# ARTIFICIAL HYBRIDIZATION OF DNA STRANDS AND EMBEDDED SYSTEMS

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## ABSTRACT

This paper introduces artificial hybridization of DNA strands as a bio-inspired alternative for the evaluation of inference rules in a conventional expert system. Biological hybridization process is a binding event between two complementary DNA single strands that leads to the formation of a double-stranded helix. The proposed technique to detect the hybridization is based on direct comparison of data allowing a high degree of parallelism. It makes an approach to its implementation on a restricted and low-cost architecture like a commercial microcontroller instances.

**Keywords:** *-Bio-inspired System, Artificial Hybridization of DNA Strands, Expert System, Embedded system, Microcontroller*

## 1. INTRODUCTION

The artificial DNA hybridization suggests a simple mechanical that compare parallel binary strands stored in data registers looking for evidence that they are complementary to each other, to validate a subsequent action. This criterion is very similar to the evaluation of inference rules in a conventional expert system [1]. Although the majority of contemporary microcontrollers present Harvard type architecture (separate data and instructions) and pipeline technology to segment the execution and data flow, these devices have restricted architecture due to the procedural instruction execution, low memory capacity and limited number of I/O ports.

The above paragraph is very important and directly affects the viability of the embedded implementation of bio-inspired architecture with microcontrollers, as it is imminently parallel nature, so that implementation on a reconfigurable architecture device (an FPGA, for example) would make more sense [2], however, the actuators in embedded control systems that are used at manufacturing as well as interfaces for home automation applications, these are equipped with microcontrollers, so we should not reject its usability and continuity [3]. In this work we make an approximation of hardware implementation in artificial hybridization of DNA strands using a microcontroller, although this type of dispositive has no advantage in parallel comparison of data registers, it shows certain good points such as the number of models and resources of immediate use to work in autonomous form, as well as a good performance at low cost.

## 2. BIOLOGICAL PRINCIPLES

DNA (Deoxyribonucleic Acid) is a chemical substance that is found in the nucleus of cells, which stores the basic code of all life translated as biological instructions. The structure of the double helix of DNA was proposed and described by J. Watson and F. Cook in 1953. Nowadays this model is still fundamental in biological analysis indicating that a molecule of DNA is constituted by two large strands of nucleotides with opposite poles (complementing each other) entwined forming a double helix shape very similar to a twisting stairway [4]. Each nucleotide consists of a sugar (deoxyribose), a phosphate group (phosphoric acid) and a nitrogenous base that can be four different types: adenine (A), guanine (G), cytosine (C) and thymine (T). The adenine and guanine both are purine bases, with a double ring structure, while the cytosine and thymine both are pyrimidine bases, with a simple ring structure, as evidenced in Figure1.

In the molecular genetics theory about DNA hybridization, single strands of DNA from two different species are allowed to join together to form hybrid double helices. These hybrid segments of DNA are used to determine the evolutionary relatedness of organisms by examining how similar (or dissimilar) the DNA base pair sequences are; in other words, the degree of hybridization is proportional to the degree of similarity between the molecules of DNA from the two species.

