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AN EFFECTIVE STUDY ON DATA FUSION MODELS IN WIRELESS SENSOR NETWORKS

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ABSTRACT

Energy consumption is a very big challenge in Wireless Sensor Networks (WSN) as the battery power of sensor is limited and limited storage capacity. In real time environment, large no of sensors are deployed for data collections and in some cases sensor fails to collect the data due to the external factors such as pressure, temperature and electromagnetic noise. Lot of energy is consumed in vain for computing these incorrect measurements. Data fusion is the best solution to reduce the energy consumption in WSN, when data collection is interrupted by the sensor failure. Using data fusion the redundant data collected from sensor can be reduced, which can reduce the energy consumption of the entire network thereby enhancing the lifetime of the sensor network. In this paper a detailed survey on the various existing data fusion models are done and the comparisons on the various fusion models were discussed.

Keywords: data fusion model, sensor fusion, data fusion architecture, WSN, energy consumption.

INTRODUCTION

WSN is also called as Wireless Sensor Actuator Network. It is designed to monitor and process the data from different environment such as temperature, pressure, sound etc. WSN is used in many applications namely health monitoring [1], military applications [2], Geospatial applications [3], Environmental monitoring [4], home land security [5], Medicine [6], etc. The WSN consists of massive amount of small sensors are deployed for knowledge collection, these sensors are grouped together to observe the measurement from environments. In some situation sensors fails to gather the information owing to the external factors like pressure, temperature, magnetism noise. So lot of energy is consumed vainly for computing this incorrect measurement. Life time of the entire sensor network will be reduced [7].

Due to the limited power and energy, energy consumption is a very big challenge. In [8], to reduce energy consumption VANET is divided into number of cluster and each cluster has cluster head (CH). CH only performs communication to outside of cluster. By this way energy consumption is reduced for other cluster nodes. To increase the security and reliable transmission of data in WBSN, this paper proposes a light weight cryptographic HIGHT (High Security and Light Weight) technique combines with ECG (electrocardiogram) signal based establishment of key for secure communication in Wireless Body Sensor Network (WSBN) [9]. In [10] different data fusion techniques architecture and their advantages and disadvantages are discussed. Data fusion is the best solution to reduce the energy consumption in WSN [11], which is used to overcome sensor failures. Data fusion will reduce the energy consumption of the complete network thereby increase the life time of energy by means of eliminating the inaccurate and redundant data collected from sensor.

Data fusion is a process of association, correlation, combination of data and information from multiple sources to achieve more accurate results. Data Fusion techniques are of great use and is rapidly growing in research area. This is useful in various applications in different areas. Data fusion is able to present solutions to different areas by means of its architecture and diversity of techniques. In [12] Community Model architecture is proposed to reduce the data transmission cost and data transmission overhead. In Figure-1 1, 2, 3, 4, 5 represent the sensor nodes. These nodes will collect the data and collected sensor data will be transmitted to fusion node to delete and reduce the redundant data using data fusion technologies. Each fusion node will have multiple sensors. Finally the fused data or processed data will be transmitted to fusion center.

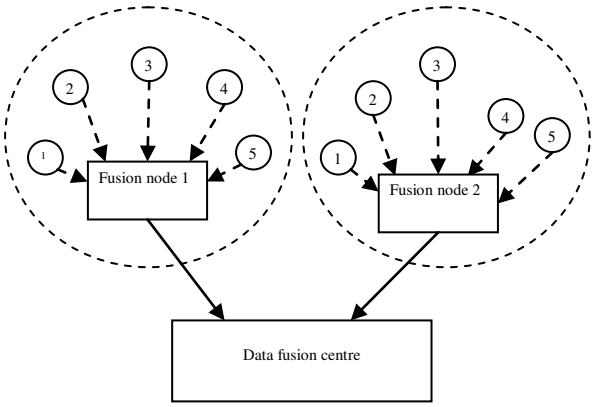

Figure-1. Data fusion in WSN.

This paper is organized as follows, first it describes about different data fusion models, next section will gives the comparative study of each model.

DATA FUSION MODEL FOR WSN

Data fusion is established as an independent research area. Data fusion is also an information fusion. Many fusion models and many sensor fusion architectures have been introduced to serve for data fusion systems. These data fusion models are categorized into a) Data-

Based Model, b) Activity - Based model, c) Role - Based model.

