Universidad de Oviedo

Master in Soft Computing
and Intelligent Data Analysis

Proyecto Fin de Máster
Master Project

Automated and personalized recommendation to customers based on their power consumption

by Rubén Enrique Parma Iadecola

July, 2012

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Abstract

In the companies of these days every customer plays a very important role, and must be integrated in the business model. Techniques like customer relationship management (CRM), helps to maintain good relations with customers. But for those big companies with hundreds of clients, it can be very difficult to have a personalized contact with each customer. So, if an autonomous virtual agent can interact with each customer and make suggestions about their behaviour, it would be a great improvement on getting a better customer relationship. However the way this it interacts with the customer should be as *natural* as possible to make him feel as it is talking with a real person that understand its situation.

The aim of this project is to contribute to define a methodology and architecture to develop computational applications for generating linguistic descriptions of data. The methodology proposed is a mixture of different techniques from researches made at the Unit of Computing with Perceptions of the European Centre for Soft Computing.

The Granular Linguistic Model of Phenomena (GLMP), provides a linguistic description of the current situation of the customer that is easy to understand. This is much better than present either a table with some values or graphics that shows a quantitative description of the customer situation.

Additionally, to gain empathy with the customer, the autonomous virtual agent should show some emotional behaviour. These emotions came from the Affective Computing, and can be shown on two forms: incorporating emotions to the phrases that describes the situation and the suggestions; and by a visual representation of its facial expressions.

Finally, to put all these elements together, the CPA7L model was used, as it encloses all the relevant aspects that need to be taken into account to tackle the interaction needed between the virtual agent and the customer, and provides a methodology to follow in the path for its design.

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Chapter 1

Introduction

1.1 Objectives

In the companies of these days every customer plays a very important role, and must be integrated in the business model. Many techniques have been developed to include customers in the business model. One of the most common is Customer relationship management (CRM) (Buttle (2004) and Anderson and Kerr (2002)), that is a widely implemented model for managing the interaction of a company with its customers. It involves using technology to organize, automate and synchronize sales activities, marketing, customer service and technical support. CRM helps to maintain good relations with customers, having the following goals:

- Find, attract and win new customers.
- Increase customer retention.
- Increase company profits.
- Better serve the customer, increasing competitive advantage.
- Build and maintain a relationship with customers, knowing their current and future needs and incorporate trends in the company strategy.
- Reduce the costs of marketing and customer service.

But for those big companies with hundreds of clients, it can be very difficult to have a personalized contact with each customer. So, if an autonomous virtual agent can interact with each customer and make suggestions about their behaviour, it would be a great improvement on getting a better customer relationship. However the way it interacts with the customer should be as *natural* as possible to make him feel as it is talking with a real person that understand its situation.

This level of *naturality* on the communication can be achieved using both natural language processing and affective computing.

By means of natural language processing, a description of the current situation of the customer can be generated on easy terms to understand and make suggestions on it, this is much better than present either a table with numbers or graphics that need to be analysed to get a description of the current customer situation in order to make suggestions.

Finally to gain empathy with the customer, the autonomous virtual agent should show some emotional behaviour. These emotions can be simulated in the computer using Affective Computing techniques, and can be shown on two forms: incorporating emotions to the phrases that describes the situation and the suggestions; and by a visual representation of it that can reinforce the emotion that should be expressed.

To be able to design this autonomous virtual agent, the architecture CPA7L proposed by Triviño et al. (2009) will be used, as it encloses all the relevant aspects that need to be taken into account to tackle the interaction needed between it and the customer.

1.2 The Problem

This work is made in conjunction with the Spanish company HC Energía. According to studies they have made, their customers have some necessities about their energy consumptions habits, 90% of they are willing to consume less energy and 76% like to do more for the environment, but do not know what to do. This creates a necessity of information that helps the customers change their consumption habits.

The analytic intelligence process, can be divided in:

- Measure.
  - Reception and storage of the reading information from the counters.
  - Identification and collection of Customer Information:
    - Features of the electrodomestic equipment at home and ways of use.
    - Socio-demographic household features.
- Information.
  - Filter available information.
  - Defining data model. Storage and structuring data for exploitation.
  - Preparation of load curves and identification of representative series.
  - Identification of key variables and its influence on consumption behaviour.
- Knowledge.
  - Behavior definition by segment. Consumption patterns.
  - Key customer attributes.
  - Customer segments definition and description.
  - Correlation analysis. Socio-demographic attributes and devices.
- Action.
  - Customer advisory services.
  - Consumption profile description.

- Day period analysis and advice on behaviour.
- Consumption profile.
- Assess Devices efficiency advice.

The Action item, must be achieved in a personalized way for each client, but it is non feasible to employ personnel that analyses and describe each case for each customer. The solution is an Autonomous Personal Advisor(APA).

The tasks that this *APA* must achieve are summarized in figure 1.1.

	Efficiency	Advice
Information	Consumption patterns description to understand how energy is used	Descriptive information to understand and identify keys in consumption patterns and behaviours. Key references with the segment behaviour
Advice at charged periods and uncharged periods for savings	Demand management: promote consumption in valley period and limit consumption at peak periods	Advice to best period consumption
Patterns and habits identification	Time consumption comparison. Patterns of consumption per period	Global consumption. Base consumption. Peak consumption
Advice on electric devices	Increase efficiency in the use of devices and promote efficient devices	Device efficiency and use

Figure 1.1: Tasks of the Autonomous Personal Advisor

In summary, the main goal is to promote energy efficiency at households, by analytic intelligence of the customer consumption habits.

1.3 Scope

This work covers the design of the *APA* as a virtual agent to make recommendations for the customers of HC Energía, based on their hourly power consumption. Its main goals are:

- Make suggestions in a clear and natural language that lead the customer to a better use of the energy.
- Use emotions on the generated sentences and on a visual representation of itself, to gain empathy with the customer.
- Analyse the hourly consumption of a customer and make conclusions and advices based on his efficiency.

- Move the consumption trends of a customer from areas in time with high consumption to areas where the consumption is lower and cheaper.

1.4 Contents

In the second chapter, the theoretical bases of all the techniques involved will be described to have an introduction of the concepts and terminology used. The third chapter, is about how to model a simple virtual agent using the *CPA7L* architecture, explaining what should be done in each level. Fourth chapter add the ability of *Natural Language Generation*. The Fifth chapter introduces how to add *Emotions* to the expressions generated. This structure can be seen on figure 1.2. On sixth chapter, the results of a simple example putting together all these elements as the *APA*, are shown, and finally on chapter seventh, the conclusions and further work are presented.

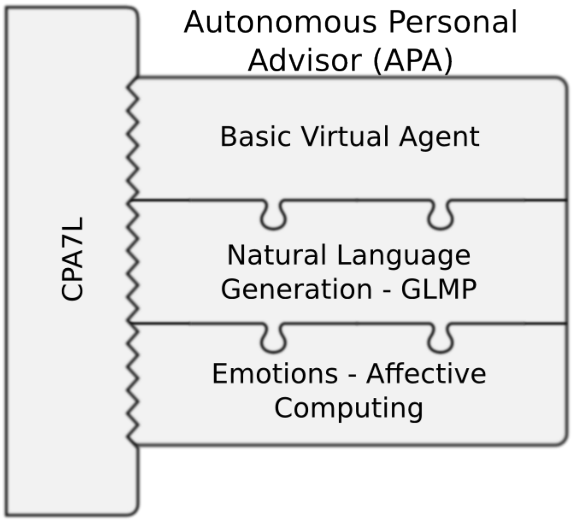


Figure 1.2: Organization Autonomous Personal Advisor design.

Chapter 2

Brief Introduction to the Applied Technologies

This chapter presents a review of all the techniques that need to be put together in order to achieve the objectives of the *APA*, as the previous work on the fields of natural language processing, affective computing and autonomous virtual agent modeling.

2.1 CPA7L

The main concept of the CPA7L has been explained in detail on Triviño et al. (2009). This architecture allows for a robust design of autonomous agents. Here is a brief description of the main components of this architecture.