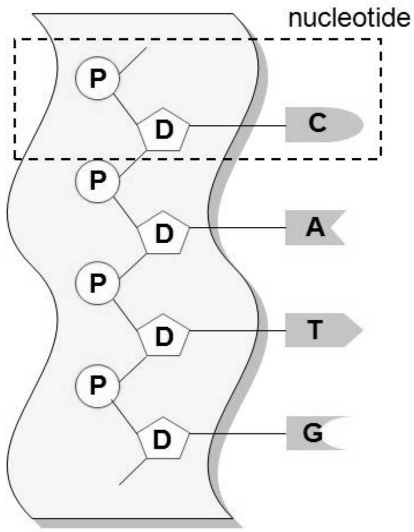


Figure1. Nucleotides strand

## 3. EXTRAPOLATION

Also known as DNA chip (or DNA microarray) it is a matrix structure where single strands of DNA are distributed similarly with the biological beginning as previously stated, which have been implanted in a silicon, glass or plastic base [6][7][8]. These simple strands have a known fixed value that incubated (compare through some artificial or biological method) with complimentary strands introduced to the chip, forming DNA helix shape that can be detected through optical or electrical methods. The formation of DNA helix shapes from the two single strands is known as hybridization and the order of the bases of a simple strand is denominated a sequence. Engineering has demonstrated that the DNA chips can be used to store and evaluate bases of Boolean or fuzzy rules in a parallel form [9]. In electronic design, hybridization can be implemented using a reference register that will be compared in parallel with others test registers, looking for evidence that they are complementary. In figure 2 this concept is shown.

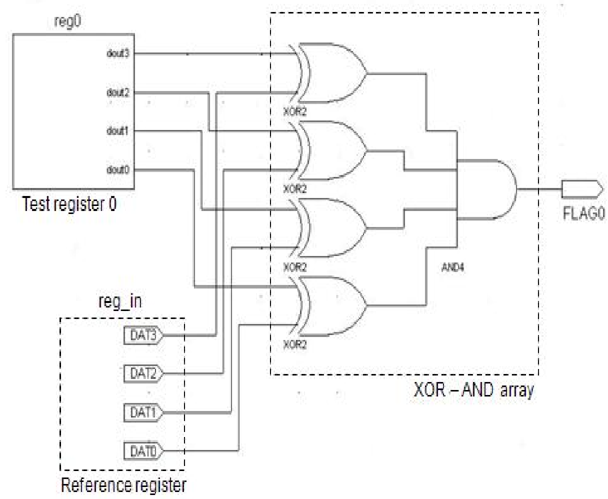


Figure 2. Model with 4 –bits data registers that represent hybridization with digital electronic elements

In this scheme the test data register represents the simple DNA strand with a fixed known value and the base data register is the DNA strand that is injected (or is introduced to seek hybridization). The base register should be unique in the architecture and it can be compared in parallel with *"n"* test registers. Note that to realize the comparison both registers should have the same size and only when they are complementary the only one output flag will provide a high logical value. The bit to bit comparison between the register will be achieved through a XOR gate and the output flag to use a AND gate with the number of entries equal to the number of XOR gates of the model.

## 4. EXPERT SYSTEM AND PROTOTYPE

For this particular proposal, we designed a prototype home automation with a microcontroller that reads the value resistive (translated as an amount of light) of a LDR sensor (photo resist), and based on this value is assigned the length of a pulse width at the device output and serves to position an actuator that opens or partially closes a window blind. The design acts as an intelligent system to regulate the automatic opening of the window blind in correspondence to the natural or artificial light intensity. In figure 3 the proposed model is shown.

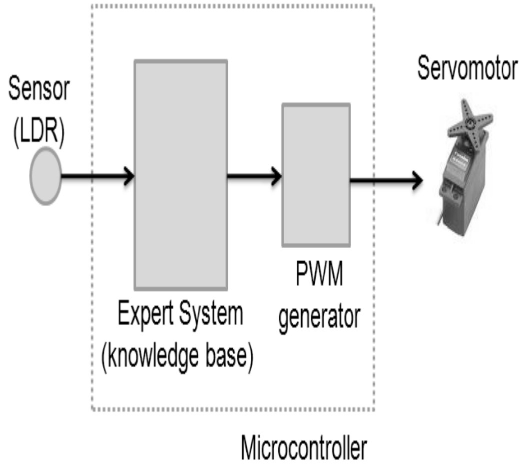


Figure 3. Proposed system

The expert system consists of a base of inference rules that will read the resistive value; it will adjust the position of the servomotor in a range between -90° and +90° (or from 0° to 180°). A servomotor is characterized by its capacity to position itself in an immediate and exact form within its movement interval when operational. For this the motor awaits a train of pulses; each pulse has a specific duration to move servomotor axis to a determined angular position. The servomotor used in this work is a Futaba model s3003 [10], with a movement range of from 0° to 180°. With 0.30ms the servomotor will be placed at the extreme left of its displacement and with 2.3ms it will be positioned at the extreme right.

