Electronic Pen for reliable Signature Authentication

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Abstract: - The paper deals with the design and use of the sensor pen which can be used for higher reliability in the process of hand written signature verification. The pen uses set of accelerometers and strain gages to measure acceleration and forces applied to the pen tip. Short description of the sensors signals processing is included.

Key-Words: - automatic signature verification, embedded systems, electronic pen, sensors, measurement, physical quantities, interface, USB, acceleration, strain gages

1. Introduction

Nowadays the automatic person authentication based on hand-written signature is required. We suppose that the images of most signatures can be forged if the forger would have enough time and possibility to drill known handwritten signature. The reliability of visual authentication of handwritten signatures is highly dependent on the skill of authenticating person.

The paper describes principles and construction of the experimental electronic pen designed for on-line hand-written signature authentication. The method is based on the use of electronic pen which monitors several mechanical issues in the pen during the sign process. Therefore the electronic pen is equipped by several sensors that produce number of time variable signals generated dependently on the pen movement and on mechanical forces in the pen.

Short description of the proposed authentication algorithm is presented as well. The real image of the signature on the paper is considered only as a side product of the whole verification process and can be compared electronically or classically by the commissioned person.

In our design of the sensor pen we use a set of dual axis accelerometers to measure acceleration of both ends of the pen. Moreover, in the pen body there is a steel beam with set of strain gages, which are used to measure forces applied to a pen tip. The signals from all sensors are conditioned and after that digitalized by embedded microcontroller. Measured data is sent in blocks to the PC host computer over the serial interface.

2. The mechanic parts of the device

The electronic pen prototype is a simple thin walled metallic pipe with central steely rod partially fixed at the top and carrying the pen cartridge at the bottom. The impact load on the pen cartridge produced by the authenticating person in the sign process raises mechanical moments in both axis of the central metallic rod. There are four strain gages stuck on the rod closely to the fixing point in order to achieve maximal fixing moment in both axes. The aim of the special construction of the pen is its ability to measure mechanical forces in the pen and acceleration of both pen ends.

There are also two accelerometers placed at both ends of the pen near the pen axis. The dimensions of used electronic elements are not negligible comparing with the pen body. This implies that we cannot reach the desired location for all sensors. This can slightly increase complexity of the algorithms for person authentication.

The electronic circuits which condition the signals are placed closely to the top of the pen because of noise reduction.

The weight of the first sample of the pen exceeds slightly the weight of the average pen, but we hope that in the next version we can correct this bottleneck significantly.

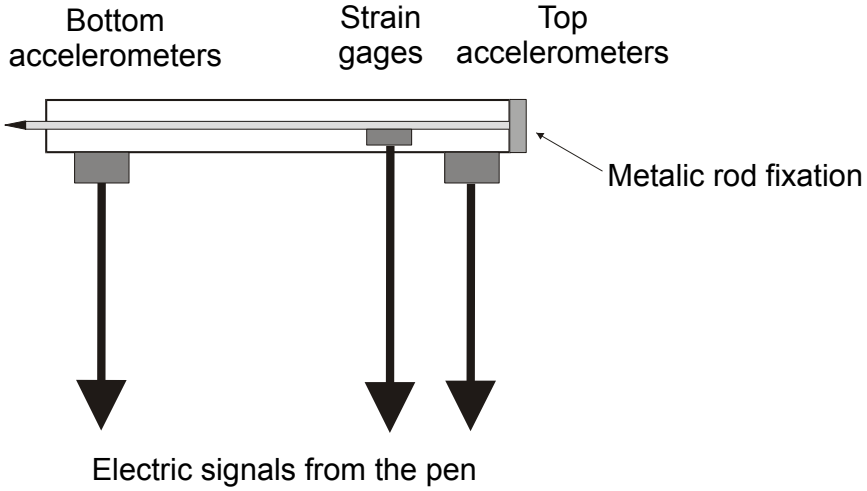

Fig. 1 *The pen mechanics*

3. The electronics part of the pen

Four semiconductor strain gages measure the mechanical stresses in the middle part of the pen. Originally the strain gages were connected into four Wheatstone bridges each with one varying element. We tried to measure also the axial force in the metallic rod. This idea seamed not to be just excellent because the length deformation of the rod is negligible compared to deformation caused due to rod deflection. Now the strain gages are connected into two half-bridges. This arrangement also reduces the number of wires which connect the pen mechanics and pen electronics to four. The acquired signals are amplified using special single supply instrumentation amplifiers AD623 that deliver rail-to-rail output swing on a single supply 5V and low-path filtered. Because the gain of the amplifiers reach relatively high values (about 10^3) the tolerance of used electronic component values can bring the signal out of active input range. Therefore one peace of dual digital potentiometer AD5232 is used to compensate this offset. The AD5232 component is connected over SPI interface which is built in the ADuC814 microcontroller.

