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Advanced Design of a Mechatronic System for Human Blood Typing

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Abstract

The possibility of human error in the blood typing analysis in emergency situations is due to the need for rapid implementation of procedures in a stressful situation and subjectivity of the analysis inherent to the health technician. Currently, the process of the blood group analysis, in these situations, occurs manually through the plate test procedure. It consists of blood collection and mixing with specific reagents, in order to determine the blood agglutination. The results are checked macroscopically.

In this paper, the main objective is to present the conceptual design of a mechatronic system for human blood typing in emergency situations. The study and development of this system is performed by taking into account important aspects such as compactness, portability, reduce weight and cost. Blood typing is achieved through image processing algorithms, without human intervention. All the mentioned features are essential in developing a device that can be implemented in the market and successfully sold, avoiding human errors with the consequent increment of human safety.

Keywords

Mechatronic system, Advanced design, Product development, Human blood typing, Human safety.

Introduction

Statistical data related to Portugal [1], which can be extrapolated to other European countries, show that there is an annual high number of accidents, especially road accidents and work accidents. In these accidents it is often necessary to perform urgent blood transfusions *in loco*, where it is essential to determine the blood type of the victim rapidly.

The need for blood transfusions is systematically growing, for example, due to the frequent occurrence of those accidents. According to [1] it occurred in Portugal, in 2010, a total of 32.541 road accidents with victims, recorded 42.162 injuries and 689 deaths. In real time, the health technicians, under hard stress conditions, must decide quickly what procedures they must apply, in order to guarantee the best treatment for the patient. Sometimes *in loco*, they must decide, too, if the patient needs, or not, a blood transfusion [1, 2, 3].

In the mentioned emergency situations, where there is no time for human blood typing, the universal donor blood type is administrated. Nevertheless, some reactions may occur, risking the patient's life [2, 3] and stock levels of blood from universal donor blood type decreases.

Nowadays, it is used the manual test, explained below, named "plate test", which consists of putting two drops of a sample of blood and another one of a reagent, not overlapping them. In this procedure becomes obvious that it is required the maximum concentration of the health technicians in order to avoid mistakes that can easily occur.

There is several equipment in the market capable of determine ABO and Rh systems autonomously. Nevertheless, these equipment have distinct ways of functioning, all of them need to be operated on laboratory (due to high dimensions, low response speed, high costs, among others). Although, sometimes the manual method of blood typing is still used once it has lower costs and it is an easier method to apply. In the "plate test" there are used four plates and, in each one, there is a distinct reagent, namely, anti-A, anti-B, anti-AB and anti-D. Each reagent is mixed with the respective blood sample and after two minutes (maximum), it is observed in which plates agglutination occurs [4]. Figure 1 illustrates an example of configuration for the two possible scenarios.

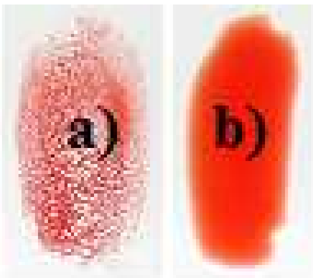

Figure 1: a) Presence of agglutination. b) Absence of agglutination [5].

Taking into consideration the occurrence, or not, of agglutination, in each of the four reagents, eight distinct scenarios may occur, as presented in Table 1. In this table "✓" means "*exists agglutination*" and "✗" means "*it does not exists agglutination*".

Table 1. Possible types of agglutinations [4]

Reagent	**Anti-A**	**Anti-B**	**Anti-C**	**Anti-D**	**Blood Type**
Aggluti-nation	✓	✗	✓	✓	**A^+**
	✓	✗	✓	✗	**A^-**
	✗	✓	✓	✓	**B^+**
	✗	✓	✓	✗	**B^-**
	✓	✓	✓	✓	**AB^+**
	✓	✓	✓	✗	**AB^-**
	✗	✗	✗	✓	**O^+**
	✗	✗	✗	✗	**O^-**

It seems feasible to reproduce those conditions is a systematic way without human intervention in the decision process decreasing or eliminating, if possible, mistakes on the blood type determination.

