

# How to Improve the Accessibility and Reduce the Total Cost of Ownership with ECOLIG Protocol and Android in Mobile Learning

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**Abstract**—A new electronic learning device generation can be created from a new paradigm in human sense and efferent resources. The brain computer interfaces (BCI) with ECOLIG protocol can be used to get the advantages from “Near To Eye” and “Augmented Reality” technologies. In this way, this paper describes the results from an experiment using a mobile phone emulator system, a BCI and ECOLIG protocol to demonstrate the benefits in eliminating the use of touch screen and keyboards features. Finally, it concludes that ECOLIG can be a long life time communication technology between Human and Machines especially in a Singularity world.

**Index Terms**—Brain Computer Interface; Singularity; Near to Eye; Augmented Reality

## I. INTRODUCTION

A good learning system should promote mobility, flexibility, scalability, a friendly user interface and preferably a low total cost of ownership. In addition, an important requirement is the accessibility, maybe one of the most important requirements, since the technology changes so fast that administrators, teachers and students are constantly away of the matter. A big challenge is to keep all persons updated about the current technical solution. It usually changes the focus from learn the content to learn how to use the current or the next learning tool.

Of course, it can be worse if the persons already have some kind of disability. What kind of technology could include those persons? What kind of technology could transfer the most of adaptive tasks to systems and not to users? What kind of technology could preserve the human interfaces in order to reduce investments with training and reduce the raw material consumption as well as the garbage when replaced?

A learning system can be improved when it promotes the interaction and communication between its agents, resources and with the environment as well. The basic concepts are the data acquisition systems (afferent) and actuators systems (efferent) in charge to capture information and eventually to make changes respectively in a learning process [9].

A long time ago, when the human being created the first tool to work, for self-defense or even to improve the interaction with the environment, the electric principles and concepts were not available, at least, not to be used as nowadays. Therefore, the intuitive mechanical stuff and actions had made the difference and brought the necessary

advantage to survive in a competitive world [18]. Nevertheless, those artifacts became sophisticated and were adapted to different uses and situations.

In spite of the improvement with research in several areas of science, most of human actions over the environment keep using mechanical tools, including the electric ones [22]. From a tree branch, when used as a tool, to a television remote control, interfaces depend on human arms, hands, bones and muscles to execute some action. Indeed, even to transfer an information through a letter, a sound wave, a keyboard or mouse, some kind of mechanical transduction is necessary.

Curiously, the eyes were already supposed to be a very fast afferent interface, where the information is well converted from multi frequencies light wave, if available, and received through the optical nerve, after reflections on the environment, and so be detected by the eyes. In a short term, this afferent channel brings and processes as much information as necessary to determine whether any action should be executed on the environment.

Since the interactions are needed to promote a learning process, the efficiency of afferent and efferent interfaces will contribute to do it in an easy or hard way. It is known that intelligence is even more complex, and depends on many agents, objects, scenarios and maturity level of the knowledge, usually gained in the life-story, therefore, a factor dependent on time. But the interfaces will contribute significantly to promote a fast or slow interaction, with direct impact in learning time and efficiency of communication with other local or remote agents.

When Uexkull described his theory about Umwelt [15], he brought up more than a systematic way to observe a phenomenon in the animal world [18]. He directed his attention to the importance of the senses in a learning process as well. Those senses are gates to the semiotic signs. Therefore, the idea is to use them to propose a universal language. However, the main issue comes from the differences between semiotic signs that are generated in each mind [1,2]. These signs are dependent on previous experiences and are the product of a cyclical process that looks for a definitive interpretation. This is a problem not so easy to solve.

Looking for an answer, it is possible to work on some specific situations. There is a chance to simplify this approach and get some advantages avoiding intermediary tools in the path to build a semiotic sign. Reducing the number of layers of transducers is expected to reduce noise, misunderstanding and timeframe to acquire reliable information and a correct interpretation of a situation.

Therefore, the proposal is to drive an information from the brain to the electronic world, faster than usual, avoiding some or every mechanical transductions [22].

