# Signal processing for low cost optical dataglove

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# SIGNAL PROCESSING FOR LOW COST OPTICAL DATAGLOVE

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**ABSTRACT**

The PolyProject initiative goal is to produce a low cost dataglove for sign language translation by using an optical detector technology and a 3D positioning system. The main innovation here is the optical system used for the glove which allows a great cost reduction. The glove also makes sign language translation much more accessible. In this article, we describe the optical signal analysis as well as the 3D positioning. These two elements will lead to the demonstration of the complete sign language translation methodology.

## 1. INTRODUCTION

The interfaces of the different e-tools available to us are becoming more and more user-friendly. In fact, most new wireless devices have no buttons, and it is now common to use a touch screen. This innovative interface could be even more sophisticated with the integration of a system that continuously perceives hand movements in space. For instance, the Wii remote uses a similar process to control some functions in video games. However, this technology is still in development because it is very difficult to capture the movements of the entire body with great precision.

This is also true for the definition of hand movements. In fact, the multiple degrees of freedom of the hand and its great range of motion make real time modeling very difficult. A new similar technology could have many uses such as sign language translation [1]. Since Sandin et al. introduced the dataglove [2], this is now possible, and there are many dataglove technologies available. For example, robot arms allow specialists to perform long-distance surgeries with great precision [3]. However, for now, it is impossible to get a high precision dataglove at a reasonable price. Some devices are less expensive, but the detection of every hand movements is not possible due to the degrees of freedom. Consequently, many researches are on the way to create less expensive datagloves [4]. Some of these researches give promising results, but the devices are often too uncomfortable to be used for a long time.

Our goal is to develop a low-cost, efficient and flexible product. We achieved this with optical detectors allowing a precision of one degree for all hand movements. Furthermore, our glove can be manufactured at a tenth of the price of similar devices on the market. The precision of our product also allowed us to develop an interface for sign language translation. In this article, we will explain the different steps of sign language translation starting with a hand movement. To this end, we will explain the analysis based on optical detectors. Afterwards, we will demonstrate the 3D positioning process. Finally, the sign language translation methodology will be discussed.

## 2. OPTICAL SIGNAL PROCESSING

### 2.1. Optical Sensors Principle

The optical sensors use the coupling loss principle to measure the flexion of the fingers. This physical phenomenon is a reciprocal logarithmic response, but the dynamic range allows a near linear response. As shown on figure 1, when the fingers bend, the optical fibre, which is fixed at one extremity and canalized at the other, moves away from the source. This decreases the luminous intensity which enters the optical fibre.

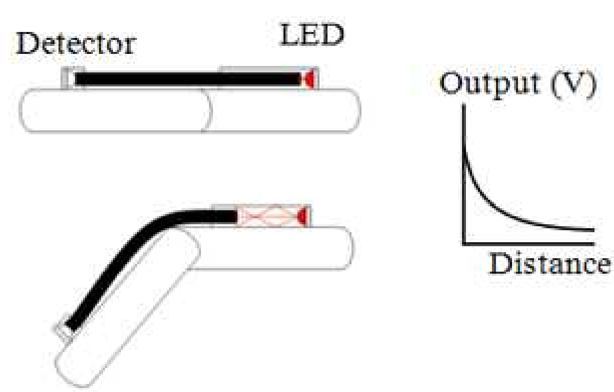


**Figure 1 – Schematic of optical flex sensor**

Figure 2 shows the relationship between the flexion angle of the articulation and the distance $x$ between the source and the optical fibre. Of note, when the articulation flexes, the radius of curvature in the optical fibre is too large to result in important flexion losses in the intensity of the signal. Therefore, these losses are not significant. The following equation shows the relationship between the linear distance $x$ of the optical fibre and the $\theta$ angle of the articulation. We can see that $x$ is proportional to $\theta$. In short, by adjusting the sensors parameters to obtain a linear variation of the signal with relation to the distance of the optical fibre from its source, we will also observe a linear variation of the signal with relation to the angle of the measured articulation.

$$x\,[mm] = \frac{\theta\,[°]}{180°}\,\pi\, r[mm] \qquad (1)$$

## 2.2. System Summary

Figure 3 and 4 shows the sensors position on the glove. The goal of this positioning is to capture a total of 15 hand movements: flexion of the two first phalanges and abduction of every finger. The flexion of the second and third phalanges is an entangled movement, so we do not measure it due to ergonomic and cost saving concerns.
A single microcontroller multiplexes these 15 signals and converts them in digital signals. Figure 4 shows the function of the microcontroller. The CPU transmits data to an interface and achieves a two-point linear calibration in order to determine the hand dynamic range, which is unique to every individual. This simple and fast calibration is achieved every time in order to obtain the most precise data for different uses such as sign language translation. In this domain, the two limit points of the movement are recorded for every sensor and the movements are then assessed on a scale of 0 to 100. This way, the obtained data are easy to process.

