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## 主論文の要旨

論文題目

REAL TIME SCHEDULING AND ANALYSIS FOR CAN MESSAGES WITH OFFSETS (オフセット付き CAN メッセージのリアルタイムスケジューリングと解析手法)

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## 論文内容の要旨

The Controller Area Network (CAN) was designed as a simple, efficient and robust broadcast communications bus for in-vehicle networks; and it has been widely used by automotive manufacturers in recent decades. In the development of CAN system, schedulability analysis theory plays an important role in evaluating whether the system is schedulable or not. This is accomplished by calculating the WCRT (worst-case response time) of every message, and comparing it with the corresponding deadline. This theory has been recognized by major automotive manufacturers; and has been applied to the design of their-vehicle networks of a wide range of cars since 1998.

In recent years, the sophistication and complexity of in-vehicle communications has seen a notable increase in the number of transmitted messages, thus decreasing the schedulability of the networks. In this context, scheduling messages with offsets has emerged as an effective method to improve the schedulability of modern CAN networks. However, it remains unsolved how to assign offsets to the messages in order to obtain a better schedule with respect to the WCRT; and how to analyze the schedulability of messages with offsets, when they are sent using FIFO (first-in-first-out) queues. These issues limit the practical application of offset-based message scheduling.

To tackle these issues, in this dissertation, an offset assignment method; a schedulability analysis method for CAN messages with offsets in a system using FIFO queues; and a schedulability comparison between priority queues and FIFO queues for CAN messages with offsets are proposed. The contributions of this dissertation are as follows.

- An offset assignment method that employs the Simulated Annealing (SA) algorithm for a better offset assignment with respect to the WCRT. The method initializes offsets by restricting the objective function of SA, which is selected as Maximum Interference Function obtained from messages in each station, as small as possible. Then, according to the WCRT corresponding to the initial offsets, the method modifies the objective function and reforms the offsets to guarantee that all messages meet their deadlines. Compared to previous work, the proposed method improves the schedulability of CAN messages effectively.
- A schedulability analysis method for CAN messages with offsets in a system using FIFO queues. In the analysis method, a new critical instant theorem is proposed to locate the worst case situation for a given message. Then, based on this theorem two algorithms for calculating the WCRT are proposed. The new critical instant theorem is proved to be valid; and several experiments, using synthetically generated message sets and a real-world message set provided by an automobile manufacturer, are conducted to confirm the method to be effective.
- A schedulability comparison between priority queues and FIFO queues for CAN messages with offsets. The results show that priority queues achieve higher schedulability for normal message sets, but FIFO queues are better for some special message sets. To combine the advantages of the two types of queues, a new scheduling method that uses both priority and FIFO (P&F) queues in a single station is proposed. The schedulability analysis results using a real-world message set — provided by an automobile manufacturer — show that the combination of priority and FIFO queues can achieve higher schedulability than either priority or FIFO queues alone.