Abstract

Now-a-days real-time systems have been intensively explored by the research community around the world due to many future technologies require real-time processing. Enormous efforts have been made on the upcoming technologies such as Internet of Things (IoT), Machine-to-machine (M2M), Cyber-Physical systems (CPS), Big data etc. These new technologies rely on wireless sensor and actuator networks (WSAN) as a communication media to perform real-time control and communication. However, by using WSAN, the point-to-multipoint mode of communication cannot guarantee reliable and real-time communication. Thus unreliable communication severely degrades the overall system performance and as well as it can affect the control and computation of the real-time system. To ensure real-time and guaranteed communication for point-to-multipoint configuration, data recovery scheme is needed. One of the examples of real-time point-to-multipoint systems is CPS, which enable orchestrating networked computational resources with physical systems. Moreover, CPS have many benefits over conventional network control system in terms of network integration and scalability point of view and also attract attention in a variety of different areas such as smart grid, health care, intelligent transportation, etc.

CPS enable the virtual world to interact with the physical world in order to monitor and control the intended parameter in real-time basis through the feedback control loop. Thus, the proper timing and accuracy of feedback data is very important for the interaction between the cyber and the physical world. Therefore a data recovery scheme is designed to ensure uninterrupted control in CPS.

This dissertation concerns research of technological issues for analysis of data, design and evaluation of a data recovery algorithm and error minimization from the recovered data. The overall objective of this dissertation is to develop a data recovery scheme, which provides quality of result in terms of efficiency and real-time.

In the data analysis part, the data patterns of various physical systems are investigated and a general classification is made according to the property such as data series with small variation, or large variation and/or repetition exist on the data series. To recover various patterns it is important to know the nature of their underlying property. To do this, a data pattern analyzer is proposed which is able to classify various data patterns, as a data pre-processing step. iHouse data and Intel Berkeley Research lab data are examined using the analyzer.

Some data series remain stable with small change time and some time it is highly correlated with space. Thus to recover this, a data recovery scheme, called Efficient spatial data recovery (ESDR) scheme is proposed. In this scheme, a recovery algorithm is presented with Pearson correlation coefficient (PCC) to efficiently solve the long consecutive missing data. The proposed scheme is evaluated on iHouse data. On the other hand some data patterns have a randomness and variation in its nature, which make a great challenge to maintain the real-time control whenever the data is lost. To handle these kind of data, an Efficient Temporal and Spatial Data Recovery (ETSDR) scheme is proposed. The proposed scheme consists of two phases. In the first phase, which is pre-processing step, the temporal model is identified for large variation data and determined the spatial effects of neighbors. Auto Regressive Integrated Moving Average (ARIMA) model is a very

powerful model to identify the auto-correlated nature or trend of a data series. In the next phase, which is real-time/online, temporal model and spatial effect is utilized to recover missing data.

Moreover to improve the recovered data, Kalman filter is used to reduce the error from the model estimated data. The temporal model, generated from ARIMA has internal errors and the model parameters may not remain constant. Thus, to improve the accuracy of the estimated data, a Kalman filter is incorporated to reduce the error. Before that, the window for Kalman filter is fixed to determine the proper process noise co-variance in real-time. Numerical results reveal that the proposed ETSDR/EM are very promising regardless of the increment percentage of missing data in terms quality of result (QoR).
This proposed research can help the development of CPS applications by ensuring uninterrupted control.

Keywords: correlation, cyber-physical systems, data recovery, real-time, quality of result.