The distinction between Concepts, Procedures and Attitudes (CPA) has its origin in Cognitive Psychology and appears in the Theory of Elaboration introduced by Reigeluth et al. (1980). These researchers were investigating the contents of the learning process in the general context of Education. Some years later this classification was used as one of the theoretical bases of the Spanish educational system. In the book by Coll (1991) definitions of the key concepts of the theory are provided:

Concepts designate a set of similar objects, events, or symbols with common characteristics. Examples of concepts are: mammal, triangle, cloud, etc.

Procedures designate a set of ordered actions aimed at a goal. Examples of procedures are: to subtract two numbers, to draw a map, to write a sumarization, etc.

Attitudes correspond with a prevailing tendency to act in a certain way and arise in front of determined situations, objects, events or people. Examples of attitudes are: to keep your clothes clean, to enjoy listening to classical music, etc.

This classification is being used extensively by professionals in Education to describe the contents, the goals, and the methods of evaluation of courses and subjects (Ullastres et al. (1998)). For example, let us suppose that the objective of a class is to teach the students how to use a map. An analysis of what this objective involves can reveal de following elements: First, the students must learn the concept of map, the concept of scale, symbols for road, forest, etc. Next the students can learn the procedures to locate their position, to define a path, etc. The attitude to teach is that a map as a useful tool in certain situations. This attitude will help the students to use maps when the situation requires it, for example, when the planning of a holiday trip.

Figure 2.1 shows the seven levels of the architecture (arrows represent relations of use). The higher level components add new functionality to the system using the resources provided by the components situated below. The CPA7L layers are described as follows:

Physical Level This level contains a description of the physical elements of the system, which includes mechanical, electro-mechanical and electronic components of importance, such as sensors, actuators, visual/physical appearance, communication devices, as well as other parts of hardware of the processing system.

Symbolic Level For processing information about the physical world it is necessary to establish a bridge between it and the symbolic world (Pylyshyn (1986)). The Symbolic level creates this bridge by providing the necessary mechanisms to access the Physical level from the symbolic context of the higher levels. The Symbolic level includes a description of primitive concepts (communication channels with hardware) and primitive procedures (software primitive functions) which are used to access sensor measurements and to manage the actuators or change the visual/physical appearance.

Reactive Level Describes the mechanisms with which the system reacts autonomously in real time, using the basic concepts and procedures provided by the Symbolic level. This component contains the system's basic attitudes. As in the previous levels, the elements at this level are usually highly optimized and cannot be easily modified (e.g. by learning) in a practical application (Brooks (1986)).

Structural Level The previous levels could be sufficient to describe a simple autonomous system. Normally additional software infrastructure is needed for a more complex semiautonomous system, such as, an operating system, a communication system, a database management system, etc. These elements are organized at the Structural level and provide the support needed for the higher levels. A second role of the Structural level is to isolate higher level functionality from lower level functionality. As a result these higher level components can be reused on similar platforms. Effectively the Structural level provides a generic interface that allows the higher levels to access the basic concepts, procedures and attitudes from the low level components.

Conceptual Level Contains a network of concepts corresponding to the world where the agent operates. This World Model not only contains concepts related with the perceptions in its environment, but also concepts related with the perception of the elements that are part of the itself, as well as abstract concepts related with the objectives.

Procedural Level The view of the architecture at this level contains the procedures associated with the network of concepts available at the conceptual level. Using these procedures it is able to create a possible plan of action that will lead the system from the current conceptual situation to a new situation with a higher degree of goal achievement. This level describes the high level operations that the agent can perform. In the procedural level is the definition of methods of a class like in Object Oriented Programming, and in the conceptual level, there are the attributes.

Attitudinal Level This level describes the expected system behavior in different circumstances. It includes descriptions of the willingness of the agent to achieve certain objectives, or the preferences of some actions over others. Note that these descriptions will be done by making reference to the concepts, procedures and basic attitudes introduced in the previous levels.

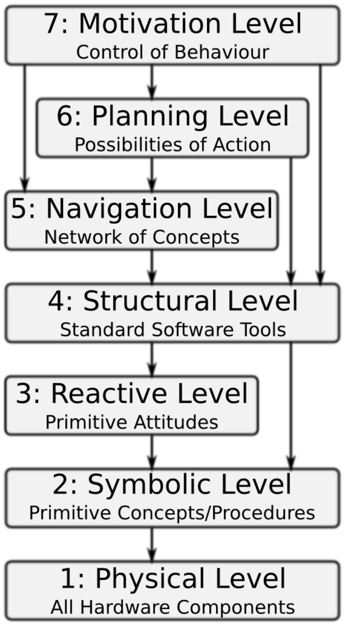


Figure 2.1: A view of the architecture structured in seven levels including the relations of use.

2.2 Computational Theory of Perceptions and Granular Linguistic Model of Phenomena

Computational Theory of Perceptions (CTP) was introduced by Zadeh (1999) and Zadeh (2001). It grounds on the fact that human cognition is based on the role of perceptions, and the remarkable capability to granulate information in order to perform physical and mental tasks without any traditional measurements and computations. Natural language (NL) is a suitable powerful tool to describe our perceptions.

This is a key paradigm used for developing computational systems able to generate linguistic descriptions of data (Méndez Núñez and Triviño (2010), Alvarez-Alvarez et al. (2012), Alvarez-Alvarez and Triviño (2012)). Figure 2.2 shows the approach to the architecture of a computational system for generating linguistic description of data, indicating processes with ovals and data structures with rectangles.

During a preliminary off-line stage, the designer collects a corpus of NL expressions that are typically used in the application domain to describe the relevant features of analyzed phenomena. The designer analyzes the particular meaning of each linguistic expression in specific situation types to build *Granular Linguistic Model of Phenomena* (GLMP) and *Report templates*. Later on, the *Report* is obtained from *input data* as result of instantiation processes of these two generic data structures.

During the on-line stage, the computational system selects (instantiates) among these available possibilities the most suitable linguistic expressions to describe the input data.

The main components of GLMP are described below.

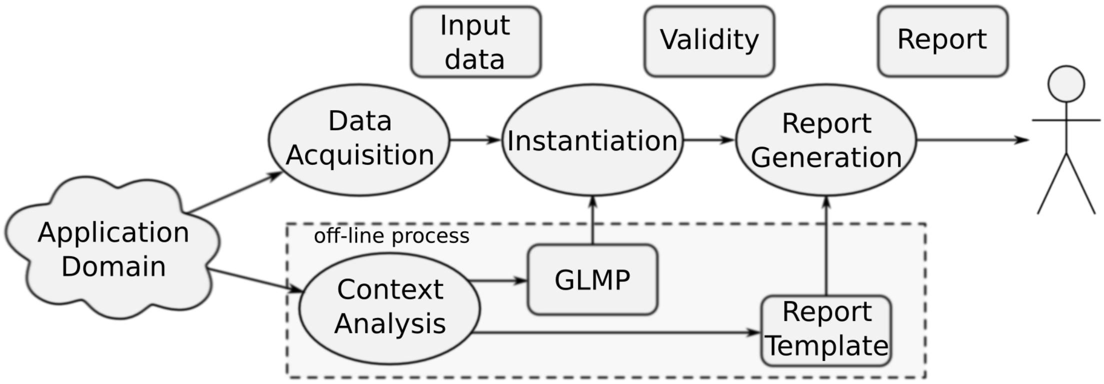


Figure 2.2: Architecture of a computational system for generating linguistic description of data.

2.2.1 Computational Perception

The concept of Computational Perception (CP) is based on the concept of linguistic variable introduced by Zadeh (1975). CPs are computational models of information units (granules) acquired by the designer about the phenomenon to be modeled, i.e., CPs correspond with specific parts of the phenomenon at certain degree of granularity. A CP is a tuple (A, W) described as follows:

$A = (a_1, a_2, \ldots, a_n)$ is a vector of linguistic expressions (words or sentences in NL) that represents the whole CP linguistic domain. In the application context, each a_i describes the value of the CP in each situation of the phenomenon with specific degree of granularity. These sentences can be either simple, e.g., $a_i =$*"The temperature is quite high"* or more complex, e.g., $a_i =$*"Most weekends the efficiency of client A was low"*. During the preliminary off-line stage, these values are assigned by the designer extracting the most suitable sentences from the linguistic corpus of the application domain.

