, as they do in this article [95], where it is used to handle robots. The authors tried to create a human-machine interface with natural language because they have a greater impact on users, especially when they have no training. Therefore, they presented an interface that received orders in natural language and transformed them into orders for the robot.

An example similar to the robots is the one in this article [96] where the authors used NLP to create SQL statements. With this, the authors sought to bring SQL to non-professional users, so that they could write a sentence in natural language that was transformed to the corresponding query in SQL by using an **expert system** made in Prolog that contains the experience in that domain.

Currently, there are also investigations that deal with the collection of information based on the textual requirements given by a client. In the first example, we have the lips tool, which integrates NLP within the IDE Eclipse to translate the specifications in plain text to formal models of Ecore, UML or SysML, and that can be used in the EMF to create its implementation in Java [97]. On the other hand, and quite similar, there is this second investigation [98], in which they created a prototype called Requirements Analysis and Class Diagram Extraction (RACE), which facilitates the analysis of requirements and the extraction of classes from these by means of NLP and ontologies, using the Apache OpenNLP tool, and thus help the students to see all the steps from the requirements until the creation of the classes. The third example of this type of research is [99]. In this research, the authors proposed a way to obtain the name of the classes and their details from the textual requirements delivered by a client, thus eliminating the ambiguities and possible interpretations that these documents have.

VIII. CONCLUSION

As we can see in this paper, the Artificial Intelligent is a very vast field. Besides, we have seen some examples of the use of AI with the IoT and how this fusion can create very important and interesting applications. However, we have only touched four of the most important parts: Machine Learning, Computer Vision, Fuzzy Logic, and Natural Language Processing.

These four subfields are very related to each other; mainly, by the algorithms that are used to process the different information or the techniques that are used to teach the necessary information to create the model that different techniques need. Furthermore, these subfields are used to create smarter machines or programs to help us in our daily life, like the Internet of Things is trying to do. For instance, Machine Learning could be used to create a better module with enough intelligence to automate and take decisions, Computer Vision to automate visual scenarios, Fuzzy Logic to give intelligence and take decisions to save money, electricity, and so on, and NLP to improve the understanding between machines and the humankind.

This is why the integration of these fields, the IoT with Artificial Intelligence, could open a new world of opportunities, as the related work has shown. Even though, they have been only a few works on this topic and it is necessary a lot of research in the intersection of these two fields.

REFERENCES

[1] A. M. Turing, "Computing Machinery and Intelligence," Mind, vol. 59, pp. 433–460, 1950.

[2] J. Fuegi and J. Francis, "Lovelace & babbage and the creation of the 1843 'notes,'" IEEE Ann. Hist. Comput., vol. 25, no. 4, pp. 16–26, Oct. 2003.

[3] J. H. Holland, "Outline for a Logical Theory of Adaptive Systems," J. ACM, vol. 9, no. 3, pp. 297–314, 1962.

[4] M. Melanie, An introduction to genetic algorithms, 5th ed. MIT press, 1999.

[5] J. McCarthy, "What is Artificial Intelligence?," 2001. [Online]. Available: http://lidecc.cs.uns.edu.ar/~grs/InteligenciaArtificial/whatisai.pdf. [Accessed: 26-Apr-2016].

[6] J. McCarthy, M. L. Minsky, N. Rochester, and C. E. Shannon, "A Proposal for the Dartmouth Summer Research Project on Artificial Intelligence," Dartmouth, 1955.

[7] J. McCarthy, M. L. Minsky, N. Rochester, and C. E. Shannon, "A Proposal for the Dartmouth Summer Research Project on Artificial Intelligence," AI Mag., vol. 27, no. 4, pp. 12–14, 2006.

[8] J. R. Stuart and N. Peter, Artificial Intelligence A Modern Approach, 2nd ed. New Jersey: Prentice Hall, 2003.

[9] S. Nadella, "The Partnership of the Future," 2016.