Someone might consider this as a reductionist way to see the arms, legs and hands, since it seems to be a set of interconnected transducers to promote any interaction between the brain and the environment. Indeed, the idea of using the brain commands to members of the body as part of an electric protocol is even better than using arms and fingers to type some key and send some information to an electronic device. In addition, the possibility to connect thinking to the electronic world can offer a better tool to handle semiotic signs [3].

The proposal is to create an alternative way to send information directly from the mind to the electronic world, keeping as reference the human sensorial system of information associated with the human body.

Therefore, if the senses and actions are essential for any learning system, it would be better to move the interaction to an electric mode, especially considering that human life has been inserted in an electronic world. Once human neural communication uses ionic signals, it is possible to connect it with the electronic world. Moreover, it should be easier to communicate through electric interfaces than mechanisms that need movement, biological or artificial ones, as hands or car wheels steering, for example. The main benefit comes from ubiquity, the capacity to be everywhere at the same time, since the senses and actions can be anywhere through electronic systems.

A good point to capture a semiotic sign is in the brain. In that region it is possible to associate some electric activity to some signification in a specific maturity level. From the brain, one can obtain feedback and so associate brain activities [14] to primitives of a protocol, in order to construct a universal language. In that part of human body is possible to identify similar cognitive information between individuals of the same species. Moreover, the interpretation is a product of mind, so the brain can be a key place to associate electric signals to codes in a semiotic protocol that can be used to communicate with electronic world [22].

## II. A SEMIOTIC PROTOCOL

A knowledge level can be seen as a state of a process in an intelligent system, a level of understanding, interpretation and assimilation. The semiotic theory proposes that knowledge evolves in cycles [4]. Indeed, this evolution seems to be a spiral where each ring is closed with a semiotic sign and a new ring starts looking for a new sign which could better define the previous state [22].

When one tries to transmit knowledge to another person or to the electronic world, it is likely that the first one will drive the other through the same spiral, like a journey, Fig. 1. But if the trajectory, the velocity and other conditions are affected by several factors as expertise, previous experiences and base of knowledge, for example, how can someone drive another to walk through the same spiral, or at least stop by at the same check points, the semiotic signs?

It seems even more difficult to answer this question, because this journey takes place in an abstract region, the mind of every person, and both are supposedly unable to be connected directly, so far.

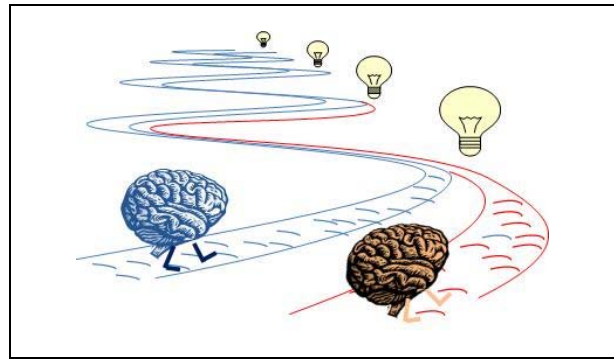


Figure 1. The convergency of two semiotic spirals

TABLE I. PRIMITIVES OF ECOLIG PROTOCOL

Categories		
<i>Humanist</i>	<i>Trans humanist</i>	<i>Cognitive</i>
Vision; Hearing; Smell; Tact; Taste; Movement or Proprioception; Balance.	Magnetism; Radiation; Presence; Augmented-Vision	<i>Private codes defined by each person.</i>

From ECOLIG specifications (UNICAMP)

ECOLIG is denominated a semiotic protocol due the possibility to redefine its primitives according to a cognitive process [20, 23]. That protocol was developed by scientists from UNICAMP (State University of Campinas, Brazil) and it is composed of Humanist and Trans-humanist categories of codes. This protocol allows expanding the range of human perception and action. There are primitives to allow a complete remote interaction, Table I.

