Application of Multi-Resolution Integration Algorithm (MRIA) in RFID-based distributed sensor network

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Abstract

The Radio-Frequency Identification (RFID) based Distributed Sensor Networks (DSNs) is most extensively used in distributed network technologies. Each sensor in a cluster measures the same parameters. It is possible that some of them are faulty. Hence it is desirable to make use of this redundancy of the readings in the cluster to obtain a correct estimate of the parameters being observed. This research investigates the application of multi-resolution integration algorithm (MRIA) [1] *in RFID-based distributed sensor network and it impacts on operation processes.*

Keywords: RFID-*based distributed sensor*, DSN, MRIA, MADSN

1. Introduction

The RFID sensor nodes can increase the computation load, while more faulty sensors can cause the integration to be unreliable. Therefore the algorithms that are sought should not be significantly affected by network scaling. The latter idea was based on constructing overlap function of sensors outputs in a cluster and resolving this function at various successively finer scales of resolution to isolate the region over which the correct sensors lies.

2. MRIA in DSNs sensor

The MRIA in DSNs sensor was used to determine the effectiveness abstract sensors. We classified abstract sensors into two categories: correct sensors and faulty sensors. The correct sensor is an abstract sensor whose interval estimate contains the actual value of the parameter being measured. Otherwise, it is a faulty sensor. The faulty sensor is tamely faulty if it is a correct sensor, and is wildly faulty if it does not overlap with any correct sensors. For example if sensors $S_1 \ldots S_N$ feed into a processor P. Let the abstract interval estimate of S_j be $I_j (1 \le j \le N)$, the closed interval $[a_j, b_j]$ with end points a_j and b_j (see equation (1) below). The characteristic function χ_j of the jth sensor S_j is defined as follows:

$$\chi_j(x) = \begin{cases} 1, & \text{if } a_j \le x \le b_j \\ 0, & \text{if } x > b_j \text{ or } x < a_j \end{cases} \quad (1)$$

And if $\Omega(x) = \sum_{j=1}^{N} \chi_j(x)$ the "overlap function" of the N abstract sensors, then for each $x \in R$ (R is the set of the real number of 1-dimension), $\Omega(x)$ gives the number of sensor intervals in which x lies; that is, the number of intervals overlapping at x.

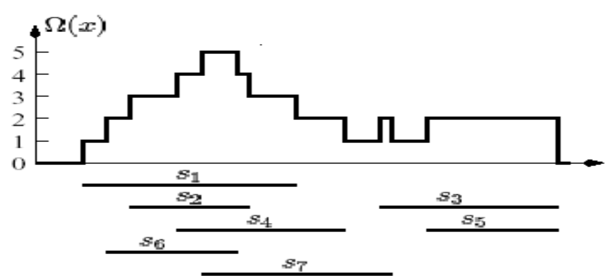

Figure 1: Overlap function of a set of 7 RFID sensors

The Figure 1 above illustrates the overlap function for a set of 7 RFID sensors calculated from their characteristic functions. The crest is a region in the overlap function with the highest peak and the widest spread. The tamely faulty sensors cluster around correct sensors creates maximal peaks in the profile of $\Omega(x)$. The wildly faulty sensors on the other hand do not overlap with correct sensors, and therefore contribute to smaller and narrower peaks.

However, the actual value of the parameter being measured lies within the regions over which the maximal peaks of $\Omega(x)$ occurs with the widest spread. The multi-resolution analysis of the overlapping function expected time is O (n log n), which is the time required to maintain $\Omega(x)$.

The algorithm is also robust, and ensures that minor changes in the input intervals cause only minor changes in the integrated result. The Figure 2 shows simulations of the multi-resolution analysis outcomes.