[10] V. García-Díaz, J. Pascual-Espada, C. Pelayo G-Bustelo, and J. M. Cueva-Lovelle, "Towards a Standard-based Domain-specific Platform to Solve Machine Learning-based Problems," Int. J. Interact. Multimed. Artif. Intell., vol. 3, no. 5, p. 6, 2015.

[11] P. Simon, Too Big to Ignore: The Business Case for Big Data, 1st ed. Wiley, 2013.

[12] M. Wernick, Y. Yang, J. Brankov, G. Yourganov, and S. Strother, "Machine Learning in Medical Imaging," IEEE Signal Process. Mag., vol. 27, no. 4, pp. 25–38, Jul. 2010.

[13] E. R. Nuñez Valdez, J. M. Cueva Lovelle, O. Sanjuán Martínez, C. E. Montenegro Marín, G. Infante Hernández, and S. Verma, "Social Voting Techniques: A Comparison of the Methods Used for Explicit Feedback in Recommendation Systems," Int. J. Interact. Multimed. Artif. Intell., vol. 1, no. 4, p. 61, 2011.

[14] C. González García, D. Meana-Llorián, V. García-Díaz, and E. R. Núñez-Valdez, "Social Recommender System: A Recommender System based on Tweets for points of interest," in Proceedings of the 4th Multidisciplinary International Social Networks Conference on ZZZ - MISNC '17, 2017, p. 7.

[15] A. McCallum, K. Nigam, J. Rennie, and K. Seymore, "A Machine Learning Approach to Building Domain-Specific Search Engines," Int. Jt. Conf. Artif. Intell., vol. 16, pp. 662–667, 1999.

[16] P. Viola and M. J. Jones, "Robust Real-Time Face Detection," Int. J. Comput. Vis., vol. 57, no. 2, pp. 137–154, May 2004.

[17] C. G. Keller, T. Dang, H. Fritz, A. Joos, C. Rabe, and D. M. Gavrila, "Active Pedestrian Safety by Automatic Braking and Evasive Steering," IEEE Trans. Intell. Transp. Syst., vol. 12, no. 4, pp. 1292–1304, Dec. 2011.

[18] I. H. Witten, E. Frank, and M. A. Hall, Data Mining: Practical Machine Learning Tools and Techniques, 3rd ed. 2011.

[19] T. Menzies and Y. Hu, "Data mining for very busy people," Computer (Long. Beach. Calif)., vol. 36, no. 11, pp. 22–29, Nov. 2003.

[20] J. Leskovec, A. Rajaraman, and J. D. Ullman, Mining of Massive Datasets. Cambridge University Press, 2014.

[21] M. Mohri, A. Rostamizadeh, and A. Talwalkar, Foundations of machine learning. MIT press, 2012.

[22] T. Hastie, R. Tibshirani, and J. Friedman, The Elements of Statistical Learning: Data Mining, Inference, and Prediction, 2nd ed., vol. 27, no. 2. New York, NY: Springer New York, 2009.

[23] N. Lange, C. M. Bishop, and B. D. Ripley, "Neural Networks for Pattern Recognition," J. Am. Stat. Assoc., vol. 92, no. 440, p. 1642, Dec. 1997.

[24] X. Zhu, "Semi-Supervised Learning Literature Survey," Sci. York, pp. 1–59, 2007.

[25] J. A. Hertz, A. S. Krogh, R. G. Palmer, and A. S. Weigend, Introduction to the Theory of Neural Computation, vol. I, no. June. Basic Books, 1991.

[26] A. Gammerman, V. Vovk, and V. Vapnik, "Learning by transduction," in Fourteenth conference on Uncertainty in artificial intelligence, 1998, no. l, pp. 148–155.

[27] T. Joachims, "Transductive Inference for Text Classification Using Support Vector Machines," in ICML '99 Proceedings of the Sixteenth International Conference on Machine Learning, 1999, vol. 99, pp. 200–209.

[28] T. Joachims, "Transductive Support Vector Machines," 2006, pp. 105–118.