$W = (w_1, w_2, \ldots, w_n)$ is a vector of validity degrees $w_i \in [0, 1]$ assigned to each a_i in the specific context. The value of validity depends on the application, i.e., it is a function of the precision of each sentence to describe specific input data. During the on-line stage, this validity values are assigned (and updated) in function of the phenomenon current state. Typically, A is a strong fuzzy partition of the domain of existence of CP and therefore $\sum w_i = 1$.

For example, provided input data, a $CP_1 = (A_1, W_1)$ that models the energy consumption of a client at some hour, could be instantiated as:

a_1 = "Client A consumed little energy at hour t", $w_1 = 0.3$

a_2 = "Client A consumed some energy at hour t", $w_2 = 0.7$

a_3 = "Client A consumed much energy at hour t", $w_3 = 0$

2.2.2 Perception Mapping

Perception Mappings (PMs) are used to create and aggregate CPs. A PM is a tuple (U, y, g, T) where:

U is a vector of input CPs, $U = (u_1, u_2, \dots, u_n)$. We call first order perception mappings (1-PMs) when U are not CPs but values $z_i \in \mathbb{R}$ being provided either by sensors or obtained from a database; otherwise PMs are called second order perception mappings (2-PMs).

y is the output CP, $y = (A_y, W_y)$.

$g()$ is an aggregation function employed to calculate the vector of degrees of validity assigned to each element in y, $W_y = (w_1, w_2, \dots, w_{n_y})$. It is a fuzzy aggregation of the input vectors $W_y = g(W_{u_1}, W_{u_2}, \dots, W_{u_n})$, where W_{u_i} are the degrees of validity of the input perceptions. In Fuzzy Logic many different types of aggregation functions have been developed. For example g could be implemented using a set of fuzzy rules. In the case of 1-PMs, g is built using a set of membership functions as follows:

$$Wy = (\mu_{a_1}(z), \mu_{a_2}(z), \dots, \mu_{a_{n_y}}(z)) = (w_1, w_2, \dots, w_{n_y})$$

where W_y is the vector of degrees of validity assigned to each a_y, and z is the input data.

T is a text generation algorithm that allows generating the sentences in A_y . In simple cases, T is a linguistic template, e.g., "Client A consumed {little/some/much} energy at weekend w".

2.2.3 Granular Linguistic Model of Phenomena

The Granular Linguistic Model of Phenomena (GLMP) consists of a network of PMs. Each PM receives a set of input CPs and transmits upwards a CP. We say that each output CP is explained by the PM using a set of input CPs. In the network, each CP covers specific aspects of the phenomenon with certain degree of granularity.

As mentioned above, first order perception mappings (1-PM) are those which are input to the GLMP. First order computational perceptions (1-CP) are the output of 1-PM. PMs which input are CPs are called 2-PM and their outputs are 2-CP. This classification is inspired on the definition of the three worlds by Popper and Eccles (1984) namely, world-1 of physical objects (*phenomena*), world-2 of the perceived objects (1-CP) and world-3 of the mental objects built by using the objects in the world-2 (2-CP).

2.2.4 Instantiation of the GLMP

Once a sample of input data is available, the aggregation functions in the GLMP are instantiated to calculate the validity degree of each CP. Therefore, this module provides as output a collection of linguistic clauses together with their associated degrees of validity.

2.2.5 Report Generation

Provided a set of valid linguistic clauses, the goal is to combine this information to build a linguistic report. This module deals with generating the most relevant linguistic report by choosing and connecting the adequate linguistic clauses based on a Report Template data structure.

2.3 Affective Computing

As said by El-Nasr et al. (2000), emotions are an important aspect of human intelligence and have been shown to play a significant role in the human decision-making process. Researchers in areas such as cognitive science, philosophy, and artificial intelligence have proposed a variety of models of emotions.

According to Picard (2011) and Picard (2000), emotion-like mechanisms inside a machine can perform functions that may or may not appear emotional to an outside observer. The best known emotion synthesis technologies usually trigger visible or verbal displays of emotion; for example, an emotion model within the Hasbro/iRobot toy doll *My Real Baby* evaluates inputs and causes the doll's facial expressions and vocalizations to change, making the doll appear to have emotions. Thus, an internal emotion model synthesizes emotion, that is, it creates an internal state that is capable of triggering the outward appearance of having an emotion, although it also may not trigger any outward appearance, and may only change what happens inside. This use of an emotion model is to identify which emotion is likely to be present given some observations now (recognition), or which emotion is likely to come next (prediction). Some emotion models can be used both for analysis (recognition or prediction) and for synthesis (simulating or giving rise to the emotion). For example, cognitive appraisal models can be used both for recognizing antecedents that may give rise to an emotion (analysis) or for actually giving rise to a state in a computational system (synthesis).

As stated in van der Heide and Triviño (2010a), the model to simulate the emotional state of a virtual agent, can be a Fuzzy Finite State Machine (FFSM) (Bailador and Triviño (2010)), because the emotions are completely related to the human mind and perceptions, and is completely imprecise. Defining the emotional states as the states on the FFSM, and giving an input vector of perceptions, the model can output the emotional state of the system. Using the linguistic variables *TimeToStay* and *TimeToChange*, as well as the state transition rules, the *personality* can be adjusted.

A FFSM is a tuple (U, S, f, Y, g, S_0) where:

- U is the input vector $(u_1, u_2, \cdots, u_{nu})$, where nu is the number of input variables.
- S is the state vector $(s_1, s_2, \cdots, s_{ns})$, where ns is the number of states.

- f is a function to calculate the state vector at time step $t{+}1$, $S(t{+}1) = f(S(t), U(t))$.
- Y is the output vector $(y_1, y_2, \cdots, y_{ny})$, where ny is the number of output variables.
- g is a function to calculate the output vector at time step t, $Y(t) = g(S(t), U(t))$.
- S_0 is the initial state of the system.

Then in van der Heide and Triviño (2010b), they showed how to model emotions using a representation closer to the Plutnik Wheel, shown on figure 2.3.

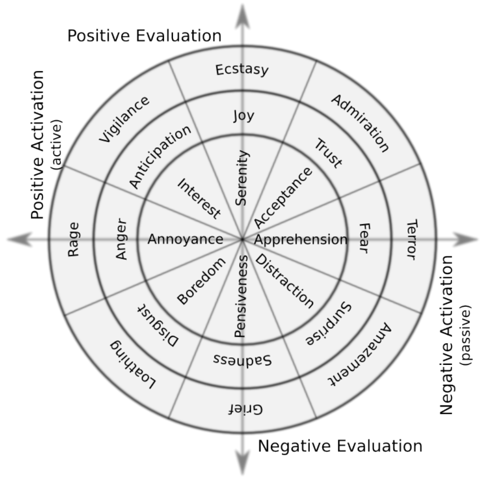
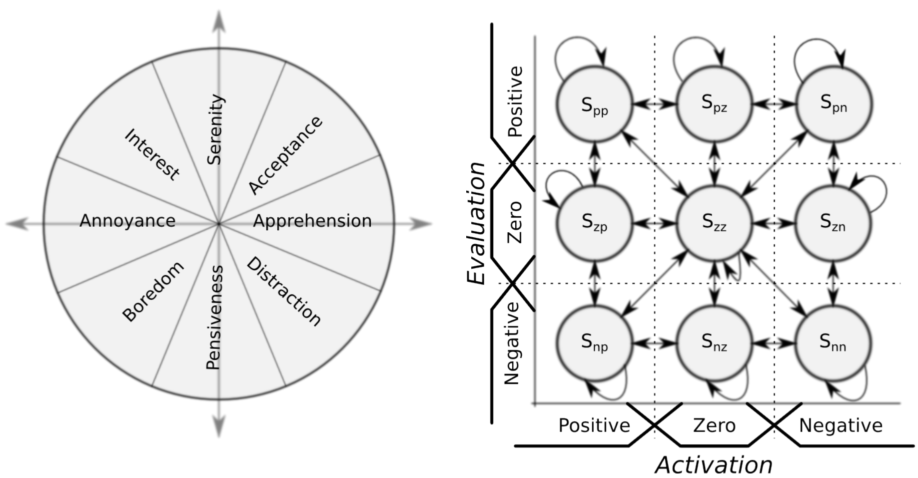


Figure 2.3: Plutnik Wheel of emotions.