The possibility of developing a mechatronic system for helping health technicians performing those tasks is a very good alternative because it can avoid human error [6]. So, in this case, there is the need for designing and developing equipment, specially focused on solving this problem, capable of determine the patient blood type in emergency situations in an autonomous way. Concerning these possible situations, the equipment should have small dimensions, high response speed, trusted results, portability, low costs and easy handling. This system aims to operate in emergency situations autonomously (eliminating human errors on interpretation) and, with this, reducing the lack of universal donator blood type in health centers.

Consequently, it is an objective of this work to design a mechatronic system capable of doing a similar procedure as the manual method described above, based on an image processing algorithm. This image processing algorithm is presented in Figure 2 [7, 8, 9].

This paper is especially devoted to the mechanical part of the system with special focus on some aspects of its design. Also, it is relevant to consider the study of important issues dedicated to the parts and components manufacture, in order to reduce production costs. This solution is focused on the elimination of the manual procedures, by eliminating human intervention on the decisions, in blood typing, and considering the plate test with disposable reagent filled plates. The developed system incorporates numerous innovative features. The reagent filled plates, for example, ensures a faster and safer use. This way, it will be the lack of universal donator blood type in health centers.

In order to achieve the proposed goals, it will be presented next the actual context related to blood typing; then the description centred on the prototype design, especially developed for the mentioned purposes; further, there will be described some aspects related with the advanced design of the prototype and, finally, some conclusions and future work to be developed in this context.

Context of the work

This project is an ongoing work and started with the development of a new technique based on an image processing algorithm, capable of analyzing, interpret and autonomously classify the obtained agglutination samples results [6, 8]. This new technique is based on the fact that as the reaction of agglutination (between blood sample and reagents) is macroscopically visible, the sample images were captured in real size, using a CCD camera (Sony Cyber-shot DSC-S750) with 7.2 megapixel resolution. The acquired images were then analyzed by using an image processing tool developed using the IMAQ Vision software from National Instruments. Figure 2 shows the schematic of the image processing techniques developed [9].

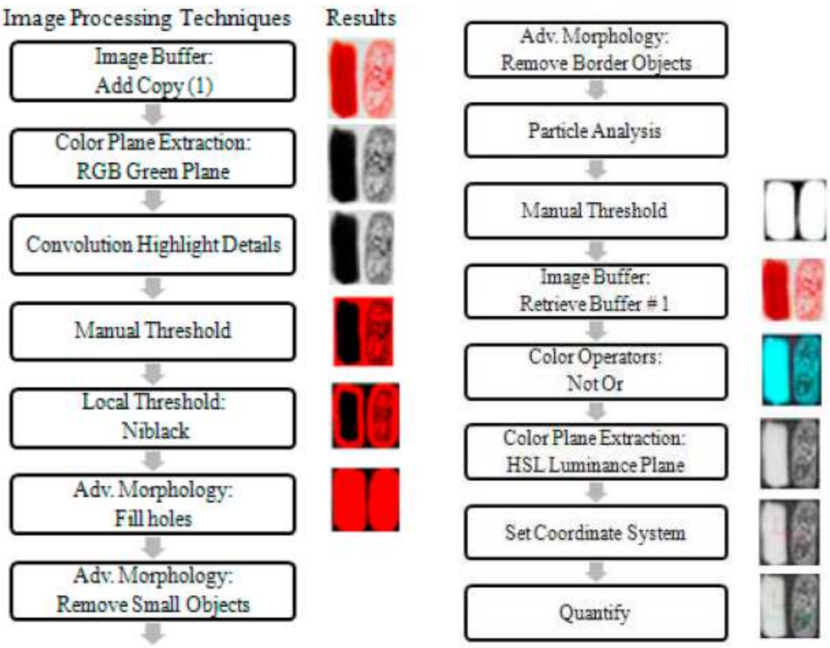

Figure 2: Image processing techniques developed [9].