The ECOLIG protocol is defined for communication between two or more Sensorial Intelligent Systems (SIS) and/or Sensorial Operators (SO) [21]. The "SO" and "SIS" are defined as electronic, organic or mixed devices, capable of capturing, measure, interpret and transmit sensorial signals. The SO, however, only act after receiving commands from any SIS. So the ability to make decisions based on these sensory inputs is what differentiates a SIS from SO. These sensorial devices, electronics, organic or mixed, are able to identify, classify and measure all or some of the feelings then known.

When used with BCI (Brain Computer Interfaces) [17] and "Near to Eye" accessories, this protocol can transmit commands to remote devices and receive sensorial signals as well. Using semiotic concepts, it is a sign oriented protocol. In this way, it can improve the relationship with the environment and other intelligent systems [10]. Capturing the aim of human thinking, ECOLIG is not mechanical actuators dependent and offers the possibility to learn with interactions in a semiotic spiral process [23]. The structure of ECOLIG protocol can be seen on the diagram shown in Fig. 2.

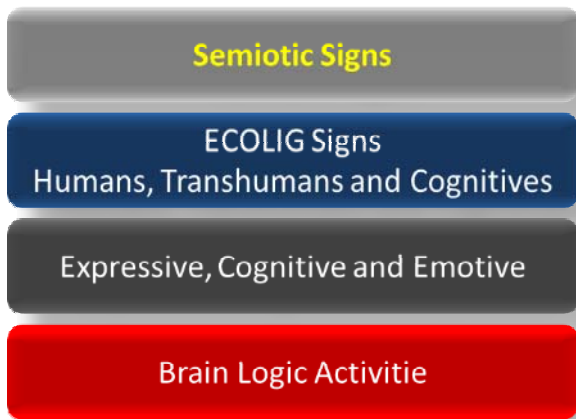


Figure 2. Layers of signals using ECOLIG protocol

In order to use the concepts associated with semiotics, is very important to establish a relationship between changes, causes and effects, in the external space with signals perceived in the inner space [13]. This direct and controlled relationship can be the necessary link so you can encode cognitive processes and semiotic development [5]. Therefore, the primitives of ECOLIG protocol will be related to certain brain activities [14] through signals received, filtered and ranked by the BCI [17]. About the used BCI, these logic signals received are classified as Expressive, Cognitive and Emotive.

The Expressive signs refer to common human actions as eye blinking and others. The Cognitive are configurable and generated from samples of signs that can be stored in the interface based on associations with thought, imagination or other brain activity in a preliminary stage of training. The Emotive signs are related to emotional feeling states of human being, as excitement or depression, for example.

Signs of ECOLIG protocol will be identified and transformed into semiotic signs as the wished action to be promoted in the outer space [21]. The concept of a protocol is usually associated with patterns that are used in processes of communication but, in this case, this concept goes beyond communication. This semiotic protocol is also associated with a set of symbols that are interpreted as semiotic signs by intelligent systems, which may be more complex commands or even meta-interpretations that may further evolve when processed by other intelligent systems [10, 11]. These meta-evolving interpretations can be considered learning processes that occur in artificial or biological neural networks.

Those new technologies can improve usability and accessibility, giving alternatives to explore remote regions with security and lower cost projects than with usual programs. The use of those new technologies with "Augmented Reality" solutions will open new possibilities for mobile applications and information technology systems.

If humans can use ECOLIG and BCI to interact with electronic solutions, instead of keyboard and mouse e.g., it is supposed to be easier to move the electronic devices to Nano metric scale, i.e., with lower power consumption and better efficiency, at least [23].

In order to verify the applicability of these new paradigms, an implementation was made using ECOLIG, An-

droid and a BCI. In this case, ECOLIG was used to communicate and interact with some mobile features. Android is an operational system from OHA (Open Handset Alliance), in this case, used to control a simulated mobile device [6, 20]. The Brain-Computer Interface was used to capture electric signals from brain activities.

The implementation was made using Eclipse, a multi-language development tool with an IDE (Integrated Development Environment) that uses a STP (Service Oriented Architecture Tool Platform).