As sensors we used a couple of double axes accelerometers ADXL202E, one placed on the top, second at the bottom of the pen body, near the pen axes as possible. Each accelerometer used is complete 2-axis accelerometer with a measurement range of ±2 g. The outputs are Duty Cycle Modulated (DCM) signals whose duty cycles (ratio of pulse width to period) are proportional to the acceleration in each of the 2 sensitive axes. There are also direct analog outputs which seem to give better results (signal quality) compared with the modulated pulse output. We used the second possibility.

After buffering the signals are directly connected to the 6 channel 12 bit sampling analog-to-digital converter. The "cat off" frequency of the low pass and sampling frequency was chosen after signal analysis by the spectrum analyzer in order to reach substantial noise suppression. Noise sources are described later. Effective frequency band extends to about one hundred of Hz. The measured data is sent in burst mode over the microcontroller's RS232 interface to the RS232 – USB converter and then directly to PC. As the USB interface circuit we use the FT232BM from FTDI. The circuit has many interesting features which can be used.

4. The embedded software

The program running on the microcontroller has relatively simple structure. After reset the setup procedure is entered, where the initialization of the serial channel is performed and the appropriate offset for both Wheatstone bridges is determined. After this beginning phase the program enters simple loop in which the data are periodically measured and sent in burst mode to the PC using a simple data protocol which provides basic data synchronization.

