Multi-sensor Data Fusion Model Based Kalman Filter Using Fuzzy Logic for Human Activity Detection

Nattawut Wichit and Anant Choksuriwong

***Abstract*—The performances of the systems that fuse multiple data coming from different sources are deemed to benefit from the heterogeneity and the diversity of the information involved. In this work a novel Multi-Sensor Data Fusion (MSDF) architecture is presented. The estimation accuracy of the system states is reduced dramatically. Therefore, applying Kalman filter to generate the importance density function has been introduced to improve the performance with slightly increasing the computational complexity. In this paper we propose a new Multisensor based activity recognition approach which fuzzy logic fusion sensors to recognize Human Behavior. This approach aims to provide accuracy and robustness to the activity recognition system. In the proposed approach, we choose to perform fusion at the Feature-level.**

***Index Terms*—Kalman filter, information fusion, multi-sensor data fusion, fuzzy logic, human activity detection.**

I. Introduction

Surveillance and observation of human behavior in the home are much more developed. To reduce accidents that may occur at any time of the residency. Especially the elderly, who are able to support themselves with less so there needs to be used to monitor and observe the behavior of the residents in the home [1]. However, at present the accuracy of the method used is not enough, there is no flexibility on the obstacles. This is because the information is not enough to make the decision to expand the concept to catch up [2]. For each sensor, which is placed in the position and form of the different sensors to collect data. The sensor on the data is not sufficient to decide the other sensor. Data and help increase decision accuracy. The total amount of data is called Data Fusion Model was originally created for use in the military [3] in planning decisions for the opponent and the location of the enemy. We are thus presenting a survey of the existing methods to outline how the combination of heterogeneous data can lead to better situation awareness in a surveillance scenario. We also discuss a new paradigm that could be taken into consideration for the design of next generation surveillance systems with the can be divided into three levels. We list several multi-sensor data fusion applications and their architectures.

Several fusion process models have been developed over the years. The first and most known originates from the US Joint Directors of Laboratories (JDL) [4] JDL model involving broadening the functional model, relating the taxonomy to fields beyond the original military focus, and integrating a data fusion tree architecture model for system description, design, and development. The data fusion approach based on Kalman filter adaptive Fuzzy logic. Fuzzy logic is a logical based on the fact that all the real world is not certainty. The concept of multimodal of data fusion is from multiple sensors for human behavior detection.

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II. Kalman Filter Algorithm

Given a discrete-time controlled process described by the linear stochastic difference equations:

$$x_{k+1} = A_k x_k + B_k u_k + w_k \tag{1}$$

$$z_k = H_k x_k + v_k \tag{2}$$

where k represents the discrete-time index, x_k is the system state-vector, u_K is the input vector, z_K is the measurement vector, w_K and v_K are uncorrelated zero-mean Gaussian white noise sequences with covariance matrices Q_K and R_K respectively; the Kalman filter algorithm can be described by next group of equations [5]

Prediction (Time Update)	**Correction (Measurement Update)**
1) Project the state ahead $\hat{x}_k^- = A\hat{x}_{k-1} + Bu_k$ 2) Project the error covariance ahead $P_k^- = AP_{k-1}A^T + Q$	***1)*** *Compute the Kalman gain* $K_k = P_k^- H^t (HP_k^- H^T + R)^{-1}$ ***2)*** *Update estimate with measurement* z_k $\hat{x}_k = \hat{x}_k^- + K_k(z_k - H\hat{x}_k^-)$ ***3)*** *Update the error covariance* $P_k = (I - K_k H)P_k^-$

Fig. 2. Kalman system.

where $\hat{x}_k$ represents the estimate of the system state vector x_k, P_k is the state-estimate error covariance matrix, and K_k is commonly referred to as the filter gain or the Kalman gain matrix. From time step k to step k+1, the current state and error covariance estimates to obtain the a priori (indicated by the super new measurement into the a priori estimate to obtain an improved a posteriori estimate [6].

The term $H_k\hat{x}_k^-$ is the one-stage predicted measurement $\hat{z}_k$, and the difference $(z_k - H_k\hat{x}_k^-)$.The Kalman filter algorithm starts with initial conditions at k = 0, being $\hat{x}_k^-$ and P_0^-. With the progression of time, as new measurements z_k become available, the cycle estimation-correction of states and the corresponding error covariance can follow recursively ad infinitum.