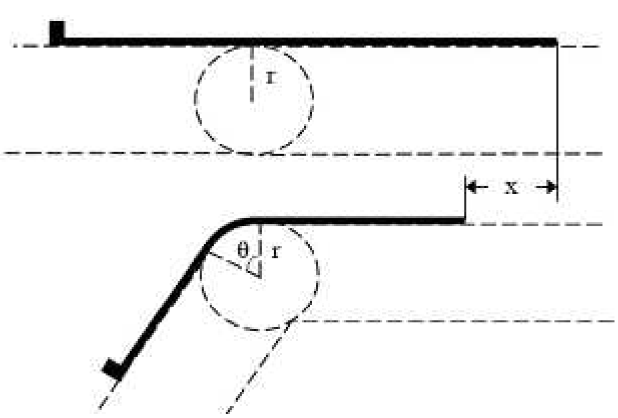


**Figure 2 - Relation of linear displacement of the fiber by the flexion of finger**

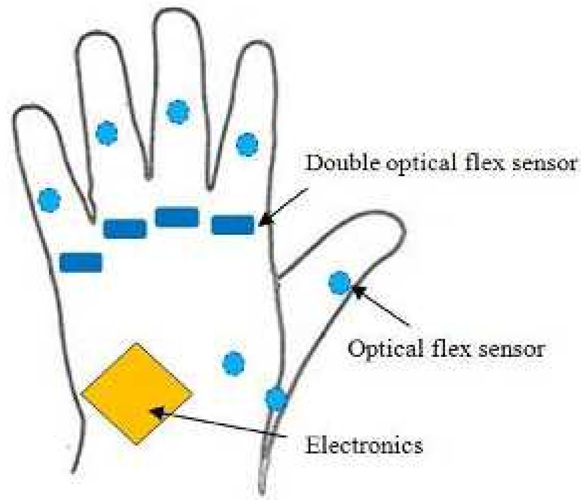


**Figure 3 - Top view of the glove showing the position of sensors**

## 2.3. Optical Sensors Characteristics

Flex sensors use LEDs with an emission peak of 940 nm (model LTE-4602), a compatible photodiode (same model) and a polymeric fibre (PMMA). In order to obtain a stable luminous signal at the source, we use an electrical regulator (model LM317).

After adjusting the system electronic components to increase the signal sufficiently, we have adjusted the LED electric current. This gave us the data shown in figure 5. These measures were taken with a micropositioner. With this adjustment, we get an almost linear signal. This way, a two-point calibration is possible.

This calibration allows a five-degree precision due to the linear estimation of the calibration. The precision can be improved with a sensor pre-calibration. A two-point calibration will allow a one-degree precision, which is limited by the sensors repeatability.

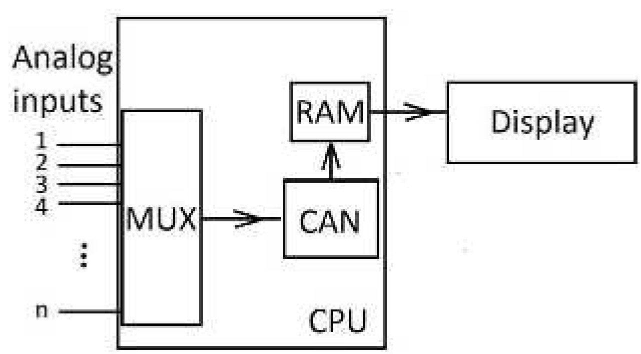


**Figure 4 – Microcontroller schematic**

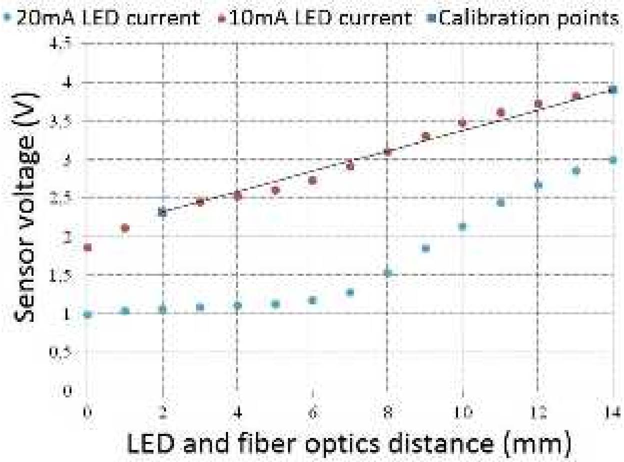


**Figure 5- Optical sensor measurement using a micropositioning stage**

## 3. 3D RENDERING

### 3.1. 3D reproduction system

The 3D reproduction system has two components: flexion reproduction and positioning in space. In our program, flexion reproduction simply imposes an angle between two joints. This angle is determined by measuring tensions and achieving calibration as mentioned in section 2. Our actual prototype allows a six-degree precision. The positioning system is more complex, but we used known methods to develop it [5]. Figure 6 shows our 3D rendering interface.

