A Second Generation Embedded Reconfigurable Input Device for Kinetically Challenged Persons

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Abstract

A second generation of an embedded input device for kinetically challenged persons is presented. The new system can detect $O(n^2)$ free motions in space with $O(n)$ hardware, and has the capability to form extendable vocabularies of motions. The improved motion detection computational model is presented, together with experimental results.

KEYWORDS: Embedded, Reconfigurable, Architecture, Motion Detection, I/O Device

1. Introduction

Various assistive devices have been developed for persons with kinetic challenges, including voice-activated systems, head motion detection systems, and eye movement tracking systems [2], [3], [4]. Most of these systems use either large FPGA's or PC-class fixed computer resources. The present system, comprising of a low-cost 8-bit ATMEL AVR microcontroller, a low-end Xilinx XC4010 FPGA, and Analog Devices ADXL210 accelerometers as sensors aims at a less-than $70 total system cost. In a previous publication [1], we showed that a model of independently operating finite state machines (FSM) offers a good design tradeoff vs. the usage of microcontrollers alone for free space motion detection.

The main contribution of this work is the improved model for motion detection, with ability to recognize $O(n^2)$ distinct motions (vs. $O(n)$ in the first generation) with $O(n)$ hardware complexity, and the generation of complex motion vocabularies from synthesis of simpler motions.

2. Motion Detection Model

The computational model of the first generation system is that of parallel FSM's, each of which is comprised of stages for detection of values/ranges of X-Y data, followed by stages to wait for a predefined period of time (including 0-time). This way, each detectable motion was represented in terms of thresholds, which needed to be exceeded for the state to be active, followed by periods of "not examining the input", which were useful in avoiding

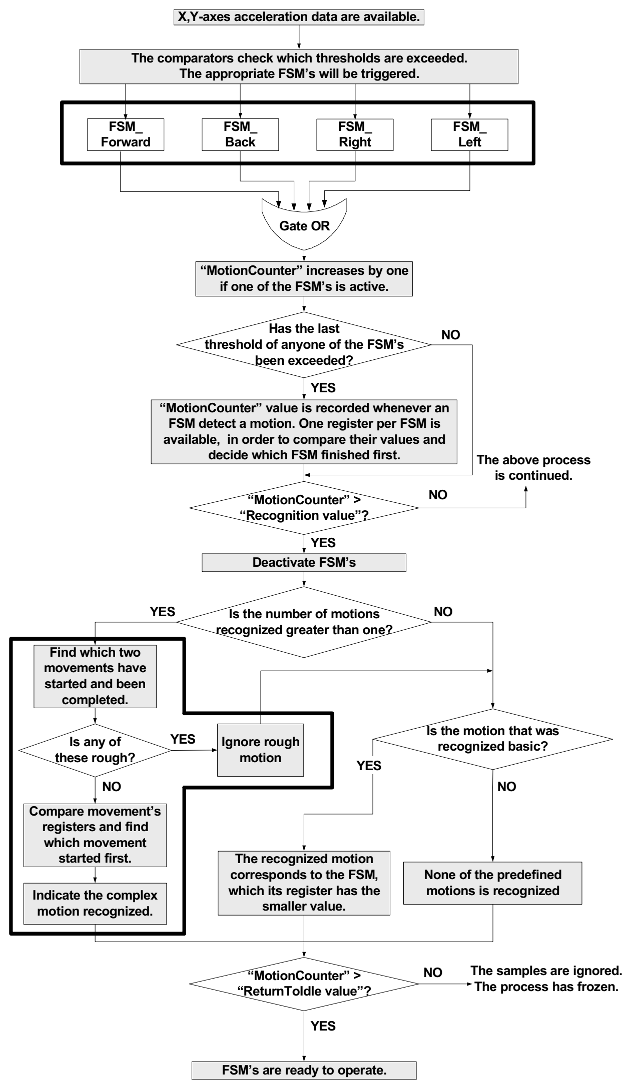

Figure 1 Second generation model of parallel FSM's

local minima (from irregular motion or noise). The model was based on the concept that the complex motions are constituted by detectable sequences of basic motions, e.g. circular movements were represented by more thresholds of accelerations than basic motions. During preliminary clinical evaluation of the system it turned out that a large number of complex motions was undesirable to the user, *regardless of system capability,* leading to the second generation of the system. The model presented below is based on the concept that *sequences of simple motions are used in order to produce a complex "vocabulary"*. This approach allows for a succession of two motions with n possibilities each, to produce n^2 distinct motions vs. n (potentially more complex) motions in the first generation. In both cases n is the number of FSM's. The hardware cost is O(n) because the same FSM's are re-used for each segment of the motion in the second generation of the system. The FSM's that are integrated in the design are only those that led to the detection of the simple motions. *The maximum number of motions* that the present system can detect is $4^2 = 16$.

The flow chart of the second generation model is shown in Figure 1. The differences with the first generation are represented with the subsystems inside bold lines. The flow of operations up to the point where the "MotionCounter" exceeds "Recognition value" is identical for both models. The "MotionCounter" is used to measure the elapsed time after the trigger of an FSM, whereas the "Recognition value" is a predefined value that corresponds to the maximum time space that is allowed for the completion of a motion. Once an FSM detects a motion, within that time frame, the value of "MotionCounter" is recorded. If the "MotionCounter" exceeds the "Recognition value", the FSM's are led to an "inactive" state, where the check for detected motions is performed.

In the first generation model, each FSM is completely dedicated to a single motion and the algorithm simply outputs the type of the first corresponding motion that was successfully recognized. In the second generation model the following procedure takes place:

- The controller checks which two motions have been detected.
- The controller checks if some motion was "rough" in order to avoid false positives from tremble. If this is true, the motion is ignored and the algorithm executes the "non-complex motion" process, whereas if it is false, the values of registers are compared to find which basic motion was triggered first.
- The algorithm outputs the type of motion, which is synthesized by the two basic motions that have been recognized.

3. Experiments and Conclusions

Many experiments have been done with a person with no kinetic problems, as well as with a kinetically challenged person. One of the significant results of the experiments was that the preferred motions for the person with kinetic challenges are forward, back, left, right. The combination of the time series analysis of complex motions and the clinical results led to the improved computational model. The motion detection model works very well for the motions that a person with kinetic disorders can realize.

Table 1 presents a comparison of system complexity for the two systems. The frequency of operation is orders of magnitude higher than the required one for real-time operation, in both cases.

	FSMs	Motions	CLBs	Speed
1st system	6	6	350	30 MHz
2nd system	4	16	375	28 MHz

Table 1. Comparison between the characteristics of the two hardware implementations.

Summarizing, we have shown an improved motion detection model for real-time continuous motion recognition. The recognition rate of the system approaches 90-95%. At present, a new version of the system is under development with a Spartan FPGA.

4. Acknowledgements

We wish to acknowledge the Greek Secretariat of Research and Technology (GSRT) and the British Council, under the EPET II European Union program. We also acknowledge generous donations by Xilinx Corporation, and electronics parts support by Analog Devices. We wish to thank Dr. T. Kean for his contributions and his valuable advice and Mr. S. Koutsorinakis for his willingness to test our system.

5. References

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