The microcontroller PIC16F628 [12] used in this project has the possibility to read resistive data directly from the LDR sensor without the necessity of additional circuits, giving a value between 0 and 255 (8bits) assigning the value 0 for a large luminous quantity and a values of 255 for the absence of light. The abstraction module raised in Figure 2 was restricted to 8 data test registers, so it was decided to normalize the input values of the LDR sensor to only eight possible; similarly, were considered only 8 possible output values (length of pulse) for the servomotor. For data entry identified a proportionality of 255 / 8 = 31.9, so a read of the LDR value between 0 and 31.9, it will get a resistive value equal to $000_2=0$, because they were designed 3-bit data registers for the model of artificial hybridization. For a reading between 224 and 255 a normalized value of $111_2=7$ was assigned. In Table 1 the values for the entry readings are listed.

Table 1. Normalized entry values

| LDR reading (Decimal) | Normalized value (Binary) | Corresponding entry value |
|---|---|---|
| 0 a 31.9 | 000 | 0 |
| 32 a 63.9 | 001 | 1 |
| 64 a 95.9 | 010 | 2 |
| 96 a 127.9 | 011 | 3 |
| 128 a 159.9 | 100 | 4 |
| 160 a 191.9 | 101 | 5 |
| 192 a 223.9 | 110 | 6 |
| 224 a 255 | 111 | 7 |

To control the output connected to the servomotor was necessary to divide the range of motion in 8 different values. Below in Table 2 are listed the inference rules defined for this design.

Table 2. Inference rules.

| |
|---|
| *If* ***entry = 0*** *then* ***duty = 0.30 ms*** |
| *If* ***entry = 1*** *then* ***duty = 0.59 ms*** |
| *If* ***entry = 2*** *then* ***duty = 0.87 ms*** |
| *If* ***entry = 3*** *then* ***duty = 1.15 ms*** |
| *If* ***entry = 4*** *then* ***duty = 1.42 ms*** |
| *If* ***entry = 5*** *then* ***duty = 1.70 ms*** |
| *If* ***entry = 6*** *then* ***duty = 2.00 ms*** |
| *If* ***entry = 7*** *then* ***duty = 2.30 ms*** |

## 5. BIO-INSPIRED MODEL

The normalize value corresponding to each reading of the LDR sensor was assigned to a 3-bit base register which would be compared with all test registers seeking its exact complement for the hybridization as shown in the simple model in Figure 2. To the test registers the fixed values registered in table 3 were assigned. Note that all data is stored as complements (logical negation).

Table 3. Test register.

| Test data register | Assigned value (Binario) |
|---|---|
| RP0 | 111 |
| RP1 | 110 |
| RP2 | 101 |
| RP3 | 100 |
| RP4 | 011 |
| RP5 | 010 |
| RP6 | 001 |
| RP7 | 000 |

In Figure 4, bio-inspired architecture that resolved the artificial hybridization for the suggested expert system is shown. Firstly the comparison was resolved (hybridization logical XOR-AND) between the register base and the 8 test registers labeled as RP0 and up to RP7. This comparison was not made parallel due to the sequential action that predisposed the microcontroller. As a result of successful hybridization (the base register that has found its unique complement), a single flag (labeled FLAG0 until FLAG7, the same figure 5) will have a logic high to enable the corresponding tri-state register (labeled PWM7 up as PWM0) that contains the data pulse width that will move the servomotor (see Table 2). The microcontroller can emulate tri-state data registers through code, as provided in this design.