[29] R. Caruana, "Multitask Learning," Carnegie Mellon University, 1997.

[30] J. R. Quinlan, "Induction of Decision Trees," Mach. Learn., vol. 1, no. 1, pp. 81–106, 1986.

[31] R. Agrawal, T. Imieliński, and A. Swami, "Mining association rules between sets of items in large databases," ACM SIGMOD Rec., vol. 22, no. 2, pp. 207–216, Jun. 1993.

[32] S.-C. Wang, "Artificial Neural Network," in Interdisciplinary Computing in Java Programming, Boston, MA: Springer US, 2003, pp. 81–100.

[33] Y. Bengio, A. Courville, and P. Vincent, "Representation Learning: A Review and New Perspectives," IEEE Trans. Pattern Anal. Mach. Intell., vol. 35, no. 8, pp. 1798–1828, Aug. 2013.

[34] Y. LeCun, Y. Bengio, and G. Hinton, "Deep learning," Nature, vol. 521, no. 7553, pp. 436–444, 2015.

[35] J. Schmidhuber, "Deep Learning in neural networks: An overview," Neural Networks, vol. 61, pp. 85–117, 2015.

[36] B. E. Boser, I. M. Guyon, and V. N. Vapnik, "A training algorithm for optimal margin classifiers," in Proceedings of the fifth annual workshop on Computational learning theory - COLT '92, 1992, pp. 144–152.

[37] C. Cortes and V. Vapnik, "Support-Vector Networks," Mach. Learn., vol. 20, no. 3, pp. 273–297, 1995.

[38] K.-R. Müller, A. J. Smola, G. Rätsch, B. Schölkopf, J. Kohlmorgen, and V. Vapnik, "Predicting time series with support vector machines," in Artificial Neural Networks—ICANN'97, vol. 1327, no. X, 1997, pp. 999–1004.

[39] M. S. Aldenderfer and R. K. Blashfield, Cluster Analysis. Sage Publications, Inc., 1984.

[40] R. Duda, P. Hart, and D. Stork, Pattern Classification and Scene Analysis. John Wiley & Sons Inc, 1973.

[41] V. Estivill-Castro, "Why so many clustering algorithms," ACM SIGKDD Explor. Newsl., vol. 4, no. 1, pp. 65–75, Jun. 2002.

[42] U. Fayyad, G. Piatetsky-Shapiro, and P. Smyth, "The KDD process for extracting useful knowledge from volumes of data," Commun. ACM, vol. 39, no. 11, pp. 27–34, Nov. 1996.

[43] L. Greiner, "What is Data Analysis and Data Mining?," 2011. [Online]. Available: http://www.dbta.com/Editorial/Trends-and-Applications/What-is-Data-Analysis-and-Data-Mining-73503.aspx. [Accessed: 26-May-2016].

[44] N. Friedman, D. Geiger, and M. Goldszmidt, "Bayesian Network Classifiers," Mach. Learn., vol. 29, no. 2/3, pp. 131–163, 1997.

[45] C. Wang, N. Komodakis, and N. Paragios, "Markov Random Field modeling, inference & learning in computer vision & image understanding: A survey," Comput. Vis. Image Underst., vol. 117, no. 11, pp. 1610–1627, Nov. 2013.

[46] R. Muhammad Anwer, D. Vázquez, and A. M. López, "Opponent Colors for Human Detection," in Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), vol. 6669 LNCS, 2011, pp. 363–370.

[47] T. B. Moeslund and E. Granum, "A Survey of Computer Vision-Based Human Motion Capture," Comput. Vis. Image Underst., vol. 81, no. 3, pp. 231–268, Mar. 2001.

[48] N. Dalal and B. Triggs, "Histograms of Oriented Gradients for Human Detection," in 2005 IEEE Computer Society Conference on Computer Vision and Pattern Recognition (CVPR'05), 2005, vol. 1, pp. 886–893.