They build a successfully prototype using a FFSM to represent emotions, creating a simplified version of the Plutnik Wheel (figure 2.4(a)) and placing states over it (figure 2.4(b)).



(a) Simplified version of the Plutnik Wheel

(b) States of the FFSM

Figure 2.4: States of the FFSM to model emotions used in van der Heide and Triviño (2010b).

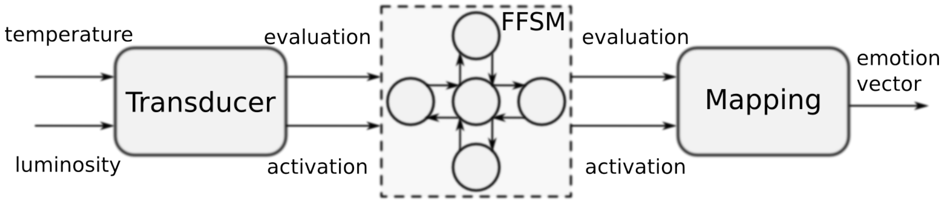


Figure 2.5: Modules of the architecture proposed by van der Heide and Triviño (2010b).

Additionally, they proposed a 3 modules system, as seen on figure 2.5, that allow the designer to customize and adjust the personality.

Here is a brief description of each module:

Transducer Module This module translates any combination of input variables into only a couple of basic emotion variables, this makes it possible to use well known emotional models. It is implemented using a set of fuzzy rules. During the design of the linguistic labels and rules the designer can tune the module behavior in accordance with the specific application needs.

Fuzzy Finite State Machine This module functions as the memory of the internal emotional state, and it is responsible of determining the activation degree of the states that the system can show.

Mapping This module is responsible of calculate the emotional state that is *externally visible*, generally represented by a vector. In this computational module, the designer has again an opportunity to model new characteristics of a simulated emotional personality.

2.4 Virtual Interactive Agents

Many research have been done in the field of virtual interactive agents and the advantages of this kind of interaction are well studied. According to Reeves (2000), some of them in Social Intelligent Interfaces are:

1. Psychological responses to mediated social interaction affect important metrics in teaching and business.
2. Increase memory and learning, and make online education more effective.
3. Persuade and increase up-sell, cross-sell and conversion rates.
4. Motivate users to stick with interactions longer.
5. Engage users by encouraging them to return over time.
6. Increase trust and make people feel more secure and comfortable about disclosing personal information online.

7. Promote continuity across interactions by welcoming people back to interactions using information from prior conversations.

8. Create feelings of friendliness and liking, and support positive feelings toward organizations that sponsor the interactions.

9. Increase a sense of personalized experience and make people feel special and not like they are one user among a million.

On his article, shows how the user could think that is interacting with the virtual agent as if it was a real being, despite the fact that he knows that is not. Thus, the user creates a model of the virtual agent mind, and assigns a personality to it, making the interaction seems more like human-to-human, which in turn makes it feel more comfortable.

Also Thompson et al. (2002), emphasizes the importance of having personalized intelligent systems to take into account the specific preferences and behaviors of each user or customer. They created a personalized, long-term user model for their adaptive recommendation system, that improve the quality of the interactions with the end user.

Few commercial solutions in the field of virtual conversational agents were developed to provide a web based implementation of those technologies. A few of them are described below.

Anna from IKEA Developed by Artificial Solutions, using his proprietary *Teneo Engine*, for Natural Language Interaction; Anna is a virtual web agent that was designed to guide users around the IKEA website. Anna has a visual animated representation, that can show emotions in the form of face gestures, and through the use of natural language expressions to gain the confidence of the user.

***Contact Us* section from Vueling.com** Developed by Anboto, Vueling virtual assistant has two main aims: act as an virtual assistant to help the customer schedule a travel, and as an automatic email response system. According to *Alex Cruz, CEO of Vueling*:

> With Anboto's Automatic Email response we have reduced 38% incoming e-mails and calls without reducing customer satisfaction level. Return of Investment (ROI) is around 4 months, so it has been a fantastic investment

Unlike Anna from Ikea, this virtual agent does not have a visual representation, it acts more like a text based chat and is less emotional.

Eva Virtual Assistant from imq.es Also developed by Anboto, Eva is a Virtual Assistant for IMQ, a spanish healthcare company. Eva's objective is to help IMQ clients find doctors online and book appointments with them.

Because it's a Interactive Virtual Assistant, it can understand natural language, show emotions and even comprehend ambiguous phrases. It' can also engage in a social dialogue or correct spelling mistakes.

Eva has a visual realistic representation, having the image of a girl (Eva Pérez Lorenzo a employee of IMQ) who using mimic and facial expressions transmits its emotions to user.

Chapter 3

Design of a Basic Virtual Agent

This chapter presents the design of a basic virtual agent using the CPA7L architecture, explaining the components of each level.

3.1 Physical Level

First, the virtual agent need to get inputs from the environment. These inputs are the customer hourly consumption measures. To get them, the current consumption meters at the customers houses that only takes accumulative measures, can be replaced by new smart-meters that store and send measures hour by hour. In this way a customer consumption profile can be built.

Additionally, there is the need to communicate with the customer. The preferred channel is the printed bill because it reaches all the consumers, but making monthly reports, that is, if the bill is bimonthly, two reports should be included, one per each month. Also those reports could be accessed from the web page of HC Energía, after the customer confirm his identity, but those web-based reports should be the very same that are printed on the bill, and not an interactive virtual assistant, because that is out of the scope of this design.

Based on this model, a number of different channels of communication may be used, but these are the initially suggested.

In both of the previous cases, the virtual agent need a visual representation that makes it easier for the customer to create a mental image of of it. Based on the graphical scheme of the images on the web page of HC Energía, a possible appearance is shown on figure 3.1.

3.2 Symbolic Level

The hourly consumption measures should be read. The most common way of making interface between the system that reads the measures from the meters installed on the customers houses, and the virtual agent, is through plain text files. So, low level routines to read and process these text files are needed.

The same way, it should have a mechanism to publish information to the customer, and again, the common way to export the information, can be text files with the generated

Figure 3.1: Visual representation of the virtual agent.

advices. These resulting text files, can be sent to the bill printer process in order to be printed on each customer bill. Then routines to write and handle text files are needed as well.

Also, using these output text files, the web page module can be updated, but maybe some kind of webservice should be more suitable. In that case, this webservice should be provided to deliver the information when the web page request it. Another alternative, is to use a database (DBMS) to act as a bridge, in that case, basic routines that allow writing the reports to the database have to be implemented.

These not are the only ways to communicate between different systems, but if more complex or sophisticated methods are needed, they belong to this level.

It can be considered that these elements belongs to the Structural Level, but they are mentioned here for didactic reasons to explain the whole functioning of the CPA7L architecture. In fact, these routines are just calls to low level routines or services already implemented on the Operating System, a Web Server, or a DBMS.

3.3 Reactive Level

Here, the main role is to detect failures in the hardware supporting the virtual agent. Also, this level consists of validation mechanisms over the input data. Scenarios like incomplete data, too much data, incorrect measures, etc, should be detected and handled adequately, because these kind of data, can cause a malfunction of the virtual agent. In addition, the mechanisms to respond to extreme measures, too high or too low, should be included here.

As this should be a batch process, to analyse a group of clients, errors should be reported in the form of logs that should be provided to the operators of the system if some of these error or unexpected situations occurs.

3.4 Structural Level

Here, the software environment where the virtual agent will "live" is to be defined. It should be a server, with enough computational power to process the data obtained from each customer. In average, there should be approximately 720 lectures (1 lecture per hour during a month) to be processed, which is not a very heavy load, but when the number of customers increases, there are a few million of lectures to be processed. Despite of that, the process is an off-line process, so the time of processing, is not too critical. This server should have access to the network to get the inputs generated by the acquisition system, to deliver its results and to get the to basic information of the customers from the main databases is also needed, in order to know who is each customer.

Also, a local database may be useful in order to store the state of each customer to have continuity on the reports generated. All this must run over an operating system that may be a Linux server, because all services that must be implemented in, are quite simple and requires no special application. Linux also provides a secure and stable environment to maintain the applications, however, any operating system of these days, is adequate to the task.