Considering several tests performed, by trial and error, it was verified that when agglutination occurs in the blood/serum mixture, the standard deviation values of he analyzed image (available in the quantify function) are greater than 16. With this data it is possible to correctly classify the blood type [9].

Together, with this image processing tool an initial prototype was developed, fully assembled with reused material, whose operations were based on the manual method described in the previous section. However, the built system had precision limitations requiring improvements [6, 8]. Following the knowledge obtained by this first prototype a new one was developed, and it is presented in the next sections.

Design of the prototype

As mentioned in previous sections, the main characteristics of the prototype are:

- Portable;
- Small;
- Easy to use;
- Easy to handle;
- Without possibility of incorrect placement of the samples for further analysis;
- Without probability of human errors on results interpretation;
- With high response speed;
- Final low cost;
- As simple as possible (mechanical solutions instead electronic solutions);

The overall aspect of the prototype is presented in figure 3.

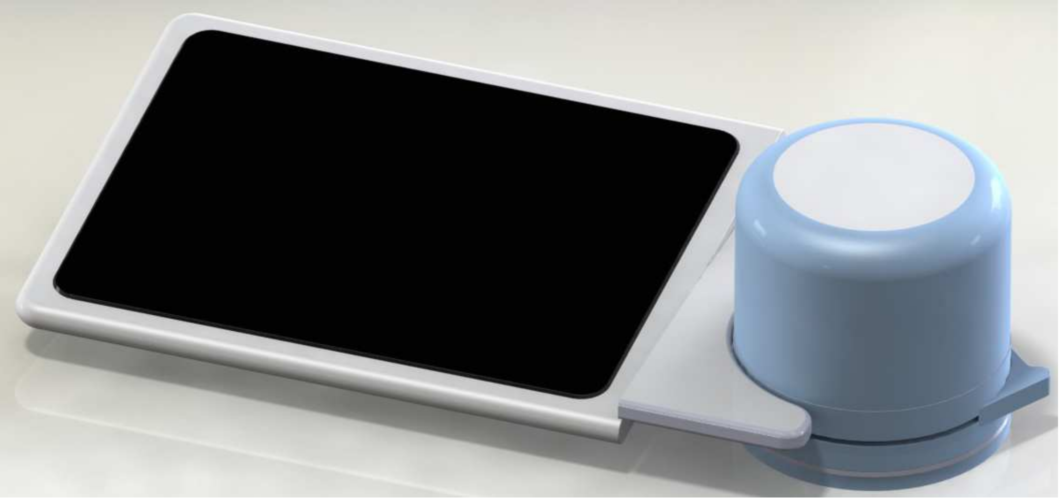

Figure 3: Final aspect of the developed prototype.

The developed equipment is composed by two main parts: the embedded electronic system (on the left side, in figure 3) and the mechanical (cylindrical) part (on the right side, in figure 3). The mechanical part contains the device for samples introduction, the mixture system of the blood and reagents and also the image caption system. The electronic system is composed by the monitor, ,to display the results, and the control system that analyzes and processes the captured image.

The procedure for an analysis of blood samples obeys to a systematic as follows:

1. Collect the blood;
2. Placement of reagents;
3. Mixture of blood and reagents;
4. Image capturing;
5. Data acquisition by the embedded electronic system;
6. Running software program for image analysis;
7. Presentation of the results on the monitor;

All of the mentioned steps have been taken into account during the development of the mechatronic system.

- **Electronics and software of the mechatronic system**

The embedded controller of the developed system is from Lilliput Electronics Co., Ltd [10]. In this application it is used the model GK 7000. This model is an industrial control device (figure 4) with Windows CE 5.0 operating system. It has a core CPU of S3C2440 processor based on ARM Frame 32 bit, 64 MB of memory Flash and 128 MB of SDRAM. This mini embedded system is much applied, such as, industrials machines monitoring, video conferencing systems, hotels, stores, hospitals, among others.

Figure 4: Embedded electronic system: Lilliput GK 7000.