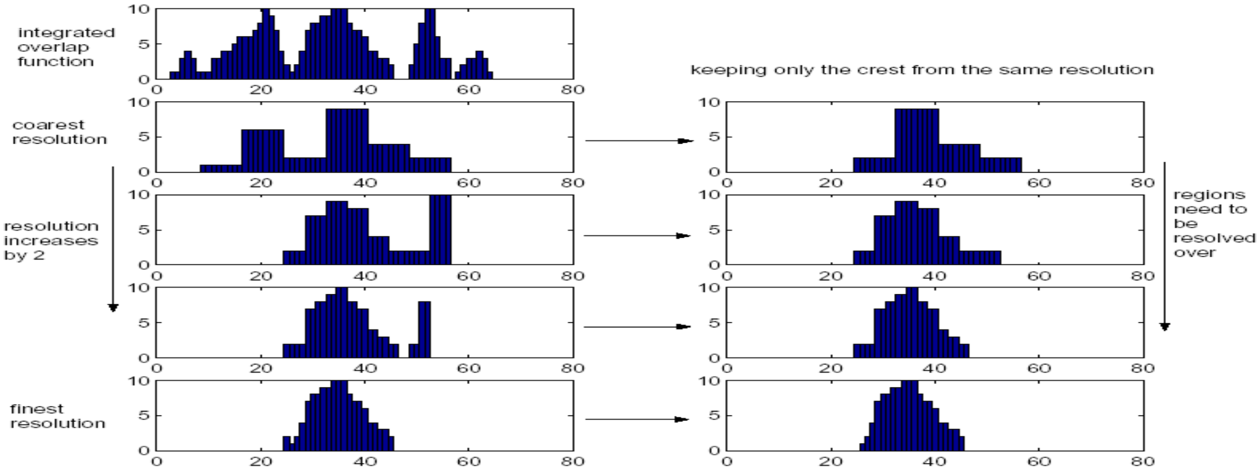

Figure 2: The overlap function

3. Decentralised MRIA

The traditional DSN, data are collected by individual sensors, and then transmitted to a higher-level processing element, which performs sensor fusion. During this process, large amounts of data are moved around the network. When the Mobile-Agent-Based DSN (MADSN) adopts a new computation paradigm the data stay at the local site, while the integration process (code) is moved to the data sites. By transmitting the computation engine instead of data, MADSN offers the following important benefits [2]:

- Network bandwidth requirement is reduced: Instead of passing large amounts of raw data over the network through several round trips, only the agent with small size is sent. This is especially important for real-time applications and where the communication is through low-bandwidth wireless connections.
- Better network scalability: The performance of the network is not affected when the number of sensor is increased. Agent architectures that support adaptive network load balancing could do much of a redesign automatically [3].
- Extensibility: Mobile agents can be programmed to carry a task-adaptive fusion process, which extends the capability of the system.

In a mobile-agent-based DSN (MADSN), the mobile agents migrate among the RFID sensor nodes and collect readouts.

Therefore, $MA_{i,j}$ always carries a partially integrated overlap function which is accumulated into a final version at PE_i after all the mobile agents return. During this process, if MADSN applies the multi-resolution analysis method in the same way as DSN does, that is, enabling $MA_{i,j}$ to carry the partially integrated overlap function in its finest resolution and then use multi-resolution analysis (MRA) to find the crest at the desired resolution at PE_i, the advantages of mobile agents will be nullified because of a heavy data migration. The basic MRIA was enhanced for MADSNs and presents a more efficient implementation. The key concept underlying the enhanced algorithm is that MRI is applied before accumulation of the overlap function. A 1-D array, $\omega_{i,j}$, can serve as an appropriate data structure to represent the partially integrated overlap function carried by $MA_{i,j}$. We use the following notation PE_i is the processing element of interest, m the number of mobile agents dispatched, $MA_{i,j}$ the mobile agent dispatched by PE_i ($1 \le j \le m$), and [A_i, B_i] the interval that covers readouts from all the sensors migrated by $MA_{i,j}$. The Tables 1 and 2 below shows the step-by-step execution result for each agent.