3.5 Conceptual Level

The concepts that the virtual agent must handle, are first those related to:

- Customer.
- Energy Efficiency.
- Consumption peak.
- Consumption valley.
- Ordinary intervals.
- Daily consumption.
- Weekly consumption.
- Monthly consumption.
- The measures of the customer consumptions, expressed on kWh.
- Objectives for the next consumption period.

Then concepts related to the generation of the advice should be included. Also concepts related with how to aggregate the inputs needs to be defined, which elements should be used to perform the analysis of the energetic efficiency of the customers and any other concept related to some specific functionality.

3.6 Procedural Level

Knowing all the concepts, here are the associated procedures to handle them.

- The procedure of load the inputs.
- The processing of the data by aggregation in some ways.

- The generation of objectives related to the customer habits.
- Summarization of the data.
- Comparison of the results again the objectives proposed to generate the corresponding advise.
- Publish the generated information, in the form of web services, text files or other ways of export it.
- Procedures to retrieve the customer information from the databases.

And as many procedures that are needed to handle new concepts added should be defined at this level.

3.7 Attitudinal Level

In the final level, the attitudes of the virtual agent should be defined. These attitudes define the objectives and motivations that it has. This may include:

- Provide personalized attention.
- Achieve energetic efficiency.
- Promote the reduction of the consumption peaks.
- Promote an increase of the consumption on low cost hours.
- Keep the customer informed of his consumption habits.

Every final objective or motivation, should be defined on this level, and should be achieved using the procedures and concepts described in the previous levels.

At this point, it is a very generic autonomous virtual agent that could simply generate bills like these of today. In the next chapters, more functionality and more detail will be added.

Chapter 4

Adding the Ability to Generate Natural Language Expressions

On this chapter, the ability to generate Natural Language Expressions, will be added to the Autonomous Personal Advisor. Also, the ability to compute using perceptions will be added, allowing the aggregation of the data to be done in a more human-like fashion, this helps to generate complex analysis of the data in a relatively simple way.

4.1 CPA7L Levels

The physical, symbolic, reactive and structural levels, remain as initially proposed in the previous chapter, because, all these elements are still required. This feature lies on the functionality of the elements provided by these levels.

4.2 Conceptual Level

By using the Granular Linguistic Model of Phenomena, a series of Computational Perceptions should be described. These CPs will be described on this level plus other concepts that helps to define these CPs.

Let's consider, for example, the efficiency on the consumption during weekends in low cost zone. There are various concepts that need to be described:

Hourly Customer Consumption It is the raw input data. Its taken using the functionalities provided by the lower levels of the model.

Amount of Energy Consumed Hourly ($1\!-\!CP_{CC}$)**:** It represents how much energy was consumed at hour t during the month. Phrases like *You consumed much energy at hour t* can be produced with this CP. Represents the fuzzy set defined by the labels: *little/some/much* hour by hour.

Weekend It is defined as the Saturday and Sunday, but by means of the fuzzy logic, weekend can be defined in fuzzy terms, so the weekend can start the Friday in the afternoon with a low membership degree, and can last to the Sunday night.

Weekend Consumption ($2\text{−}CP_{CDW}$)**:** It is the consumption during the weekend defined before. It aggregates the consumption of all the hours included in the weekend, and permits to generate phrases like *You consumed little energy at weekend w*. Represents the fuzzy set defined by the labels: *little/some/much* weekend by weekend.

Low Cost Zone This is the time interval where the energy has the lower production cost. It can be defined using fuzzy sets or crispy ones. One of the objectives is to increase the consumption on this zone.

Daily Consumption in Low Cost Zone ($2\text{−}CP_{LC}$)**:** Is the daily consumption during the low cost hours. This permits the generation of phrases like *You consumed some energy in low cost zone at day d*. Represents the fuzzy set defined by the labels: *little/some/much* day by day.

Weekend Consumption in Low Cost Zone ($2\text{−}CP_{LCW}$)**:** It is the consumption during the weekend but just in the low cost zone. Phrases like *You consumed little energy in low cost zone at weekend w*, can be generated from this concept. Represents the fuzzy set defined by the labels: *little/some/much* weekend by weekend.

Weekend Consumption Efficiency ($2\text{−}CP_{EW}$)**:** This is a ratio of energy consumed during the whole weekend and the energy consumed on weekend but only in the low cost zone. Phrases as *Your efficiency was low during weekend w* can be generated. Represents the fuzzy set defined by the labels: *low/medium/high* weekend by weekend.

Consumption Efficiency Summary ($2\text{−}CP_{SEW}$)**:** It is the final summarization of the data using quantifiers, this permits to aggregate the efficiency of all the weekends. So phrases in the form *Most weekends your efficiency was medium.* Represents the fuzzy set defined by the labels: *low/medium/high* and *few/some/most.*

All these concepts, form the GLMP shown on figure 2.2. Also the Report Template used for the generation of the reports, should be described as a concept on this level. This template is shown on figure 4.1. In the next level, the procedure to use this template is explained.

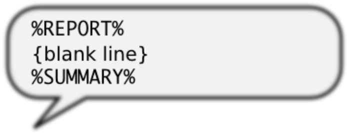


Figure 4.1: Report Template used by the Report Generation Module for generating Natural Language Reports.

4.3 Procedural Level

At this level, some procedures to aggregate the CPs are needed, these are the Perception Mappings, that allows the transformation and analysis of the customer consumption data.

Following the previous example of the efficiency on the consumption during weekends in low cost zone, these are the PMs (procedures) used:

Hourly Consumption ($1-PM_{CC}$): This produces the degree of validity for the $1-CP_{CC}$, by applying fuzzy sets defined for *little/some/much* energy consumed to each hourly consumption data.

Consumption During Weekends ($2-PM_{CDW}$): This produces the degree of validity for the $2-CP_{CDW}$ *little/some/much* energy consumed, summarizing the $1-CP_{CC}$ using an integral function and the definition of weekend (in hours of the week).

Consumption in Low Cost Zone ($2-PM_{LC}$): This produces the degree of validity for the $2-CP_{LC}$ *little/some/much* energy consumed, summarizing the $1-CP_{CC}$ using an integral function and the definition of low cost zone.

Consumption in Low Cost Zone During Weekends ($2-PM_{LCW}$): This produces the degree of validity for the $2-CP_{LCW}$ *little/some/much* energy consumed, summarizing the $2-CP_{LC}$ using an integral function and the definition of weekend in days (the previous definition was expressed in hours).

Efficiency During Weekends ($2-PM_{EW}$): This produces the degree of validity for the $2-CP_{EW}$ *low/medium/high* efficiency, combining the $2-CP_{LC}$ and $2-CP_{LCW}$ using a set of if-then rules in the form:

- IF *You consumed little energy at weekend w* AND *You consumed little energy in low cost zone at weekend w* THEN *Your efficiency was medium during weekend w.*
- IF *You consumed little energy at weekend w* AND *You consumed some energy in low cost zone at weekend w* THEN *Your efficiency was high during weekend w.*

⋮

- IF *You consumed much energy at weekend w* AND *You consumed much energy in low cost zone at weekend w* THEN *Your efficiency was medium during weekend w.*

Summary of Efficiency During Weekends ($2-PM_{SEW}$): This produces the degree of validity for the $2-CP_{SEW}$ *no/few/some/most/all* weekends the efficiency is *low/medium/high*. It is done simply by counting the number of times each of the three levels of efficiency is higher for a week in $2-CP_{EW}$, and then dividing by the number of weeks. Then applying the partitions to *no/few/some/most/all*, to get the membership degree to these labels. This is not the recommended way to make aggregation, but this is the easiest way of aggregation and, as at most the number of weeks is four for a set of data to be processed, this method produce results more congruent with the information represented in the $2-CP_{EW}$ than the method of the cardinality proposed originally by Zadeh.

These elements are used to process the customer consumption data, which is the GLMP Instantiation shown on figure 2.2. In addition, the Report Generation Module should be described on this level. The report consist of two parts using the template shown on figure 4.1, these two parts will be replaced with the elements of the report. The last part, the `%SUMMARY%`, came directly from the $2-CP_{SEW}$, which resumes the efficiency of all the month. Then in the `%REPORT%` the idea is to explain week by week, what happened and why. To achieve that, the $2-CP_{CDW}$, $2-CP_{LCW}$ and $2-CP_{EW}$ are used. As seen in the $2-PM_{EW}$, $2-CP_{CDW}$ and $2-CP_{LCW}$ are combined using a set of if-then rules, so this *logic* is what is shown on the report. Additionally all the weeks that have the same values, are grouped to make the report not redundant and more easy to read.