Lilliput GK 7000 works through touch panel and is powered by a DC adapter or a battery. GK 7000 has features of rich resource interfaces, low consumption and high reliability, among others. GK-7000 has the same integrated developing environment of PCs; users can use Embedded Visual C++ 4.0, as well as Visual Studio which enables to easily developing application interfaces and writing widget's matter processing codes. It has a full panel of high performance microprocessor for specific applications allowing high resolution graphic displays. This system has the advantage of being low cost, hovering only 200 €. Finally the fact of being very small, having only 7 inch of dimension, make this mini PC small enough to be embedded into the system to be developed. GK 7000 measures 200 mm of length, 151 mm of height and 50 mm of width, it weighs 516 g without battery, and 610 g with battery.

As shown in figure 3, this embedded system is placed in a rectangular frame that can have some different inclinations in order to be flexible different users improving, this way, the human-machine interface.

- **Mechanical system for mixture of the blood with reagent**

In this sub-section there are described, in detail, the first three steps of the systematic procedure for analysis of blood samples and, following these first three steps (Collect the blood, Placement of reagents and Mixture of blood and reagents), there were considered all the main characteristics of the prototype referred previously . The developed system is presented in figure 5.

Figure 5: Mechanical part of the system.

This system, presented in figure 5, has 118 mm of height and 94 mm of diameter.
The systematic procedure for blood samples analysis is the following:

1 – To put the blood on the plates part. It must be highlighted that the methodology analysis of this is based on image processing. This way, it is mandatory to guarantee some reference points in order to identify the relative position of the different reagents. The way developed for solving this problem was to guarantee that the plates' part is always connected with bar 2, of the rotational system, in the same manner. In order to eliminate the possibility of mistakes – when coupling the plates part with bar 2 of the rotational system – it is guaranteed that this part is only possible to join the bar 2 of the rotational system, in an unique position, as illustrated in figure 6. These pin and hole guarantee that the plates of the samples of blood will be inserted always in the correct position. Also the pin and hole positioning system placed on the center of the support part guarantees the correct rotation and positioning of the samples' part. Concerning the addition of reagents, it is supposed that the plates for samples contain the respective reagents, when they are supplied for the respective supplier. The plates' part has a cover that must be removed in order to allow the blood deposition and must be, then, closed for performing the tests.

Figure 6: Mechanical restriction for coupling the plates with other parts of the mechanical system.

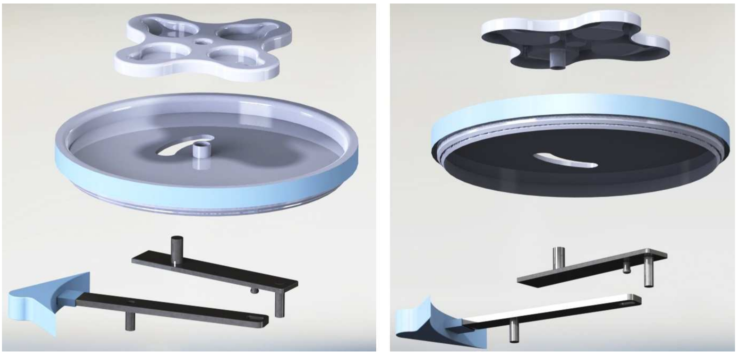

Figure 7: Positioning and guiding system for the plates' part.

2 - Mixture of the blood with reagents. After closing the cover of the plates' part, this part must be inserted and connected with bar 2 of the rotational system. After this, using manual actuation, the user moves the pushbutton of the rotational system. The rotational system is composed by two bars (bar 1 and bar 2) that are connected by a pin and a slot (figure 8). This system was developed this way because it is intended to have fast accelerations on the beginning of the movement and to multiply the tangential velocity of the pushbutton when pushed by the user. When the pushbutton is pushed the bar 1 rotates, around rotation center of bar 1, making the increment of tangential velocity in the contact point of the slot and the pin that connect the two bars. As the bars are connected, when the bar 1 rotates, the bar 2 rotates too around the rotation center of bar 2. This mechanism will reproduce a very higher tangential velocity in the pin that will move the platform with the plates of blood samples (figure 8). The basis of this rotational system is fixed and the rotation centers of bars 1 and 2 pass in the respective holes of this part (this detail can be observed in figure 5). As this rotational system allows the bars movement till the external of the limit diameter of the "cylinder" – defined by the internal dimensions of the cover - the slot that exists in the support part limits the curse of movement for avoiding this situation.