### 3.2. Electronic specification

The new version of our positioning system uses a LSM330DLC chip by STmicroelectronics. This chip has a three-axe gyroscope as well as a three-axe accelerometer, which are both digital. This allows us to lower the production cost and to have better ergonomics than with the traditional components used in general.

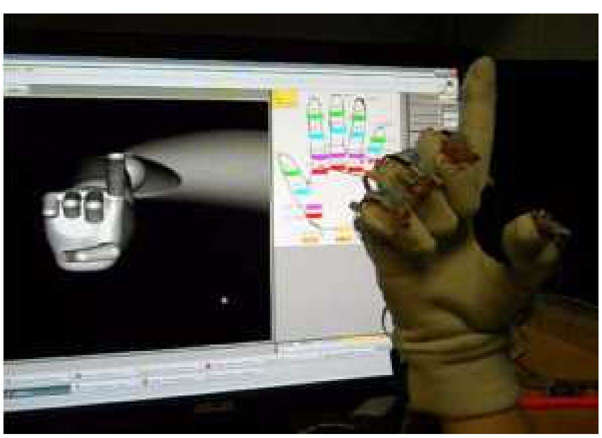

**Figure 6 – Real time 3D rendering**

## 4. SIGN LANGUAGE TRANSLATION

### 4.1. Basic signal

At this moment, the developed systems can capture the different parts of the hand. Their positioning is also linked to a time variable and, this way, we can determine the actual hand movement in space. What we want to do is take this information and analyse it continuously in order to translate these movements, from sign language to plain words.

In this effect, the first step was memorizing a particular position of all sensors on the hand and allowing a margin of error for every data. This process is quite simple for a word represented by a static hand position. Figure 7 shows our first translation interface using this process. In this case, the condition can be the position captured during a precise period of time: when the positioning and timing conditions are met, the sign is translated to a word. Concerning a word translated by a single movement, the process is relatively similar. In fact, instead of having a single position in a given period of time, a number of positions will be associated with different time periods. In such a situation, an uncertainty lies on the positioning and the relative time periods between different positions.

With this technique, we can create a reliable basic word bank, as long as the hand positioning and movements associated with these words are very different. This process is quite limited because many words are represented by similar movements. Consequently, we tend to decrease the uncertainty on the positions or the relative time periods in order to differentiate two words, but this process decreases translation accuracy.

It would be interesting to use an artificial intelligence system for adjusting the uncertainties linked to the critical elements of similar words. At this moment, an efficient technique is to prepare a smaller sample for every word and randomly add afterwards a Gaussian noise on a large sample. This way, the artificial intelligence system increases its databank and recognizes different elements more easily. Of course, it is not desirable to repeat the same word tens of times with different users, because the procurement process would be too long and expensive.

### 4.2. Utilisation method

Once the implementation of the artificial intelligence system is complete, a reliable sign language translation appears on our computer screen. In our project, words are translated from sign language to French. Such data in text format are very easy to manipulate. The words can be translated in any language with different translation tools widely available on the Internet. Moreover, many tools already available transform written words in audio files, in the desired language. The data for translation are very versatile, and this process can be used anywhere on the globe.


**Figure 7 - Translation interface**

Furthermore, since independent word management is totally ensured by artificial intelligence, it would be easy to integrate a personalized word add function. This way, a user could add his name or any other word not already in the word bank. Some movements could be defined to interact with the computer. In fact, any personalized movement can be used to interact with the interface, and it would be possible to entirely replace the mouse or any similar device having the same function.

### 4.3. Language dynamics

Sign language consists of visual patterns which reflect their real meaning. Moreover, only the key words of a sentence are communicated by sign language. In other words, the corresponding translation will not be the generally used written or spoken sentence, but a very basic group of words. For more interesting results, it will be necessary not only to translate the hand movements of sign language but also to understand syntax, semantics and the meaning of every sentence in order to match the translation and signs as much as possible.

## 5. CONCLUSION

The dataglove allows for multiple interesting applications in many fields. In the case of sign language translation, we have demonstrated that it is possible to get conclusive results with a low-cost, precise and ergonomic product. This was achieved with optical sensors and accelerometers combined to gyroscopes.

In order to get this result, we used optical sensors which allowed a precision of six degrees. This allows a great cost reduction for production. However, according to our experiments, the product lifespan is not sufficient to be used by the general public. In fact, the fibre broke many times because of high flexion. Researches are on the way to fix this problem. It would also be possible to obtain a precision of one degree with some adjustments.

We have demonstrated that the new 3D positioning model has been greatly improved. Consequently, we can now translate with satisfactory precision the movements of sign language. However, we will have to expand the word bank in order to produce a convenient device for potential users.

Finally, datagloves could totally revolutionize the way we interact with any electronic device. The dataglove could replace all items used to control electronic devices. We can easily foresee how this can be possible for interacting in a virtual world in 3D. Moreover, since our product reproduces hand movements, it could be used for technical dexterity training in different trades such as aircraft piloting or surgery. This would allow a better capacity and precision in action analysis.

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