The results were collected from two cases over a mobile emulated environment. The first case was a navigation test over "Google Maps" using a pointer and a virtual keyboard, both accessed by mind control. The second case did not use the pointer and virtual keyboard but semiotic signs interpreted from the ECOLIG protocol [21]. In the last case, the usability and accessibility could be explored to test the new paradigm of interaction with other intelligent systems through electronic world using brain signals and a semiotic protocol.

The graphics and reports can demonstrate the new possibilities using these technologies with "Near to Eye" devices to reduce cost, size and wasted material with wearable solutions applied to learning systems.

### III. TRAINING SECTION

Using the development environment and the conceptual structure a training procedure was created to familiarize some persons with the protocol, hardware interfaces and the training software that were used in cases to be studied. At this stage the individuals submitted to sessions of preparation and adaptation should be able to properly utilize the BCI (Brain-Computer Interface) and repeat commands that are sent to the computer via a wireless communication interface using ECOLIG protocol [8, 22]. Finally, it was verified the effectiveness of the training procedure and the goals of usability with that emulated mobile device using the ECOLIG protocol. The procedure sought to ensure the physical and psychological safety of the people involved. Simultaneously, it tried to ensure minimum attention needed to obtain results that can be measure, structured and could be reproduced accurately over known and controlled conditions. The choice and preparation of people, training and test environment as well as the correct installation and attachment of equipment were also important.

The persons were submitted to training sessions during 10 consecutive days, two sessions per day. The first daily session took 30 minutes in the morning and the second one took the same time frame in the afternoon, for each person. There was at least 6 hours of interval during each session used to recharge batteries of BCI as well. The procedure to associate an electric signal, acquired from brain activity, with a code of ECOLIG protocol was repeated 30 times in 15 minutes. Each person tried to command an order during 15 seconds and then rested for 15 seconds before starting over again [21]. The number of positive answers was registered and plotted in a chart, Fig. 3 and 4.

In order to analyze the behavior and the conformity with ECOLIG protocol, four types of Cognitive and Expressive signals were tested with a respective code of ECOLIG protocol each one.



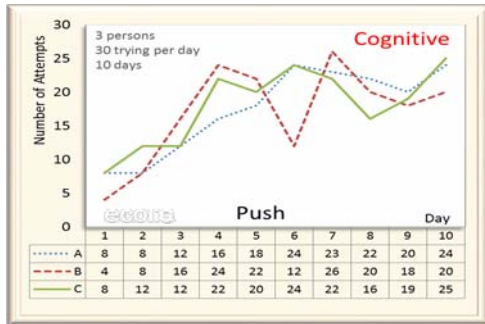


Figure 3. Cognitive learning curve

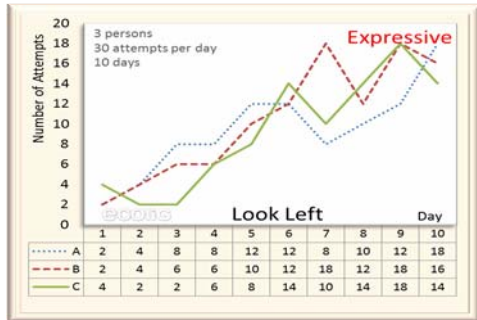


Figure 4. Expressive learning curve

#### IV. NAVIGATION CASE

The proposal in this case was to verify if some previously trained persons could navigate through Google Maps using ECOLIG and BCI. They sent commands to an emulated mobile device using only electric signals from the brain. Those persons could control a pointer in a standard user interface using primitives of ECOLIG protocol that were associated to brain activities.

Android was a good option since it is an open platform used with mobile devices. When using Android, some procedures could be easily implemented to improve the control with some primitives of ECOLIG protocol. In order to offer a flexible development environment, Eclipse was the IDE (Integrated Development Environment) used to configure all tools used with those tests. One more reason to use a STP (Service Oriented Architecture Tools Platform) was to be able to program using several languages and using some already available library of tools. Therefore, the necessary environment was ready for the proposed test of navigation using ECOLIG-BCI [21].