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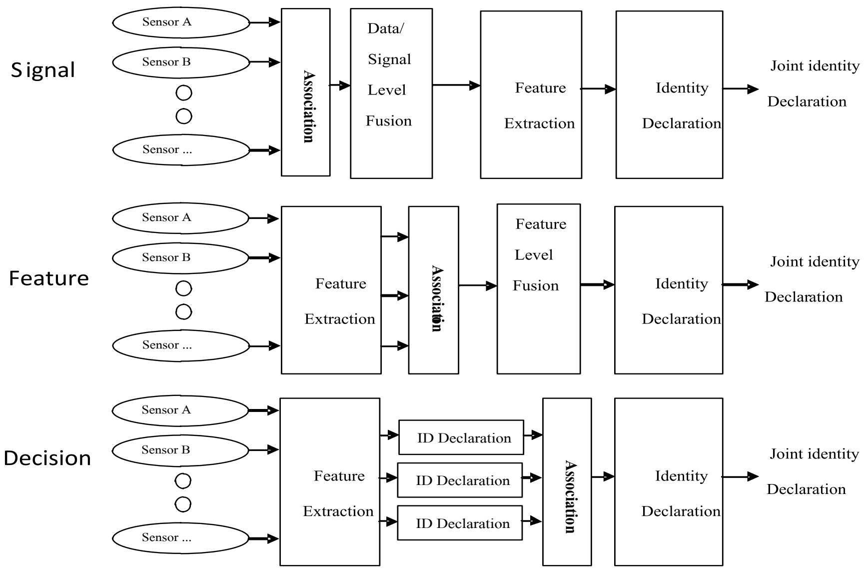

Fig. 1. Data fusion model.

III. Architecture and Fuzzy Logic

Our approach is fuzzy logic to combining multi-sensor (camera, passive infrared, acoustic, and pressure and contact sensors) to improve the recognition of human activities [7]. Fuzzy logic comprises 3 main process, (1) fuzzification, (2) Rule inference, and (3) defuzzification.

Fuzzy sets that have been already determined. In contrast to classical logic where the membership function $u(x)$ of an element x belonging to a set A could take only two values: $u_A(x) = 1$ if $x \in A$ or $u_A(x) = 0$ if $x \notin A$, fuzzy logic introduces the concept of membership degree of an element x to a set A and $u_A(x) \in [0, 1]$, here we speak about truth value. Fig. 3 shows the main fuzzy inference system steps.

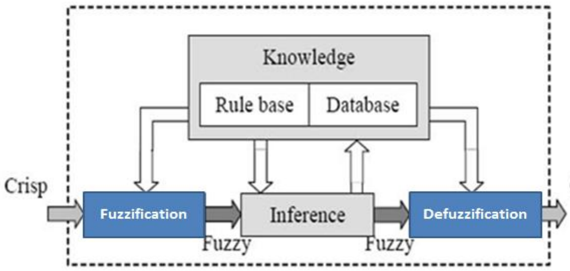

Fig. 3. Fuzzy inference system steps.

There are used our human activities recognition systems which are:

A. Fuzzification

First step in fuzzy logic is to convert the measured data into a set of fuzzy variables. It is done by giving value (these will be our variables) to each of a membership functions set.

B. Fuzzy Rules and Inference System

The fuzzy inference system uses fuzzy equivalents of logical AND, OR and NOT operations to build up fuzzy logic rules. An inference engine operates on rules that are structured in an IF-THEN format.

C. Defuzzification

The last step of a fuzzy logic system consists in turning the fuzzy variables generated by the fuzzy logic rules into real values again which can then be used to perform some action. There are different defuzzification methods in our platform decision model can use Central of Gravity (COG) that popular today in the equation 3.

