Comment

Impact of Brooks-Iyengar Distributed Sensing Algorithm on Real Time Systems

Vijay Kumar

Abstract—In this paper we evaluate the merit of Brooks-Iyengar distributed sensing algorithm and highlight its impact on cost-effective processing of real-time sensor data stream. We discover that it has a long-lasting impact, not only on sensor networks, but also on computer operating systems. We believe that as we learn more about the usefulness of this algorithm, it will become an essential component of system that use sensors in some form.

Index Terms—Real-time, two-phase locking, sensor network, sensor, sensor stream

1 Prologue

Time to time some algorithms appear and significantly affect technology. One such algorithm is Brooks-Iyengar Distributed Sensing Algorithm [1], [2], [3], [4], [5] that has had a profound impact on sensor technology similar to the effect thethe TCP/IP suite of protocols has had on data communication, Dijkstra's algorithmhas had on process synchronization, and two-phase locking protocols has had ontransaction serialization. It solved a number of complex issues in the deployment of large scale sensor networks and continues to do so as the technology moves forward.

In 1996, the Iyengar's group, in collaboration with Brooks and with funding from Oak Ridge National Laboratory, observed that mapping a group of sensor nodes to estimate its value accurately needs all the sensors to exchange the values with each other making it computationally expensive. In their framework, the sensors array that are highly distributed and contain individual sensors measure a common phenomenon. The real-time sensor stream is sent to a virtual sensor that aggregates the set point only from the good sensors. If the sensors are able to communicate within themselves then some of the redundant information can be eliminated, but such cooperation would be highly energy inefficient. The design of such distributed systems would not know how many faulty sensors are present, so the use of the Byzantine algorithm, which allows a solution to this gap, invented a method of fault tolerance modeling that offered a computationally inspired real-time task management solution. The algorithm referred to as the Brooks-Iyengar algorithm or the Brooks-Iyengar hybrid algorithm is a distributed algorithm that improves both the precision and accuracy of the measurements taken by a distributed sensor network, even in the presence of faulty sensors. The algorithm does this by exchanging the measured value and accuracy value at every node with every other node. In addition, it computes the accuracy range and a measured value for the whole network from all of the values collected. The algorithm demonstrated that even if some of the data from some of the sensors are faulty, the sensor network does not malfunction.

- *The author is with the University of Missouri-Kansas City, Kansas City, MO.*

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With time, system developers recognized other strengths of this algorithm. It played a key role in adding real time extensions to Linux Operating Systems. Many of these algorithms were used and installed in the RT Linux Operating System. They are now working on formal model verification by incorporating the algorithms into a new embedded kernel for robotic applications. The profound contribution of the Brooks-Iyengar distributed computational sensing work has enhanced new real-time features by adding fault tolerant capabilities.

Motivated by the profound impact of this algorithm, the DARPA agency Sense-IT system used the Brooks-Iyengar fusion approach to combine sensor readings in real-time. Acoustic, seismic, and motion detection readings from multiple sensors were combined and fed into a distributed tracking system. This work was an essential precursor to the Emergent Sensor Plexus MURI from the Penn State Applied Research Laboratory (PSU/ARL). Following this demonstration, a number of other groups effectively deployed the algorithm in this product. For example, the Thales Group, a UK Defense Manufacturer, used this work as partof its Global Operational Analysis Laboratory.

2 Epilogue

Sensors have become highly pervasive. They have become the spinal cord of every system. The struggle for efficient inter-sensor and intra-sensor communications has found its life blood in this algorithm. Take an example of driverless cars and automatic control of traffic that presents us with a highly complex distributed sensor network. It requires accurate data sharing for accident-free traffic control, self-synchronization [6], [7] of moving vehicles at road intersections, and a number of other communication tasks. The Brooks-Iyengar algorithm will play a crucial role in the automation of moving vehicles in 2D and 3D space.

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