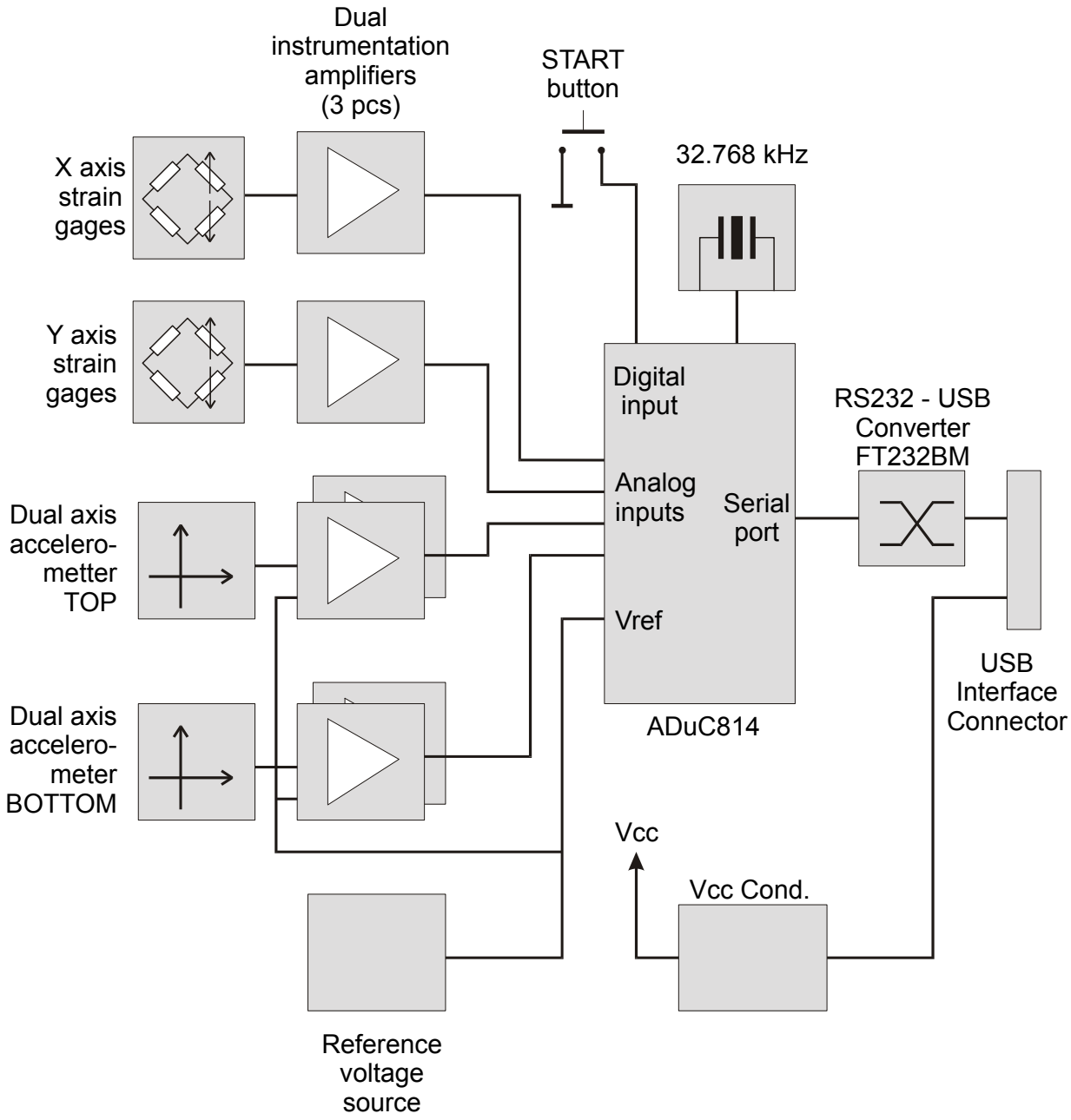

Fig. 2 *Block diagram of the pen electronic.*

5. Authentication Algorithm

The authentication algorithm is under development. We have not on-line version of the algorithm yet. The results presented later in this paper were achieved with off-line algorithm. The data gathered from the pen were first stored in the file, which was used as authentication program input data source.

5.1. Sensor signal processing

There are several sources of signal noise in the process of sign. The essential role plays the roughness of the paper which in conjunction with relatively small diameter of the ball point produces strong vibrations. These vibrations cause strong high frequency signals on the accelerometers outputs. Therefore output signals of both sets of accelerometers are first low-pass filtered in order to remove high frequency vibration signals and to avoid aliasing problems. Filtered signals are amplified and sampled by 12bit A/D converter at sampling rate 200 samples/sec. Strain gage signals are amplified and converted to digital data synchronously with accelerometers signals. Digital data are digitally filtered by low-pass FIR filter with break frequency of 40 Hz.

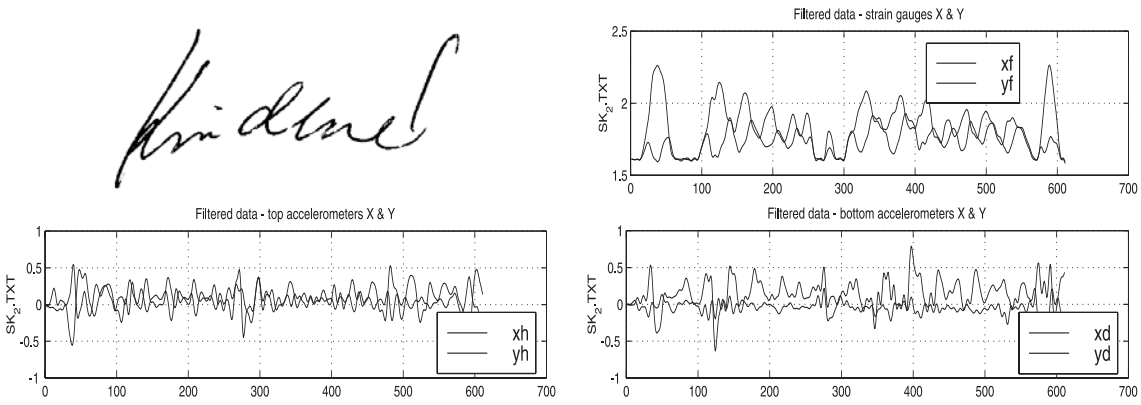

Fig. 3 The signature and filtered signals from the pen.

6. Signature authentication process

Signature authentication is the task of the pattern classification type. The statistical methods are commonly used for this class of task. Before the process of classification, the algorithm is trained using the large number of patterns of known class. The training is used to get statistical data, which describe the "paradigm" for each class. In the classification process, the a posteriori probability of membership in all classes is computed for the observed pattern. These probabilities are used to select the most probable class for the pattern.

Similar method could be used for the signature verification. The drawback of this method is the necessity of collecting of the number of signatures for the training process. This is not acceptable for practical use in banking applications etc. Therefore simplified and more straightforward method was tested. Sampled signature signals are time adjusted and compared with set of small number (2 – 4) of "paradigm" signatures. This method shows good performance in detection of the fake, while there is relatively big number (10 – 50%, depending on the writer's skill) of authentic signatures which are incorrectly classified as the fake. The solving of these problems will be in our focus in the next.

7. Conclusions

The hand written signatures are still heavily used for person authentication. The use of the electronic pen can significantly increase the reliability of the verification process.

The application fields of such an electronic pen have much wider range than it was indicated. It was observed, that some diseases (Parkinson disease, etc.) in early progress stages manifest also as the disturbances in the hand kinesis. So the medical diagnostic can be the next application area.

8. Acknowledgement

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