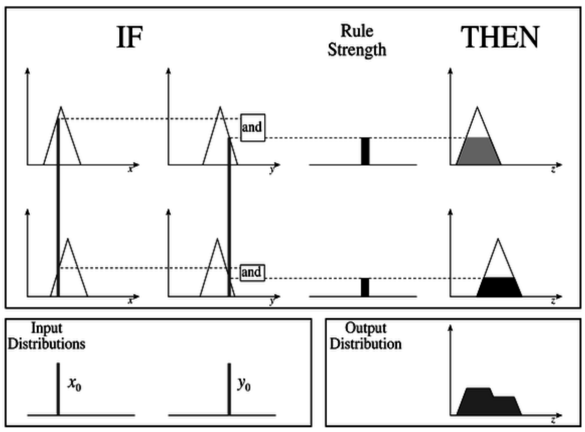

Fig. 4. Rule mamdani with crisp input.

$$\mathrm{COG} = \frac{\sum_{i=1}^{n} u_A(x_i)xi}{\sum_{i=1}^{n} u_A(x_i)} \tag{3}$$

where x_i ($i = 1, 2\ldots n$) arrive the maximal values of $u_A(x)$.

IV. Proposed Approach Overview

Our approach consists in combining the measurement streams with the contact information to improve the recognition of elderly activities [8] (Fig. 4);

This approach has three main tasks:

- The first task consists for the vision component in detecting and tracking people and to recognize predefined video events. For instance, a typical video event is a person sitting down on a chair.
- The second task consists in acquiring sensor streams, in filtering them and in recognizing predefined contact events.

- Finally, the last task consists in combining the video and the contact events recognized by the previous tasks.

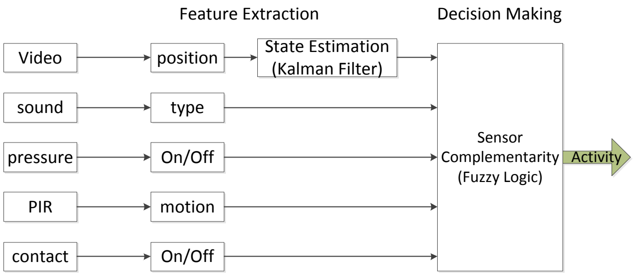

Fig. 4. Approach overview.

The input is the video frame, and the output is the tracking result for each object in the frame. First, the system does the background subtraction and the foreground objects are extracted. After that, for each object that has already been tracked in the previous frames, the Kalman filter prediction is performed. The next stage is to detect whether the object is under occlusion or not. There are a few criteria to determine the occlusion situation. If it is not, the segmentation result is dependable, so the segmentation result is selected as the corresponding measurement.

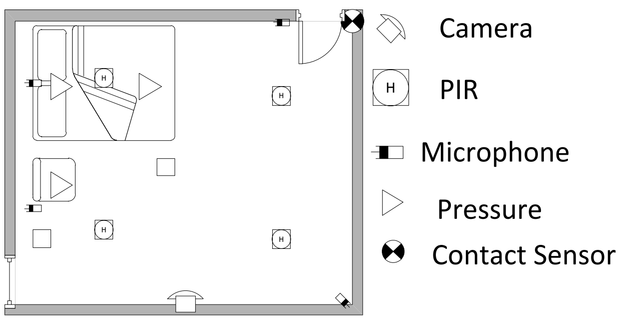

Fig. 5. Overview of multi-sensor in home.

Otherwise, we utilize multiple kernels tracking from which we get the multiple measurements and apply probabilistic data association. By using the measurement either from segmentation results or the multiple kernels tracking results, we are able to update the Kalman filter and display the tracking result.

TABLE I: FUZZY SETS DETERMINED

Membership function	Composition
IP camera sensors	Position
Acoustic sensors	Open-Close Door, Knock
Passive Infrared sensors	present, absent
Pressure sensors	on, off
Contact sensors	on, off

From Table I, subsystem five inputs are built. (1) camera sensor the position classification in home, (2) Acoustic sensors, (3) Passive Infrared sensors use to movement detection in area, (4) Pressure sensors to measured pressure levels on chair, table and bed , (5) Contact sensor use to in-out the door detection.

The next step of our fuzzy logic approach is the fuzzy inference engine which is formulated by a set of fuzzy IF-THEN rules. This second stage uses domain expert knowledge regarding activities to produce a certainty in the occurrence of an activity. Rules provide the recognition of common performances of an activity, as well as the ability to model special cases. The output of human activities recognition such as sitting, standing, sleeping, walking, and in-out the door. A code was developed in the MATLAB environment and simulations were performed [9]. The example below represents the tested model. An example fuzzy rule for human activity detection is:

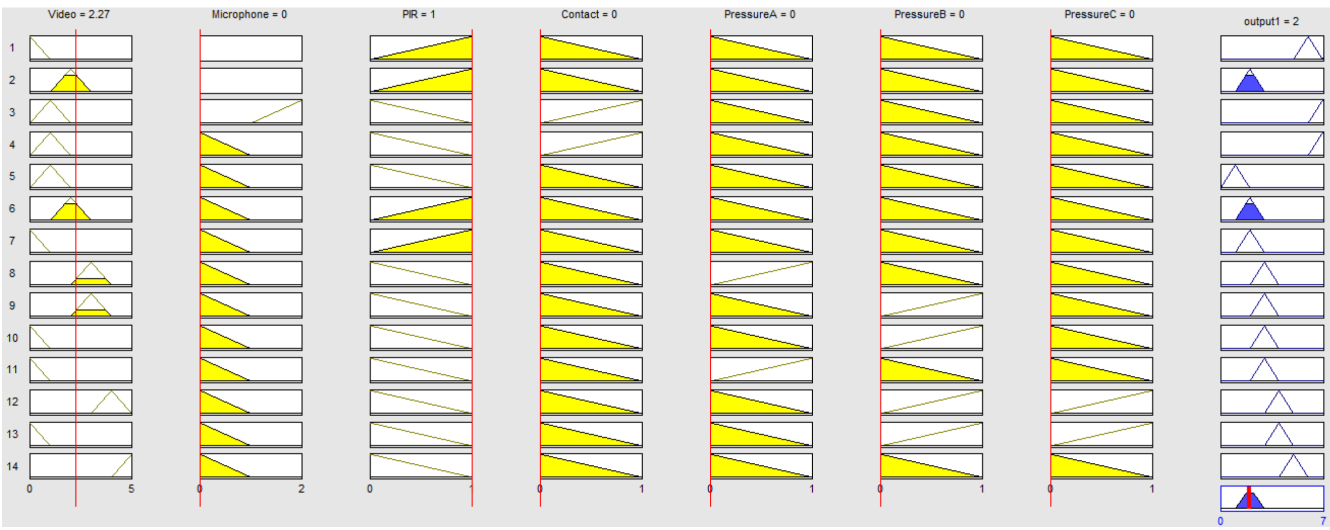

Fig. 6. Rule of Fuzzy set activity (walk).

V. CONCLUSION

In this paper a suitable scheme for Multisensor fusion using Kalman filter has been proposed. This approach takes the advantage of Kalman filter optimality improved real-time performance [10]. A set of Kalman filters with different measurement noise covariance matrix around the adapted one is applied to have a statistical measurement for each sensor. The main advantages of the present method consist of the low computational from the characteristics of fuzzy logic system.

This approach allows the easy combination between data and adding other sensors. The fuzzy logic decision supports the secure detection of elderly. Finally, the based multi-sensor data fusion is able to extract the measurement data with higher precision in real time. The architecture is effective in where there are several sensors measuring the same parameter and each sensor measurement is contaminated with a different kind of noise. This work has applications in the development of smart structural health monitoring systems, robotics, controls, biomedical imaging, and target tracking. Moreover, it reflects the efficiency and feasibility to real-time circumstance measure and data processing in a system condition monitoring and measurement.

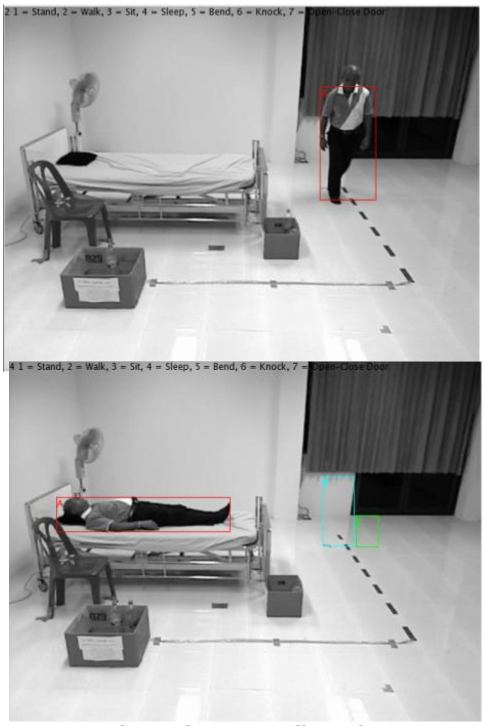

Fig. 7. Behavior detection (walking, sleeping).

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