[49] Dong-Chen He and Li Wang, "Texture Unit, Texture Spectrum And Texture Analysis," in 12th Canadian Symposium on Remote Sensing Geoscience and Remote Sensing Symposium, 1989, vol. 5, pp. 2769–2772.

[50] Dong-chen He and Li Wang, "Texture Unit, Texture Spectrum, And Texture Analysis," IEEE Trans. Geosci. Remote Sens., vol. 28, no. 4, pp. 509–512, Jul. 1990.

[51] L. Wang and D.-C. He, "Texture classification using texture spectrum," Pattern Recognit., vol. 23, no. 8, pp. 905–910, Jan. 1990.

[52] X. Wang, T. X. Han, and S. Yan, "An HOG-LBP human detector with partial occlusion handling," in 2009 IEEE 12th International Conference on Computer Vision, 2009, no. Iccv, pp. 32–39.

[53] D. G. Lowe, "Object recognition from local scale-invariant features," in Proceedings of the Seventh IEEE International Conference on Computer Vision, 1999, vol. 2, no. [8, pp. 1150–1157 vol.2.

[54] R. Funayama, H. Yanagihara, L. Van Gool, T. Tuytelaars, and H. Bay, "Robust interest point detector and descriptor," US 8,165,401 B2, 2006.

[55] S. H. Walker and D. B. Duncan, "Estimation of the Probability of an Event as a Function of Several Independent Variables," Biometrika, vol. 54, no. 1/2, p. 167, Jun. 1967.

[56] D. R. Cox, "The Regression Analysis of Binary Sequences," J. R. Stat. Soc., vol. 20, no. 2, pp. 215–242, 1958.

[57] Y. Freund and R. E. Schapire, "A decision theoretic generalization of on-line learning and an application to boosting," Comput. Syst. Sci., vol. 57, pp. 119–139, 1997.

[58] M. Begum and F. Karray, "Visual Attention for Robotic Cognition: A Survey," IEEE Trans. Auton. Ment. Dev., vol. 3, no. 1, pp. 92–105, Mar. 2011.

[59] Y. Liu and Q. Dai, "A survey of computer vision applied in Aerial robotic Vehicles," in 2010 International Conference on Optics, Photonics and Energy Engineering (OPEE), 2010, vol. 1, no. 201, pp. 277–280.

[60] M. Mubashir, L. Shao, and L. Seed, "A survey on fall detection: Principles and approaches," Neurocomputing, vol. 100, pp. 144–152, Jan. 2013.

[61] H. Foroughi, A. Naseri, A. Saberi, and H. Sadoghi Yazdi, "An eigenspace-based approach for human fall detection using Integrated Time Motion Image and Neural Network," in 2008 9th International Conference on Signal Processing, 2008, pp. 1499–1503.

[62] Zhengming Fu, E. Culurciello, P. Lichtsteiner, and T. Delbruck, "Fall detection using an address-event temporal contrast vision sensor," in 2008 IEEE International Symposium on Circuits and Systems, 2008, pp. 424–427.

[63] H. Foroughi, B. S. Aski, and H. Pourreza, "Intelligent video surveillance for monitoring fall detection of elderly in home environments," in 2008 11th International Conference on Computer and Information Technology, 2008, no. Iccit, pp. 219–224.

[64] B. Jansen and R. Deklerck, "Context aware inactivity recognition for visual fall detection," in 2006 Pervasive Health Conference and Workshops, 2006, pp. 1–4.

[65] C. González García, D. Meana-Llorián, B. C. Pelayo G-Bustelo, J. M. Cueva Lovelle, and N. Garcia-Fernandez, "Midgar: Detection of people through computer vision in the Internet of Things scenarios to improve the security in Smart Cities, Smart Towns, and Smart Homes," Futur. Gener. Comput. Syst., vol. 76, pp. 301–313, Nov. 2017.