JDL data fusion model

JDL is the most popular and well known data fusion model. This JDL Model is proposed by U.S. Joint Directors of Laboratories and Department of Defense (DoD) in 1985. The goal of data fusion group is to coordinating Department of Defense activities and improves the communication and cooperation between development groups with the purpose of integrative research. This effort leads to a result, creation of number of activities. 1) Development of a fusion model for data fusion, 2) Field study for data fusion, 3) Development of engineering guidelines for building data fusion systems. JDL Model is one of the data based model which is based on the abstraction levels of data manipulated by the data fusion system. The JDL model consists of five different processing levels. They are resources, Human Computer Interaction (HCI), database and data bus which connects all components together and preprocessing source [13].

As shown in the Figure.2, the source data can be a local or distributed sensor, or the data from database or human input. Then HCI represents Human Computer Interaction which allows the interface between computers and people. HCI observe different kind of human inputs like data request, commands, reports [14].

Level 0 is the Process Alignment state. This source processing will select the appropriate source and allocate the data to the appropriate process to reduce the load in the data fusion system.

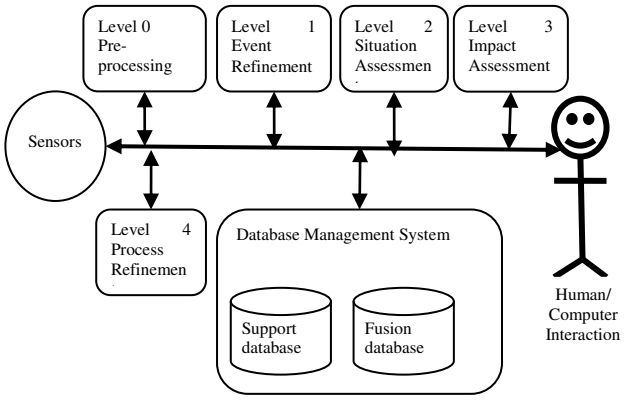

Figure-2. JDL data fusion model.

Level 1 is the Object Refinement state or Event Refinement. This will convert all sensor data to achieve more accurate and reliable estimates of position, velocity, properties, and identify the individual objects. Level 2 is the Situation Refinement state. It attempts to examine the relationship among object and observed events. Proper knowledge and environmental data's are used to identify a situation.

Level 3 is the Threat Refinement or impact assessment state. It predicts the current situation and relates with future and gives conclusion about enemy threat, vulnerability, weapon assignment, and opportunities for conducting operations.

Level 4 is the Process Refinement state. This is the final process level. This is used to monitor the performance of entire Data Fusion process is to evaluate and improve the performance of the real time systems. Also it is responsible to allocate the sources needed to obtain the specified goals [15].

Dasarathy model

Dasarathy model is a Data-Based Model. It is functionality oriented model, rather than the task it is based on fusion function. There are three levels of abstraction.

a) Data

b) Feature

c) Decision

Based on the levels of abstraction it is also known as Data-Feature-Decision. The categorization of data fusion is specified based on the type of data level at input and output.

The data levels are Low level fusion, Middle level fusion, and High level fusion.

Data in - data out is the most basic data fusion method. The primary input and output is a raw data. The output is more accurate and reliable. Data fusion is done immediately after the Data's gathered from the sensors.

In Data in- Feature out will extract the features and characteristics of raw data.

Feature in-Feature out this process is also known as feature fusion or information fusion or symbolic fusion or intermediate level fusion. A set of features will be worked to improve a feature or extract a new feature.

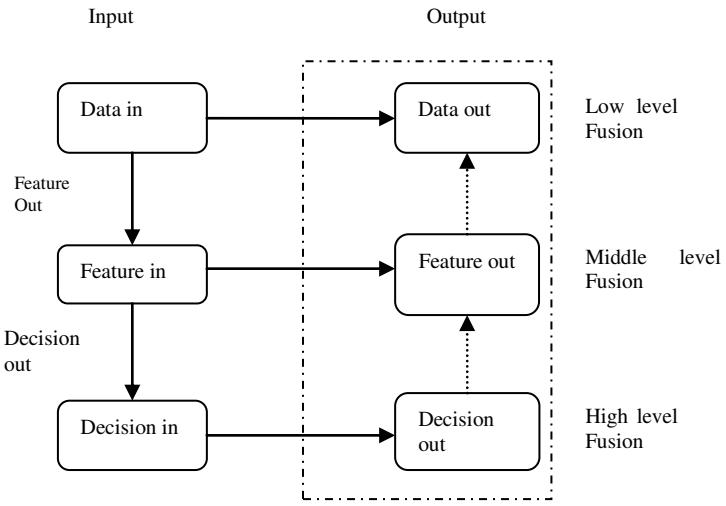

Figure-3. Dasarathy model.

Feature in - Decision out, decision can be taken based on the set of feature as an input. The decision can be Pattern recognition and pattern processing.