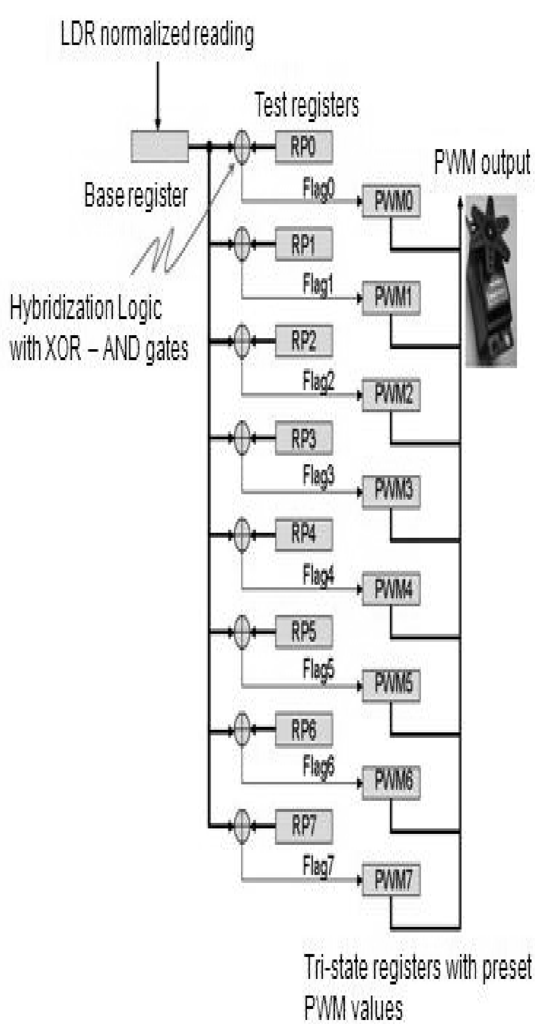


Figure 4. Bio-inspired architecture.

## 6. EXPERIMENTS AND RESULTS

The microcontroller programming was done using the high-level language PICBASIC PRO [13]. Focused on the area of home automation and programming of mobile devices, we designed a simple interface through a serial communication between the microcontroller and a Pocket PC, allows you to monitor the proper performance of the system (displacement of the servomotor). You can ignore this interface, which does not affect the automatic operation of the prototype. Figure 5 shows the prototype and reading on a PDA HP iPAQ hx2490 model, running Windows Mobile 5.0. The dispositive programming as well as the serial communication was made as shown in [14].

Figure 5. Monitoring the functioning.

It is noteworthy that the component integration was successful and the system worked correctly under the following tests:

1. The LDR was stimulated with different light sources: a regular lamp and natural light.
2. The width of pulse (PWM) was measured by an oscilloscope to verify that the microcontroller gave the correct value to the servomotor (see Figure 6).
3. The prototype worked automatically with a 9 Volt battery during 30 days allowing a stable functioning.

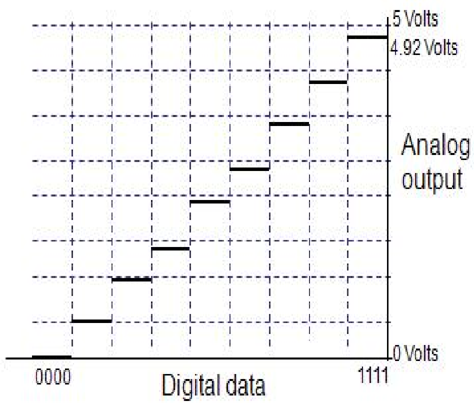


Figure 6. PWM output of the microcontroller.

## 7. CONCLUSIONS

In this work a small prototype for the home automation application at low cost and this can be easily modified, which can be used for teaching purposes, was designed. The hybridization of DNA strands permitted guiding a design towards a natural parallelization that can easily be explored through the implementation of embedded systems with commercial devices, with the intention of study practical applications using microcontrollers. The bio-inspired technique, transferred to hardware design, allowed the correct evaluation of a group of inference rules which can increase without drastic changes and can be adapted to other expert systems.

Each one of the tri-state registers used individually as a result of a successful hybridization, stored a value that can be updated in line modifying the scope of the design, in other words it is possible there exists and optimization process of the system (e.g. a PDA or a smartphone) to analyze different behaviors. This work is also being developed to strengthen this line of investigation. We should mention that the automatic system to open and close a window blind is going to be extended to control the regulation of a fluorescent lamp and thus assist in saving electricity.

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