4.4 Attitudinal Level

By adding the GLMP new attitudes arise, in the line of the example presented there are:

Promote the Consumption on Low Cost Zone during the Weekend With the information provided by the CPs of the GLMP, and this objective, some advices can be exposed. For example, if the efficiency was low most weekends, an advice could be to increase the consumption during the low cost zone or change habits at the hours where the consumption is higher.

Keep the Consumer Informed About his Consumption Habits Using the linguistic description of the consumption patterns, generated using the GLMP, the APA can explain on a natural and easy way to understand, the consumption habits of each customer.

Finally, all the elements of the GLMP for the Consumption Efficiency, can be seen on figure 4.2, showing the relation between all the CPs and the PMs.

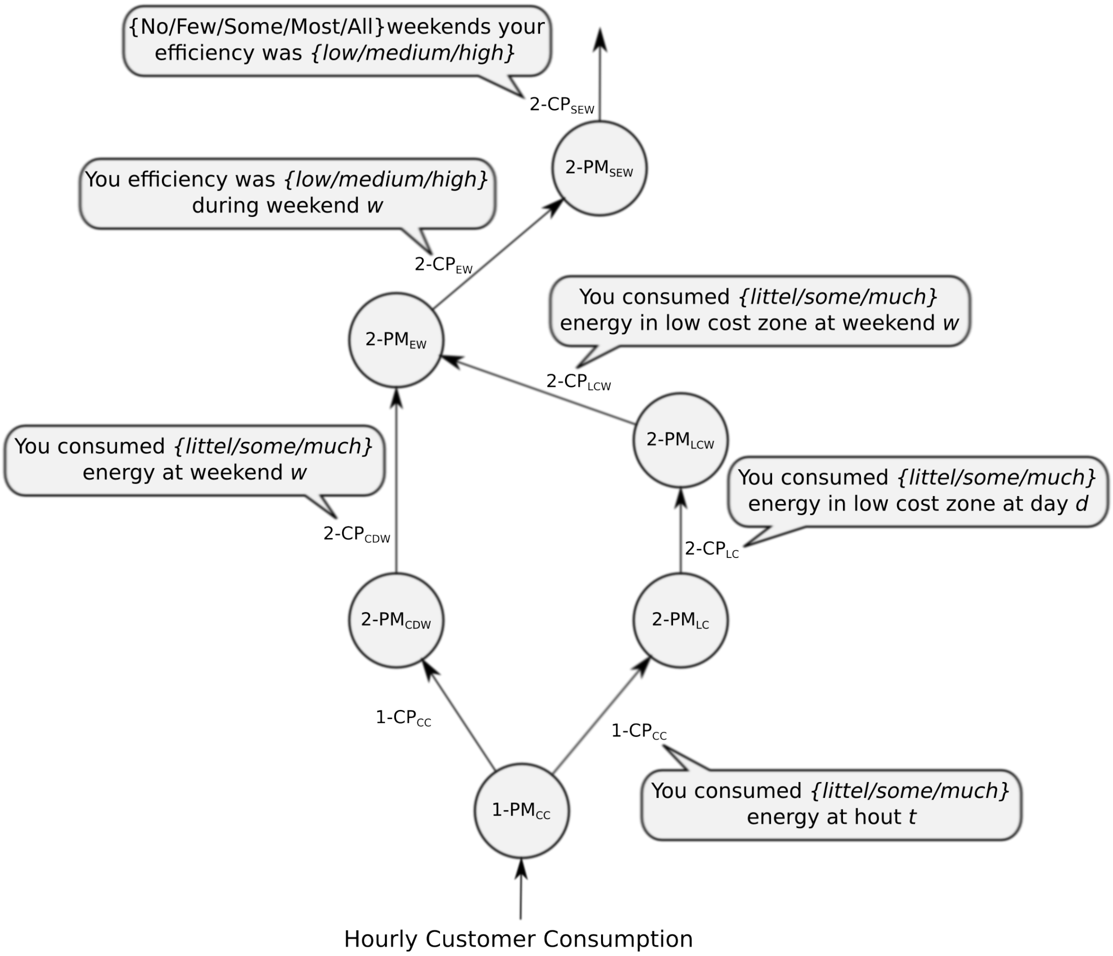


Figure 4.2: Example of the GLMP for the Consumption Efficiency.

Chapter 5

Expressing Emotions

Now that the APA can generate Natural Language Expressions, the ability to express them with emotions will be added. The emotional state is attached with the achievement of the objective of *promote the consumption on low cost zone during the weekend.* The emotional expression will consist of:

- A graphical image according to the current emotional state.
- The emotional tone of the report.
- An advice that depends both on the mood and the level of improvement on the objective.

To represent the emotional state, a simplified model similar to the one used in van der Heide and Triviño (2010a) will be used. The core is a Fuzzy Finite State Machine with five emotional states: Disappointed, Concerned, Neutral, Happy, Excited.

The Emotional component will be included in the CPA7L model being developed in the previous chapters.

5.1 The Physical Level

Until now, the representation of the virtual agent, was a static image shown on figure 3.1, but five graphical representations are needed for its emotional states. Following the same logic than in chapter 3 for creating the graphical representation, in figure 5.1 the new five Emotional States are shown. Notice that the *neutral* emotion have a small smile, to show a positive mood.

5.2 Symbolic Level

Some basic routines are needed to select the appropriate emotional expression. These routines only show the corresponding image, but the selection mechanism is implemented in the upper levels. These levels later, will make use of the functionality provided at this point, to show the correct expression.

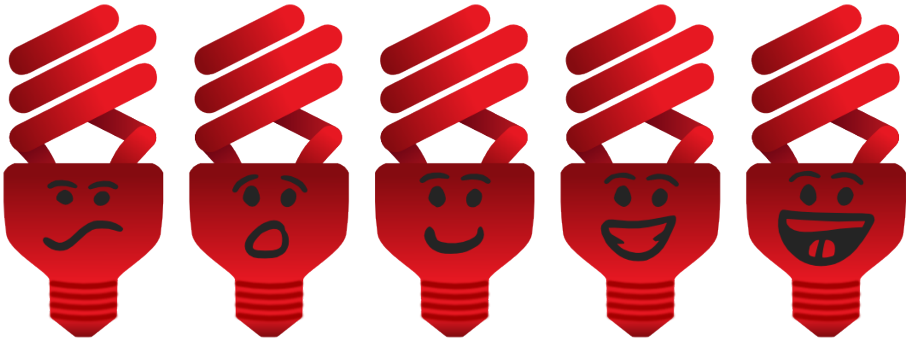


Figure 5.1: Visual representation of the five emotional states of the virtual agent: *Disappointed*, *Concerned*, *Neutral*, *Happy*, *Excited*.

5.3 Reactive and Structural Levels

These levels will remain the same because they already provide all the elements needed to implement the virtual agent.

5.4 Conceptual Level

With the addition of the emotional component, new concepts must be included in the virtual agent. These concepts allow it to simulate the emotional state, and process the data taking into account that state. Also, the conceptual elements of the FFSM will be described in this level and the functions are described in the next level.

Emotional State: Is each one of the states of the FFSM, and represents the mood in which the virtual agent is. The possible emotional states are: *Disappointed, Concerned, Neutral, Happy, Excited.*

Efficiency (Ef_t): Is the average of the consumption efficiency during the month. Is calculated from the average of the $2-CP_{EW}$ by its labels *low/medium/high.*

Improvement (I_t): Is a linguistic variable that represents the level of improvement of the efficiency from the previous month to the current one. Its labels are: *increase/stay/ decrease.*

Input Vector (U_t): Is formed by the efficiency in the current month and in the previous one (both come fuzzified from the GLMP). Has the form: $U_t = \{Ef_t, Ef_{t-1}\}$.

State Vector (S_t): Is a vector that represents the activation degree of being on each state of the FFSM. It represents the current state of the model and can be in various of them at the same time (at some degree).