Decisions in - Decisions out, Obtain a new decisions from the fused decisions. This is a high level fusion [16].

Boyd control loop

Boyd control loop is the activity based model. This is the four stage cyclic loop. This is also called OODA loop, which refers Observe, Orient, Decide, and Act. Developed by the Military Strategist and U.S States Air Force Colonel John Boyd in the year 1987.

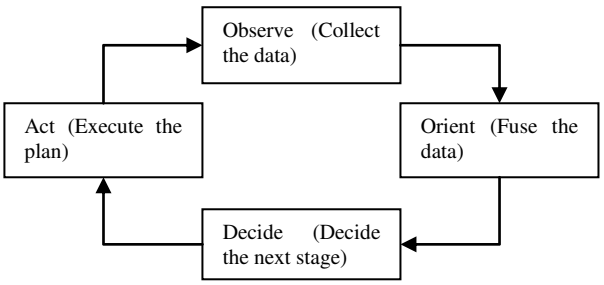

Figure-4. Boyd control loop.

The first stage of OODA is Observe; this will collect and pre-process all the data from sensor. The next stage is Orient; the collected data is fused to clarify the current scenario. Decide is the next stage, based on the previous stage, (i.e. Orient) action plans are decided for the future. The final stage is Act where the plan which is decided in the previous stage is executed. Figure-3 shows the Boyd control loop (OODA Loop) [17].

Intelligence cycle

This is the four stage cycle of intelligence process in a military intelligence agency. The intelligence cycle is also called Intelligence process by U.S Department of Defence and the uniformed services.

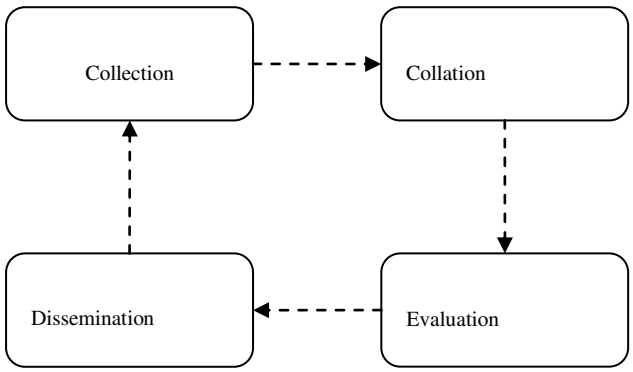

Figure-5. Intelligence cycle.

Collection is the first stage in intelligence cycle, which will collect the raw data from the environment. Collation is the next level, all the collected data is analysed and correlated. Redundant and unreliable data's are discarded. Evaluation is the third stage. In this stage the collated data's are Fused and analysed. Dissemination is the next level to produce the decision based on the result of fused data from the previous stage Evaluation [18].

Waterfall model

Waterfall fusion model is a hierarchical architecture where output of one level is the input for the next level. It is similar to JDL Data fusion model.

Water fall data fusion model is the hierarchical architecture, which is used by the UK defence data fusion community. This was proposed by M. Bedworth. This model is composing of three levels. In level 1raw data's from environment is transformed with the help of sensors. Then the transformed data's are processed. Level 2 is composed of feature extraction and pattern processing. The processed signal form the level1 is extracted and minimize the data content. In level 3 decisions are made

based on the information gathered from the previous levels [19].

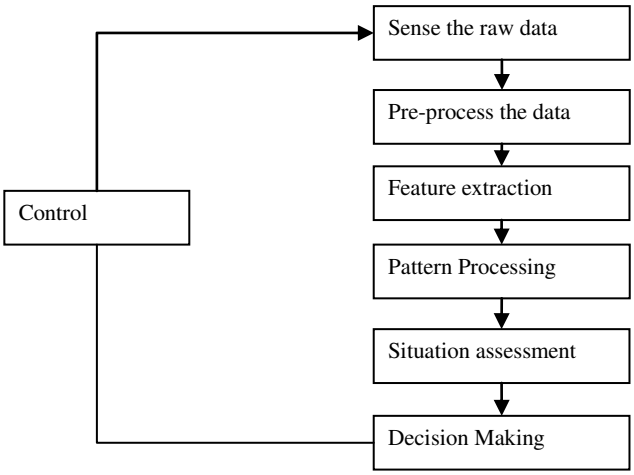

Figure-6. Water fall model.