Table 1: Tracing the change of $\omega_{i,1}$ generated by $MA_{i,1}$

$s_j[a,b]$	d_{min}	d_{max}	$d_{min}/2^{-k}$	$d_{max}/2^{-k}$	$\omega_{i,1}$
$s_1[2,10]$	8	8	1	1	[0,1,0,0,0,0,0,0]
$s_2[4,15]$	8	8	1	1	[0,2,0,0,0,0,0,0]
$s_3[10,20]$	16	16	2	2	[0,2,1,0,0,0,0,0]
$s_4[15,25]$	16	16	2	3	[0,2,2,1,0,0,0,0]
$s_5[20,27]$	24	24	3	3	[0,2,2,2,0,0,0,0]

Table 2: Tracing the change of $\omega_{i,2}$ generated by $MA_{i,2}$

$s_j[a,b]$	d_{min}	d_{max}	$d_{min}/2^{-k}$	$d_{max}/2^{-k}$	$\omega_{i,2}$
$s_6[14,28]$	16	24	2	3	[0,0,1,1,0,0,0,0]
$s_7[30,40]$	32	40	4	5	[0,0,1,1,1,1,0,0]
$s_8[21,31]$	24	24	3	3	[0,0,1,2,1,1,0,0]
$s_9[45,60]$	48	56	6	7	[0,0,1,2,1,1,1,1]
$s_{10}[20,35]$	24	32	3	4	[0,0,1,3,2,1,1,1]

4. Overlap function

In DSN, all readouts from the RFID sensor nodes are sent to their corresponding processing elements, where the overlap function at the finest resolution is first generated, and the multi-resolution analysis procedure is then applied to find the crest at the desired resolution (see Figure 3).

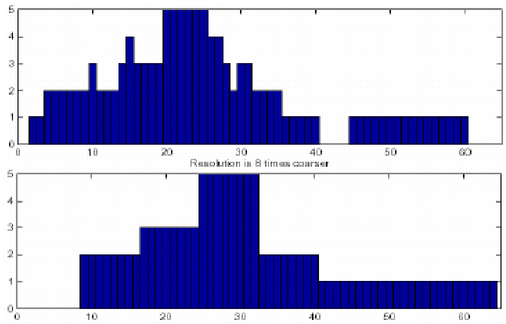

Figure 3: The overlap function at its finest resolution

If we define the unit data transfer time as the time spent for $MA_{i,j}$ migrating from one node to another, carrying a one-element array, then MADSN spends 8 * 5 + 8 * 2 = 56 units of time (assuming $MA_{i,1}$ and $MA_{i,2}$ are executed in parallel when migrating from node to node or from PE_i to node which costs 8 * 5 units of time, and in serial when returning to PE_i which costs 8*2 units of time), while DSN spends 64*10 = 640 units of time. Hence, MADSN offers up to 91.25% of data transfer time in this case. In this experiment the mobile agents is the parallel fusion carrying out the performance.

5. Conclusion

We are able to show that the application of MRIA is possible to realise the RFID MADSN. We exploits four algorithms functionalities in evaluating our experiment: multi-resolution analysis of the overlap function, modified MRIA for MADSN - before $MA_{i,j}$ leaves PE_i, modified MRIA for MADSN - before $MA_{i,j}$ at the sensor node, and modified MRI algorithm for MADSN - before $MA_{i,j}$ leaves PE_i.

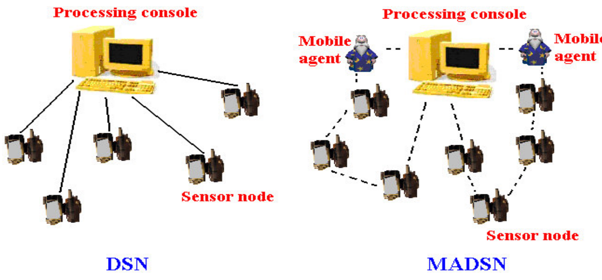

Figure 4: DSN and MADSN

Finally, we have also proved that DSN and MADSN approach can be applied to RFID technologies with the aim of making the operation processes faster [4] (see Figure 4).

6. Reference

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