Intelligent Loading and Unloading System for Signal Processing Based on OBDD

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Abstract. In order to realize the fast dynamic loading and intelligent switching for application tasks in the signal processing platform, this paper analyzes the system of intelligent loading and unloading, and builds the software and hardware resource model for the signal processing platform, situation parameter definition dictionary and intelligent loading and unloading rule base. Then through the intelligent rule decision algorithm based on the ordered binary decision diagram, it is realized that the intelligent loading and unloading for the application task under the minimum manual intervention. Finally, the algorithm proposed in this paper and sequential rule storage algorithm are compared. The results show that the algorithm of the intelligent loading and unloading for signal processing tasks designed in this paper has higher practicability, timeliness and intelligence.

1. Introduction

Since entering the era of big data [1], communication technology has entered the cognitive radio stage [2]. Software-defined multi-domain and multi-level heterogeneous signal processing platform [3] has become a hotspot in signal processing platform due to its powerful computing power. In addition, the cognitive radio [4][5] provides a theoretical basis for the realization of the cognitive signal processing system. Based on this, this paper solves the above problems by building a smart loading and unloading rule base.

In order to build the intelligent loading and unloading rule base, according to the hierarchical structure and mutual relationship of different classes, Wang Wansen uses the object-oriented linked list method to construct the rule base, which realizes the orderly storage and efficient management of rules [6]. The rule storage scheme of the doubly linked list provides a method for efficient storage of the rules for this paper. Li analyzed the basic structure of the rule base and applying it [7]. This patent mainly applies to the general rule base but is not applicable to signal processing. R.E.Bryant proposed the OBDD (Ordered Binary Decision Diagram) [8]. From then on, the intelligent rule decision tree can be modeled, quantified according to OBDD, and realized into the database. This paper can learn from the representation method of OBDD graph to express the rules. Liu further analyzed the relevant theories and construction methods of OBDD in the study for ordered bifurcation decision graphs and their construction algorithms [9], which provided a theoretical basis for the construction of rule bases.

Designing the OBDD-based rule base for the firewall, Cheng Yong et al. used OBDD to judge the rules of data packet header information, which improved the storage and invocation of firewall rule base[10]. It is not suitable for signal processing platform, but its design idea is worthy of reference. In the ordered binary decision graph representation and reasoning of the production knowledge [11], Hou
Jie et al. quantified the rule base into OBDD, realized the classification reasoning function of the commodity, and provided experimental examples for the design of the algorithm.

The above research mainly describes the basic structure principle of the rule base, and can not be directly applied to the signal processing intelligent loading and unloading system. However, the research provides a certain theory and experimental examples for the design and implementation of the intelligent rule decision engine.

2. Intelligent loading and unloading system

In [7], the rule base is divided into three parts: rule type domain, trigger domain and specific processing domain. This paper combines the software-defined heterogeneous signal processing platform and signal processing features to divide the application task intelligent loading and unloading system into seven modules, as shown in Figure 1.

3. Rule inference engine

3.1. Intelligent inference rules represented by OBDD decision trees

The intelligent decision rule base designed in this paper includes the following five rules:

1. If the external signal to noise ratio $P_{SN} < 6dB$ [12] $(x_1)$, the modulation method is QPSK $(x_2)$. It is determined that the modulation mode of the system is adjusted from QPSK to BPSK $(x_3)$.

2. If the external signal to noise ratio $P_{SN} > 6dB$ [12] $(x_4)$, the modulation method is QPSK $(x_5)$. It is determined that the modulation mode of the system is adjusted from BPSK to QPSK $(x_6)$.

3. If the positional state parameter is the body parameter $(x_7)$. Frequency $18GHz < f_P < 27GHz$ $(x_8)$, the modulation mode is QPSK $(x_6)$. Signal is continuous wave $(x_9)$. The signal processing application task is determined to be Centimeter wave satellite communication $(x_{10})$.

4. If the positional state parameter is the body parameter $(x_7)$. Frequency $1GHz < f_P < 15GHz$ $(x_{11})$. Signal is a pulse wave $(x_{12})$. The signal processing application task is determined to be a radar application $(x_{13})$.

5. If the positional state parameter is the surface parameter $(x_{14})$. Frequency $890MHz < f_P < 1GHz$ $(x_{15})$. Signal is a pulse wave $(x_{12})$. The signal processing application task is determined to be GSM900 mobile communication $(x_{17})$.

In this paper, the non-use $x'$ of $x$ is represented, then the above five intelligent decision rules can be represented by the following Boolean function expression:

$$\psi_1(x_1, x_2, \cdots, x_7) = x'_1 + x'_2 + x_3$$

$$\psi_2(x_1, x_2, \cdots, x_7) = x'_4 + x'_5 + x_6$$
For example, the meaning of rule $\psi_i$ is that $x_i$ and $x_j$ is 1, the response action is determined by $x_k$. Finally, the Boolean expression corresponding to the intelligent decision rule is transformed into the corresponding OBDD graph, which is represented by $\text{OBDD}_{\psi_1}$, $\text{OBDD}_{\psi_2}$, $\text{OBDD}_{\psi_3}$, $\text{OBDD}_{\psi_4}$, and $\text{OBDD}_{\psi_5}$ respectively. The OBDD graph of the entire intelligent decision rule base can be represented by $\text{OBDD} = \sum_{i=1}^{N} \text{OBDD} < op > \text{OBDD}_{\psi_i}$, where $\text{OBDD}$ Initialize to 0, $N$ is the number of smart rules, as shown in Figure 2.