Output Vector (Y_t): Is a vector that consist of two elements: a) a reference to the visual representation of the virtual agent emotional state; b) the text report that will be expressed.

Initial State (S_0): Is the Emotional State at time 0 and is defined as $S_0 = \{0, 0, 1, 0, 0\}$ which means a neutral mood.

As mentioned earlier, the report template belongs to this level. Now that the emotional component is added, the template is updated. The new version of the template can be seen on figure 5.2. Again, the procedure to use the new template is described on the procedural level.

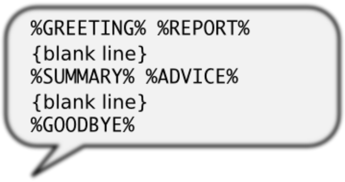


Figure 5.2: Extended Template of the GLMP for generating Natural Language Report with Emotions.

5.5 Procedural Level

Transition Function ($S_{t+1} = f(S_t, U_t)$): Is the function used to calculate the next state. This model of FFSM, does allows to stay in the same state for undefined time. This function produces the degree of validity for the state vector S_{t+1}, combining the previous state and the input vector U_t using a set of if-then rules in the form:

- IF S_t is Concerned AND Ef_t *is low* THEN S_{t+1} is Disappointed.
- IF S_t is Neutral AND Ef_t *is high* THEN S_{t+1} is Happy.
- IF S_t is Happy AND Ef_t *is low* THEN S_{t+1} is Concerned.

$$\vdots$$

- IF S_t is Exited AND Ef_t *is medium* THEN S_{t+1} is Happy.
- IF S_t is Exited AND Ef_t *is high* THEN S_{t+1} is Exited.

Output Function ($Y_t = g(S_t, U_t)$): Is the function used to determine the output vector Y_t. It uses a series of if-them rules to calculate the improvement, combining the previous month efficiency with the current month efficiency. The rules have the form:

- IF Ef_{t-1} is low AND Ef_t is high THEN I_t is Increase.
- IF Ef_{t-1} is medium AND Ef_t is low THEN I_t is Decrease.

$$\vdots$$

- IF Ef_{t-1} is high AND Ef_t is high THEN I_t is Stay.

For the initial time step ($t = 0$), these rules are omitted and I_0 is Stay.

The Report Generation module, is contained in this function to generate the text report as part of the output Y_t. The template for the report generation was modified, and is formed by 5 elements as can be seen on figure 5.2. The `%REPORT%` and `%SUMMARY%` parts of the template, stay the same, and are generated making calls to the existing procedures, and three new sections were added, all of them dependent of the current Emotional State, and the Level of Improvement. In the implementation, there are 3 matrices, each one for store the phrases for each section, having the emotional state and the improvement as the indexes to select the corresponding phrase. It seems like the current efficiency Ef_t should be included in the selection of these phrases, but in the calculus of I_t, it is implied, so for keep simplicity on the matrices it is not included. Additionally to the text, there is the associated image (the visual representation of the mood), that is selected using just the Emotional State.

5.6 Attitudinal Level

The Attitudes, concerning the emotions, are to provide the report and advices about the energy consumption, in a natural way, gaining empathy with the customer and taking into account the objective of increase the consumption efficiency during the weekends.

The virtual agent, not only says advices, it also says congratulation comments if the efficiency improved or encouraging words if the efficiency decreased. It acts like a motivational being.

Chapter 6

A Simple Example of the Autonomous Personal Advisor

To test the model proposed, a GNU R script that implements all the upper levels elements of the CPA7L model was made, and the consumption measures from a customer during four months were processed using this script. The output of the script, is the linguistic report and the current mood of the APA, as R is not intended to manage graphics, for this prototypical example, the visual representation was assembled manually on a graphical editor, using the mood for selecting the corresponding image, and the text as is generated by the script. On figure 6.5, the graphs of each weekend in each month can be seen. The results are described in the next sections.

6.1 Month *1*

The first month, shown on figure 6.5(a), corresponds to a careless use of energy, using many electrical appliances outside the low cost zone. The initial mood is *Neutral* and after processing this month, his mood is *Concerned* and the improvement is *Stay* (since it is the first month processed). Figure 6.1 shows the generated report.

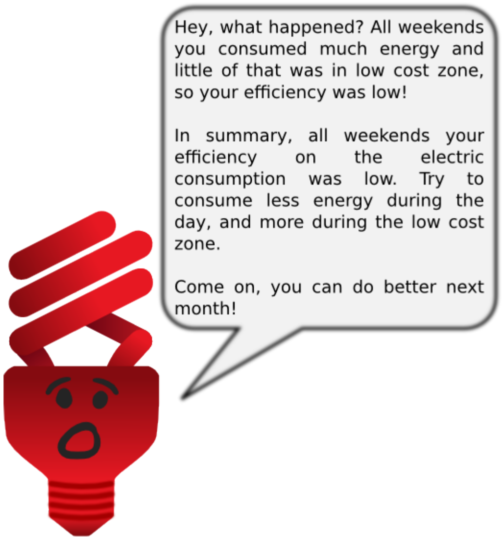


Figure 6.1: Example of the Automated Personal Advisor report for the month 1, having a Concerned Expression and giving advices on how to improve efficiency.

6.2 Month *2*

The second month, shown on figure 6.5(b), is a bit more efficient, because there are a little bit more consumptions in the low cost zone, and less overall consumptions during the weekend. The initial mood is *Concerned* (coming from month 1) and after processing this month, the mood is *Neutral* and the improvement is *Improved*, because the efficiency level increases compared to the previous month. Figure 6.2 shows the generated report.

Figure 6.2: Example of the Automated Personal Advisor report for the month 2, having a Neutral Expression and giving advices on how to improve efficiency.

Note that in this report for weekends 1, 3 and 4, the antecedents are *little* and *little*, and the consequent is *medium*; and for weekend 2 the antecedents are also *little* and *little*, but the consequent is *low*. This is because of the level of granularity chosen for the linguistic variables. This level *low/medium/high* is not enough to differentiate the subtle differences in the variable, so a higher level of granularity should be used.

6.3 Month *3*

The third month, shown on figure 6.5(c), is much more efficient, despite the fact that there is more energy consumption, but most of these are in the low cost zone (maybe programming the washing machine in that hours or programming an electrical oven to cook the lunch). The initial mood is *Neutral* (coming from month 2) and after processing this month, the mood is *Happy* and the improvement is *Improved*, because the efficiency level increases compared to the previous month. Figure 6.3 shows the generated report.

Note that, there is one more level of happiness in the possible emotional states (*Excited*), and that level is reached if the previous mood is *Happy* and the efficiency is *high*.

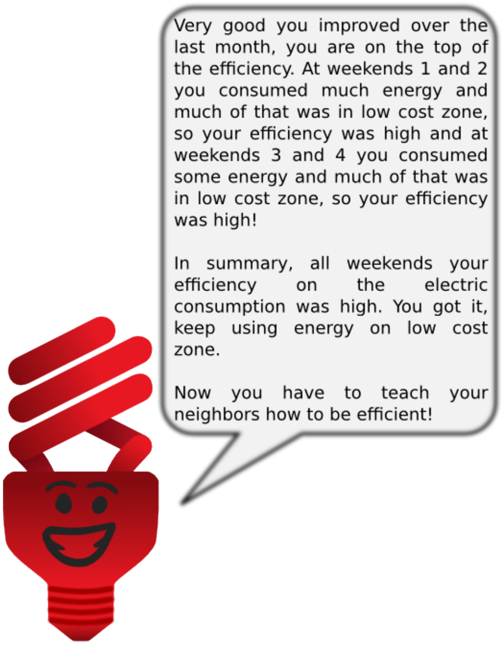


Figure 6.3: Example of the Automated Personal Advisor report for the month 3, having a Happy Expression and making jokes about the consumption efficiency.

6.4 Month *4*

The fourth month, shown on figure 6.5(d), is not efficient at all, because there is much energy consumption during the weekend, but little was in the low cost zone. The initial mood is *Happy* (coming from month 3) and after processing this month, the mood is *Concerned* and the improvement is *Decrease*, because the fall from being highly efficient to be much less efficient. Figure 6.4 shows the generated report.