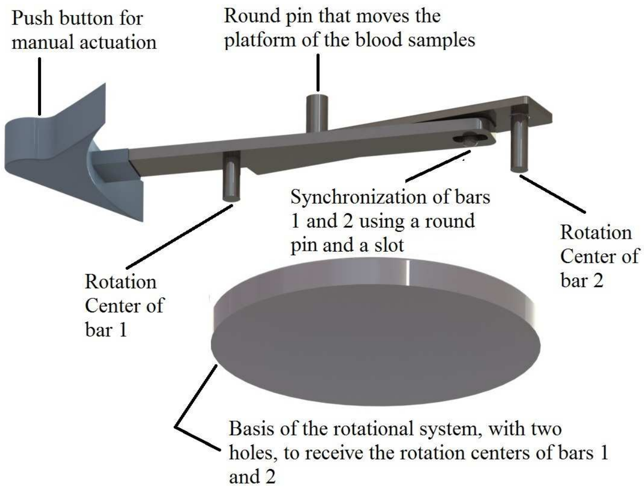

Figure 8: Rotational system composed by two bars.

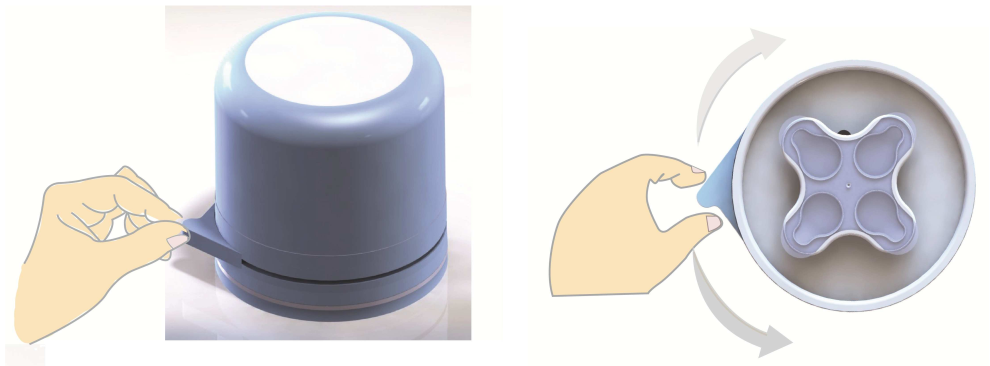

Figure 9: Rotation of the plates' part.

3 – Image capturing. After mixing the blood with the reagents and waiting for a previously defined time, a picture is captured by the digital camera. After this, the data is sent to the embedded electronic equipment that – runs specific software of image analysis – especially developed for this project – gives the final result in less than two minutes.

Conclusions and future work

On the conception, design and development of this mechatronic system, all aspects concerned to manual blood typing have been considered, in order to obtain a system that uses the same principles, with fast response time, but without probability of human mistakes, as humans do not interfere with the final interpretation of results. This way, health technicians that usually are under hard stress conditions do not make mistakes because the process has been systematized and automated.

It was used a product oriented approach in order to obtain a portable system, easy to use, easy to handle, without possibility of incorrect placement of the samples for further analysis, without probability of human errors on results interpretation, with high response speed, final low cost and as simple as possible, giving privilege to mechanical solutions instead of electronic solutions.

The electronic part of the system is responsible for the data acquisition and treatment. The determination of the type of blood is done – accordingly to the first tests performed – in about two minutes.

The mechanical system has some particularities such as: is simple, use a simple manual system for the mixture of blood and reagents and it is easy to construct in industrial environment.

The obtained result is a product highly innovative with high added value that can be applied in the improvement of human safety.

The electronic embedded system has been acquired and, in this moment, the prototype is being constructed and will be tested, soon, in clinical environments.

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