Omni bus model

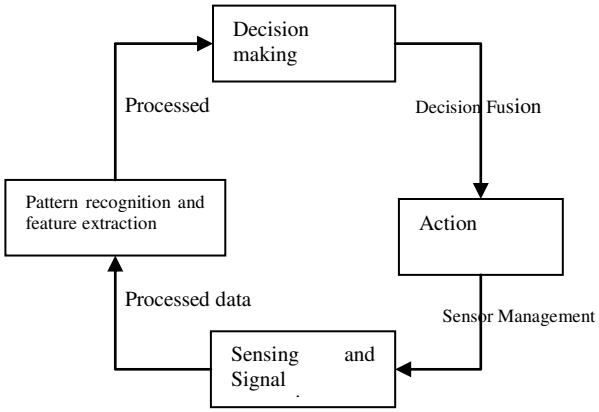

Figure-7. Omnibus model.

The omnibus model was proposed after the comparison of the entire previous model. This is proposed by Bedworth and O'Brien. There are four stages, the first stage is sense the data by means of sensor and processes the data, and it is also called sensing and preprocessing. Next stage will perform extraction and pattern processing from the gathered data. Those extracted patterns are then fused. Based on the feature extraction decision are made and threats are detected. From the decision stage the most suitable plan will be selected and executed, that is called Act stage. Omnibus model is more generalized than other data fusion model [20].

Role based model

The change of focus on the modeling and designing of data fusion systems is represented by role based model. It focuses on roles rather than activities. Like the JDL model the systematic view of data fusion is provided by the role based model. Although it gives a set of rules along with specifying the relationship between them, it does not specify the fusion activities or tasks. There are two models under this Role-Based model

Object Oriented Model
Frankel-Bedworth Architecture

Object oriented model

Kohar proposed Object-Oriented Model, Which has the cyclic architecture. There are four roles.

- Actor: The role of actor is to interact with the world, collect the data, and Environmental act.
- Perceiver: Perceiver will analyze and evaluate the data collected
- Director: Based on the evaluation and analysis done by the perceiver, the director will set the system goals to build a plan.
- Manager: It has a role to execute the plan which is provided by the director.

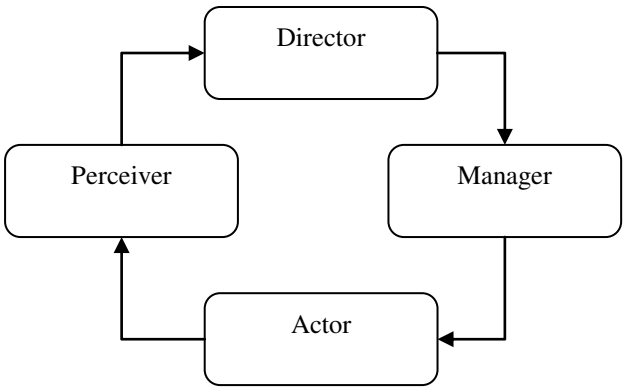

Figure-8. Object-oriented model.

Frankel-bedworth architecture

- A Fusion architecture, which needs two self regulatory processes. They are Local and Global process.
- Local: Goals and timetables are given by the Global process. Based on this execution of the current activities managed by the local processes.
- Global: Time tables and goals are updated based on the feedback given from the local processes. Providing the new goals and timetables for local processes.

Local and global processes have different roles and objectives. Local processes are similar to previous fusion model. They are

- Sense(Data gathered)
- Perceive(Focus and awareness)
- Direct(feedback based on the comparison between current and desired situation)
- Manage(Controller is activated, estimator provide the proper response, estimator gives the feed back to the controller)

Effect (selected response are applied, changes in the environment is sensed, control loop completed) [21].

COMPARISONS

Data fusion Models	Advantages	Disadvantages
JDL fusion model	Most popular data fusion model. Can be applied for both military and commercial applications.	Difficult to reuse or extend the application. Very abstract. Does not help to develop architecture for a real system.
Dasarathy model	Very useful to specify and design a fusion algorithms in WSN.	Does not provide a systematic view.
Boyd control model	It is a closed control system. Gives an overview of a system task.	Lacks to identify and separate the sensor fusion task.
Water fall model	As similar as JDL model	Exclusion of any feedback data flow.
Intelligence cycle model	It is general and applied in any application domain	Do not fulfill the specific aspects of fusion domain.
Omni bus model	It is cyclic in structure. Can be used multiple times for the same application.	Decomposition is not supported. Need to implement, test and reuse separately for different applications.

CONCLUSION AND FUTURE WORK

Data fusion plays a vital role in WSN to save energy of the sensors. Wireless Sensor Network has the ability to eliminate the redundant data, efficiently give accurate data and consequently reduce the energy consumption. In this paper, different Data fusion models and their working principle are studied, analysed and surveyed in order to understand the goals of each data fusion model. The comparison between various data fusion models are made and summarized. However, an efficient model that supports decomposition of data needs to be developed and implemented. This could be considered in future work.

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