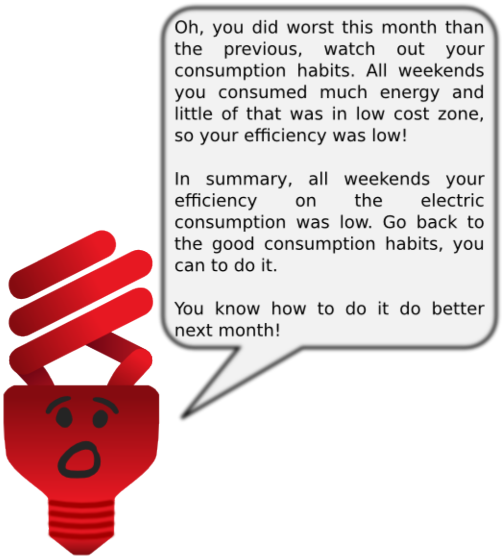
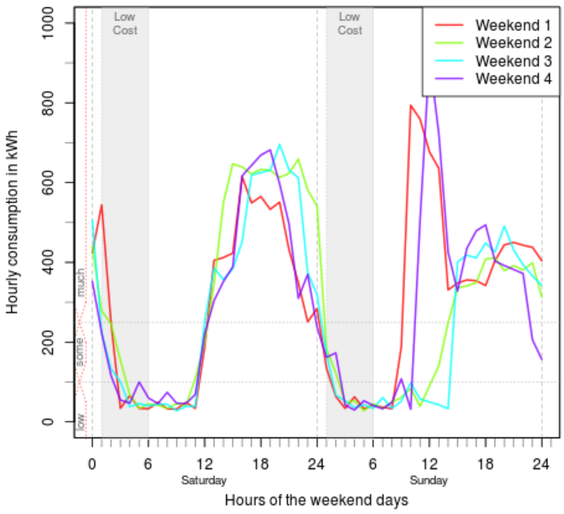
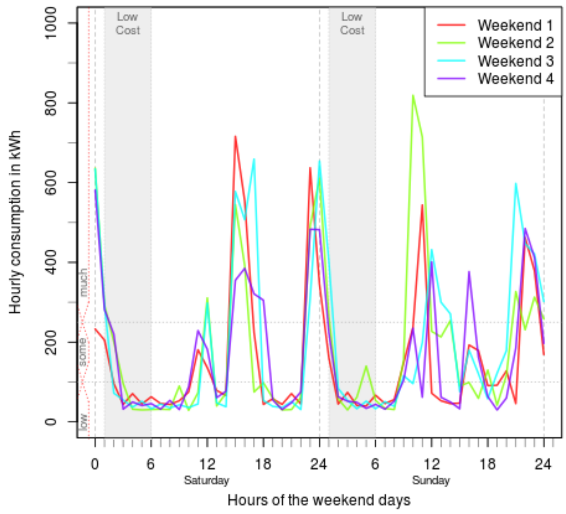


Figure 6.4: Example of the Automated Personal Advisor report for the month 4, having a Concerned Expression and giving advices on how to improve efficiency again.

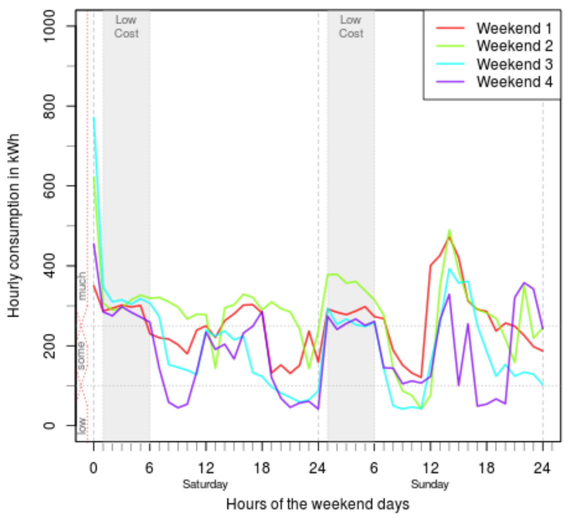
Note that, even when the emotional state is the same than on the month 1, the generated report is not equally because the *decreasing* improvement of this month.



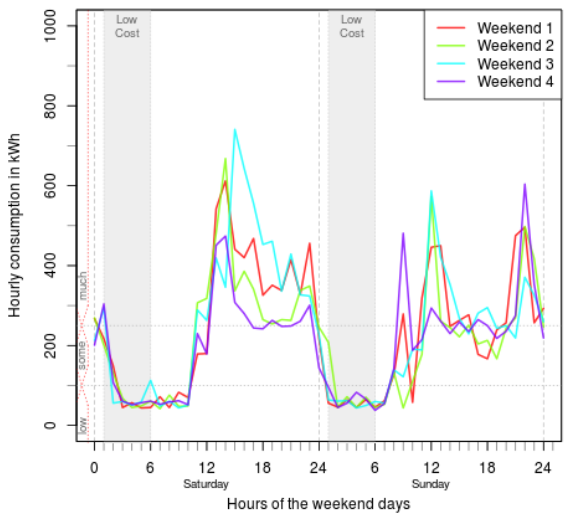
(a) Energy Consumption on the Month 1



(b) Energy Consumption on the Month 2



(c) Energy Consumption on the Month 3



(d) Energy Consumption on the Month 4

Figure 6.5: Energy Consumption during weekends on four months.

Chapter 7

Concluding Remarks

7.1 Conclusions

The work presented in this document is a merge of previous works of the Unit of Computing with Perceptions of the European Centre for Soft Computing, putting together various concepts and methodologies developed in the area.

First, the introduction of the CPA7L model, which allows a complete and exhaustive description of all the elements that form part of a complex system and allows to group and handle related elements in a modular way, which helps a lot in the maintainability and scalability, and provides a clear way to add more functionality with the less impact on the existing development.

Then, there is the computational theory of perceptions and the granular linguistic model of phenomena, which provides a extremely powerful tool both for process, analyze and model imprecise and large amounts of data using the natural language in the same way that humans are used to treat such information; and to produce elaborated reports that are much easier to understand and provide useful and precise information.

And finally, the simulation and model of emotions, that enables a more direct channel of communication with the person that is reading the reports or interacting with the machines, gaining empathy with it and a more comfortable experience and better use of the information provided.

The main contribution of this work is to bring together all these strategies in a single functional model, describing each element of it in a progressive way, introducing step by step each of them. This work also present a fully working prototype of the APA that provide reports and advices on natural language, analyzing real consumption data from a customer and expressing them with emotions; this prototype shows how to use these techniques to solve a specific problem of a real company and is the basis for the development of a robust system in order to solve that problem.

7.2 Further Work

This document should be updated and extended as the experience grows. Some examples of this future work are listed as follows:

- Add more granularity to the linguistic variables involved in the GLMP. In particular those related with the amount of energy consumed in a particular time step, because using only 3 linguistic labels, there is too much grouping of data that should be in separate labels. Of course, adding more granularity makes the generation of the rules a more challenging task, because new scenarios are opened.

- Add more Emotional Expressions. The model proposed in this work is extremely simple, because it was a proof of concept to show the potentiality of it. But there are many other situations that lead to other emotional states. Again, adding more Emotional Expressions, was the associated cost of the complexity of the expression generator, because more expressions means more templates in the report generation module, so it can be more hard to complete.

- Include the Improvement level in the function $f()$ of the FFSM that model the emotional states. The mood not only depends on the current emotional state and how well is the efficiency on the current month, it also depends on the result of the previous month, which is summarized in the Improvement level.

- Have more customer consumption data to fine tune the partitions that defines the fuzzy sets of variables and to test the functionality of the model and the validity of the generated reports and emotional state.

- Include Temporal Restrictions in the FFSM. Like the variables *TimeToStay* and *TimeToChange* used in previous works, to prevent to get in one emotional state for too long. Especially for cases where the consumption efficiency can be improved, rather than the cases where consumption is already efficient.

- Model another objectives, not only the efficiency on the energy consumption for the weekends. For example the efficiency during the working days of the week, or specific objectives of reduce the levels of energy consumed at certain hours on certain days. This is a work that has to be done together with the experts of HC Energía, to incorporate all its knowledge.

This is a relatively new field of investigation, and with more research will be growing and consolidating concepts, so there is much space for improvement and expansion of the techniques used in this work.

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