Indeed, there were more in those tests using the proposed solution, e.g., which level of control a person could achieve over a usual device? How accurate could be the interaction between human and electronic systems using that kind of non-invasive BCI? Could a human being learn and use a new code to communicate with electronic world without a mechanic tool? Can a person keep enough attention and share it with important actions simultaneously? The results were very positive and pointed to the benefits to invest even more in the ECOLIG with wireless non-invasive BCI interfaces [7].

The first positive answer came from the chosen technology. With a sensorial protocol and a lightweight wireless device, someone can feel free to express movements and emotions. After the training section described earlier, the persons could demonstrate some intimacy and good



Figure 5. Two dimensional GUI (Graphical User Interface)

control over the mobile device. It could be seen with a high level of assertive answers, as well as demonstration of a good expertise to install and use the solution ECOLIG-BCI. The average time to action and reaction, within 3 seconds, was good for this kind of application.

When using a pointer and a two dimensional GUI (Graphic User Interface) [16], the solution was used with excellent accuracy and simplicity, Fig. 5. But, since the protocol has powerful primitives, a new kind of GUI could offer better commands. An association of a coordinate with some specific symbol could be interpreted as a command to move the scenario to a specific geographic positioning, for instance. That symbol can be interpreted as a sign in a semiotic process that can be driven by a more powerful and fast mind control, since it does not have to move pointers and adjust maps with the hands.

Despite of the benefits, a critical detail to answer those mentioned, and some other, questions is the resolution that is dependent on the frequency of signal and the sampling rate. In low frequency signals, during the EEG (Electroencephalogram) signal acquisition, a usual Time for Information Acquisition (TIA) is around 10ms. With this number is possible to suggest the applicability and some restrictions to use the ECOLIG-BCI technology. In spite of this time of acquisition, there are two others so important as well: The Time for Command (TFC) and Time for Interpretation (TFI). The total number of TIA cycles required to define a TFC is each person ability dependent and how well adapted to ECOLIG-BCI he or she is. Therefore, the total time to act is a result of TFC plus TFI since each command can be interpreted in a semiotic process to execute a high level instruction.

To operate a standard GUI of a mobile device, several TIA cycles can be necessary to define each TFC. In this Navigation Case, where the commands act over a regular pointer in usual GUI, several commands will take place in order to execute a function. Indeed, several commands will move the pointer and select the function and a new sequence of commands will be necessary to coordinate the task in that selected function. Even in this situation the use of ECOLIG-BCI brought a great contribution since it eliminated the time and energy to move arms and hands in order to control the pointer and execute the same action, Fig. 6.

But, what new contributions can be done with a new protocol that does not need to use pointers and some others graphical artifacts? Indeed, a great investment is a new interface that should use a new n-dimensional package of symbols which will be interpreted as semiotic signs. In fact, a new language can be created to communicate, using a customizable sequence of codes that can be associated to high level instructions, a semiotic protocol.



Figure 6. Access through mind controlling a pointer

## V. THE CASE OF SEMIOTIC SIGNS

The concepts of semiotics and intelligent systems are at least controversial [12]. One problem is how one can represent a dynamic process of learning? Several models have been trying to explain those theories that, necessarily, have to use an idea of interaction to demonstrate a cognitive sequence. To make matters worse, the protocols used to support the interactions introduce some intermediate steps that make it harder to understand. For example, to teach someone how to type a word on a keyboard is easier than to teach the same person how to handwrite the same word with a pen. In the manual process, the tool and the interface will introduce many more steps and situations. In addition, it will require much more skill and training.

A semiotic protocol can encapsulate some sequences of actions and so minimize the TFI (Time for Interpretation) since it will reduce the number of actions. This can be done using an appropriate language based on ECOLIG.

The ECOLIG protocol is divided in three categories of code, as described earlier in this paper [21,23]. When using the cognitive class, it is possible to associate some codes of protocol to some definitions in order to execute some complex commands, in a shorter time frame. In addition to regular codes, in this case, some geographic coordinates and actions were dynamically associated to some cognitive codes of ECOLIG protocol. Therefore, the selections, movements and sequences of actions were executed just thinking in some previously defined images. Each brain activities, associated to each respective image, were identified by BCI and translated using ECOLIG to navigate with Google Maps over Android in an emulated mobile device, much faster than in the first case, Fig. 7.