**Fig. 2.** The OBDD of the rule base

### 3.2. Intelligent Rule Decision Algorithm Based on OBDD Decision Tree

Based on the OBDD decision tree, the intelligent rule decision algorithm can be expressed as the following steps:

- **Input:** internal and external situation information of the platform and inference rule base
- **Output:** signal processing application task smart loading and unloading response
- **Step1:** Convert rule base rules and situation information into OBDD and OBDD$_1$.
- **Step2:** OBDD and OBDD$_1$ are logically combined to form a new OBDD$_\text{New}$.
- **Step3:** The depth search algorithm is used to perform the OBDD$_\text{New}$ graph. And the logic "1" or "0" is obtained to judge the output of the last node.
- **Step4:** Combine the platform situation information to control, load and unload the corresponding signal processing task. Finally, the algorithm outputs a signal processing application task intelligent loading and unloading response.

### 4. Signal processing task intelligent loading and unloading instance

In this paper, the relative execution efficiency, accuracy and circle complexity of the algorithm are used as the performance indicators of the proposed algorithm. Now suppose that the five sets of external situation information are known. As the number of groups increases, the situational information becomes more and more complex. The detailed information of each group is as follows:

- **Situation information group 1:** Signal SNR is 9dB.
Situation information group 2: The Signal SNR is 8 dB and the signal has two phases.

Situation information group 3: The positional situation parameter is a body parameter. with a frequency of 3 GHz, Signal is a pulse signal.

Situation information group 4: The positional situation parameter is a surface parameter. with a frequency of 900MHz, Signal is a pulse signal.

Situation information group 5: The positional situation parameter is a body parameter. The signal SNR is 12 dB, and the signal is continuous in the time domain [12] with two phases and a frequency of 20 GHz.

Internal situational information is that all hardware resources are healthy and unloaded. This situation information is transformed into the corresponding OBDD map as the parameter input of the algorithm. And it is judged whether the application task is centimeter wave satellite communication (x10), radar application (x13) or GSM900 mobile communication (x17), so as to carry out experimental analysis.

Fig. 3. Algorithm efficiency comparison chart

Relative execution efficiency refers to the time ratio at which different algorithms make correct responses according to different situational information groups, as is shown in Figure 3. It can be seen that for the same configuration potential information, the execution time of the algorithm in this paper is smaller than the algorithm stored in the rule order. In addition, from the situation group 1~5, as the external situation information group becomes more and more complex, the time equation of making responses between the algorithm proposed in this paper and the rule sequential storage algorithm is increasing. In the rule base constructed in this paper, the response time of the algorithm is reduced by 51.8% compared with the rule sequential storage algorithm.

Fig. 4. Algorithm accuracy comparison chart
This paper uses algorithmic accuracy to measure the effectiveness of the algorithm. The accuracy of the algorithm refers to the probability of obtaining a correct response based on the current situation information, as shown in Figure 13. It can be seen from Fig. 4 that the proposed algorithm, the artificial experience and the rule sequential storage algorithm have the same probability, indicating the effectiveness of the algorithm. In the situational information group 1~2, because the external situation information is less, the algorithm cannot accurately respond, so the accuracy of the algorithm is less than 1. When the external situation information is sufficient, the algorithm can make a corresponding unique response, so its accuracy is 1.

In terms of algorithm complexity, this paper uses the method shown in [10] to introduce the concept of Cyclomatic Complexity, as shown in Equation 1.

\[ \text{Num}(G) = e - n + 2 \]  

Where \( e \) represents edges’ number in the OBDD of the intelligent decision rule base. \( n \) is the number of nodes. And the physical meaning of the circle complexity is the number of nodes in the OBDD diagram. Table 1 gives the circle complexity of the sequential storage rule base and rule base based on OBDD storage. This paper assumes that the complexity of determining the "0" and "1" branches of each node is a constant con.

| Performance parameter | Rule order storage | Storage based on OBDD |
|------------------------|--------------------|-----------------------|
| Circle complexity (con) | 20                 | 17                    |

The circle complexity comparison chart is shown in Figure 5.

![Algorithm circle complexity comparison chart](image)

**Fig. 5.** Algorithm circle complexity comparison chart

It can be seen from Figure 5 that in the same situation information group, the proposed algorithm has a lower algorithmic complexity. This is because when the OBDD of the rule base is formed, the merging and deleting of rules leads to fewer nodes for the OBDD-based rule base. In addition, with the increase of situational information, the complexity of the circle is increasing. This is because from the situation group 1~5, the external situation information is more and more complicated, which leads to an increase in the number of nodes in the entire rule base, thus increasing the algorithm's circle complexity. When the sequential storage algorithm performs deep search, each rule is traversed. However, the algorithm proposed in this paper only performs deep search on the entire OBDD graph, which leads to less increase in the complexity of the proposed algorithm than the algorithm based on the sequential storage.

It can be seen from the above three performance indicators that the accuracy of the proposed algorithm is the same as that of the manual and regular order storage algorithms, but it has higher execution efficiency and lower complexity.
5. Conclusion
In order to realize the fast switching, intelligent loading and unloading of application tasks in the signal processing platform, this paper designs a signal processing task intelligent loading and unloading library. Then the intelligent inference engine is designed based on the ordered binary decision graph, which realizes the intelligent switching, loading and unloading of application tasks. Experimental examples show that the signal processing application task intelligent loading and unloading system in this paper has lower algorithm complexity and higher decision efficiency. However, the intelligence of this algorithm is not very strong. Combining other artificial intelligence algorithms and improving the learning and strong intelligence of intelligent rule decision-making will be the focus of the next step.

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