[66] C. González García, C. P. García-Bustelo, J. P. Espada, and G. Cueva-Fernandez, "Midgar: Generation of heterogeneous objects interconnecting applications. A Domain Specific Language proposal for Internet of Things scenarios," Comput. Networks, vol. 64, no. C, pp. 143–158, Feb. 2014.

[67] C. González García, J. P. Espada, E. R. N. Valdez, and V. García-Díaz, "Midgar: Domain-Specific Language to Generate Smart Objects for an Internet of Things Platform," in 2014 Eighth International Conference on Innovative Mobile and Internet Services in Ubiquitous Computing, 2014, pp. 352–357.

[68] C. González García, D. Meana-Llorián, B. C. P. G-Bustelo, and J. M. C. Lovelle, "A review about Smart Objects, Sensors, and Actuators," Int. J. Interact. Multimed. Artif. Intell., vol. 4, no. 3, pp. 7–10, 2017.

[69] L. A. Zadeh, "Fuzzy logic and approximate reasoning," Synthese, vol. 30, no. 3–4, pp. 407–428, 1975.

[70] L. a. Zadeh, "Fuzzy sets," Inf. Control, vol. 8, no. 3, pp. 338–353, Jun. 1965.

[71] P. Grant, "A new approach to diabetic control: Fuzzy logic and insulin pump technology," Med. Eng. Phys., vol. 29, no. 7, pp. 824–827, Sep. 2007.

[72] E. Portmann, A. Andrushevich, R. Kistler, and A. Klapproth, "Prometheus - Fuzzy information retrieval for semantic homes and environments," in 3rd International Conference on Human System Interaction, 2010, pp. 757–762.

[73] O. G. Duarte, "Sistemas de lógica difusa. Fundamentos," Rev. Ing. e Invetigación, no. 42, pp. 22–30, 1999.

[74] W. A. Kwong and K. M. Passino, "Dynamically focused fuzzy learning control," IEEE Trans. Syst. Man Cybern. Part B, vol. 26, no. 1, pp. 53–74, 1996.

[75] D. F. Larios, J. Barbancho, F. J. Molina, and C. León, "LIS: Localization based on an intelligent distributed fuzzy system applied to a WSN," Ad Hoc Networks, vol. 10, no. 3, pp. 604–622, 2012.

[76] I. Chamodrakas and D. Martakos, "A utility-based fuzzy TOPSIS method for energy efficient network selection in heterogeneous wireless networks," Appl. Soft Comput., vol. 11, no. 4, pp. 3734–3743, Jun. 2011.

[77] S. Bagchi, "A fuzzy algorithm for dynamically adaptive multimedia streaming," ACM Trans. Multimed. Comput. Commun. Appl., vol. 7, no. 2, pp. 1–26, Feb. 2011.

[78] G. Cueva-Fernandez, J. Pascual-Espada, V. García-Diaz, and M. Gonzalez-Rodriguez, "Kuruma: The Vehicle Automatic Data Capture for Urban Computing Collaborative Systems," Int. J. Interact. Multimed. Artif. Intell., vol. 2, no. 2, p. 28, 2013.

[79] G. Cueva-Fernandez, J. Pascual Espada, V. García-Díaz, and R. Gonzalez-Crespo, "Fuzzy decision method to improve the information exchange in a vehicle sensor tracking system," Appl. Soft Comput., vol. 35, pp. 1–9, Oct. 2015.

[80] G. Cueva-Fernandez, J. P. Espada, V. García-Díaz, R. G. Crespo, and N. Garcia-Fernandez, "Fuzzy system to adapt web voice interfaces dynamically in a vehicle sensor tracking application definition," Soft Comput., pp. 1–14, May 2015.

[81] D. Meana-Llorián, C. González García, B. C. Pelayo G-Bustelo, J. M. Cueva Lovelle, and N. Garcia-Fernandez, "IoFClime: The fuzzy logic and the Internet of Things to control indoor temperature regarding the outdoor ambient conditions," Futur. Gener. Comput. Syst., vol. 76, pp. 275–284, Nov. 2017.