Figure 7.

ECOLIG protocol is essential in this semiotic process by allowing the meanings to be redefined in a meta-interpretation. By observing a painting, for example, this process occurs in cycles of observation and redefinition until a satisfactory level of maturity is reached in the interpreter mind [23].

When using ECOLIG protocol to codify, it can be done redefining the meaning through a meta-language. Indeed, it is like selecting the same word in a "HTML" text, but that now leads the browser to another Internet page address, because its link has been modified. Although similar to a meta-language, the power to trigger the new procedures, routines and even other systems gives the solution ECOLIG-ICC an even greater power.

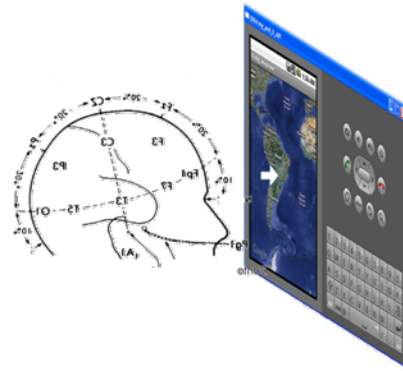


Figure 8. Direct access through mind control

It is not coincidence that this procedure has resemblance to the method proposed by Walter Andrew Shewart in the 30's, the PDCA (Plan, Do, Check, Act), and subsequently developed by William Edwards Deming with much success, PDSA (Plan, Do, Study, Act) [19]. In summary, these procedures seek to respond, in a structured way, to three fundamental questions for improvement of a process: What we intend to accomplish? How it is possible to know if that change is an improvement? What changes can be made that result in an improvement?

## VI. CONCLUSIONS

The proposed design for the work achieved the goals originally stipulated allowing persons to control mobile devices using only brain activities and ECOLIG-BCI. The protocol was validated and applied to a simulation encoded on a mobile platform into a development environment (IDE) that uses service oriented architecture. The time frame associated to each step, since installation, configuration, setup and training were considered acceptable under the proposed application. Moreover, the adoption of an interface such as non-invasive BCI was a good alternative since the aesthetics, autonomy, security, usability and reliability of information were critical to extending the application of these interfaces and ECOLIG protocol. Despite of the good results, the tests should be exposed to adverse environment related to everyday urban life, where they can use a new profile and consequently a new learning curve.

The use of cognitive signals showed a greater precision to the identification of ECOLIG protocol, although they have to be customized to each user. Nevertheless, the brain signals of "Expression" were more standardized and their use for association with ECOLIG protocol, may acquire more precision with the use and the consequent improvement of the selective capacity of users. The low selectivity of the signals can also be attributed to missing concentration on human activities, but is due mainly to the lack of common usage of these signs as a way of interaction.

The use of ECOLIG, a semiotic protocol, with BCI will be a new paradigm in human-machine interaction. Since it makes possible to capture a semiotic sign directly from a brain activity, the access to high level instructions through electronic world will offer a possibility to improve the communication and to execute powered commands just thinking. Moreover, new GUI can be developed not limited to bi-dimensional structure [16], but with a n-dimensional structure using hyperspace as a concept for a

new paradigm. In addition, the possibility to associate semiotic signs to feelings and senses will give to human beings the power of ubiquity, since they can send or receive signals of senses from anywhere through electro-electronic world [21].

The ECOLIG-BCI solution means a new opportunity for M-Learning technology which can be integrated to NTE (Near to Eye) and Augmented Reality and offer new horizons to applications over a semiotic architecture. Since the electric devices and networks will interact with humans using a human protocol, it is possible to preserve the human learning and transfer to the electronic world the adaptive task when the technology changes. Especially when used in some conceptions of Singularity or nanosystems, where the human and machines will be one part of the other and the communication in between cannot consider a keyboard, a mouse or even a regular screen.

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