[82] B. Z. Manaris and W. D. Dominick, "NALIGE: a user interface management system for the development of natural language interfaces," Int. J. Man. Mach. Stud., vol. 38, no. 6, pp. 891–921, Jun. 1993.

[83] B. Z. Manaris and B. M. Slator, "Interactive Natural Language Processing: Building on Success," Computer (Long. Beach. Calif)., vol. 29, no. 7, pp. 28–32, Jul. 1996.

[84] E. M. Sibarani, M. Nadial, E. Panggabean, and S. Meryana, "A Study of Parsing Process on Natural Language Processing in Bahasa Indonesia," in 2013 IEEE 16th International Conference on Computational Science and Engineering, 2013, pp. 309–316.

[85] B. Manaris, "Natural Language Processing: A Human-Computer Interaction Perspective," in Advances in Computers, vol. 47, no. C, 1998, pp. 1–66.

[86] C. Friedman, T. C. Rindflesch, and M. Corn, "Natural language processing: State of the art and prospects for significant progress, a workshop sponsored by the National Library of Medicine," J. Biomed. Inform., vol. 46, no. 5, pp. 765–773, Oct. 2013.

[87] K. W. Church and L. F. Rau, "Commercial applications of natural language processing," Commun. ACM, vol. 38, no. 11, pp. 71–79, 1995.

[88] F. Colace, M. De Santo, L. Greco, and P. Napoletano, "Text classification using a few labeled examples," Comput. Human Behav., vol. 30, pp. 689–697, 2014.

[89] P. Nesi, G. Pantaleo, and G. Sanesi, "A hadoop based platform for natural language processing of web pages and documents," J. Vis. Lang. Comput., vol. 31, pp. 130–138, Dec. 2015.

[90] R. Miikkulainen, Subsymbolic natural language processing: An integrated model of scripts, lexicon, and memory. MIT press, 1993.

[91] A. Akmajian, R. A. Demer, A. K. Farmer, and R. M. Harnish, Linguistics: An introduction to language and communication. MIT press, 2001.

[92] J. Allen, Natural language understanding, 2nd ed. Pearson, 1995.

[93] D. S. Carrell, D. Cronkite, R. E. Palmer, K. Saunders, D. E. Gross, E. T. Masters, T. R. Hylan, and M. Von Korff, "Using natural language processing to identify problem usage of prescription opioids," Int. J. Med. Inform., vol. 84, no. 12, pp. 1057–1064, Dec. 2015.

[94] S. Alansary, M. Nagi, and N. Adly, "A suite of tools for Arabic natural language processing: A UNL approach," in 2013 1st International Conference on Communications, Signal Processing, and their Applications (ICCSPA), 2013, pp. 1–6.

[95] P. Drews and P. Fromm, "A natural language processing approach for mobile service robot control," in Proceedings of the IECON'97 23rd International Conference on Industrial Electronics, Control, and Instrumentation (Cat. No.97CH36066), 1997, vol. 3, pp. 1275–1277.

[96] F. Siasar djahantighi, M. Norouzifard, S. H. Davarpanah, and M. H. Shenassa, "Using natural language processing in order to create SQL queries," in 2008 International Conference on Computer and Communication Engineering, 2008, pp. 600–604.

[97] O. Keszocze, M. Soeken, E. Kuksa, and R. Drechsler, "Lips: An IDE for model driven engineering based on natural language processing," in 2013

1st International Workshop on Natural Language Analysis in Software Engineering (NaturaLiSE), 2013, pp. 31–38.

[98] M. Ibrahim and R. Ahmad, "Class Diagram Extraction from Textual Requirements Using Natural Language Processing (NLP) Techniques," in 2010 Second International Conference on Computer Research and Development, 2010, pp. 200–204.

[99] A. Tripathy and S. K. Rath, "Application of Natural Language Processing in Object Oriented Software Development," in 2014 International Conference on Recent Trends in Information Technology, 2014, pp. 1–7.

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