Evidence Verification Optimal Design and Practice of Electronic Health Card System Based on FSM

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Abstract. With the health of China's "Internet + medical" to facilitate the work of the people deepen, the National and Provincial Health Commission has also accelerated the "one card (code) connection" of the electronic health card, meanwhile, the empirical verification of the electronic health card is more important. The empirical verification of the electronic health card involves children, adults, including mainland Chinese residents, Hong Kong, Macao and Taiwan residents and foreigners. The verification logic is very complicated. This paper introduces the FSM technology, combined with the design mode of "micro service + application open platform + light application", optimizes the empirical verification of the traditional electronic health card management system, puts forward the development mode and five-tier architecture mode based on the FSM, and optimizes the existing empirical verification process of card issue and using. These measures have positive roles in promoting to achieve the mutual information of diagnosis and share treatment services across medical institutions.

1. Introduction

In recent years, with the continuous development and upgrading of national health informatization, health care big data, diagnosis and treatment service process and information for the convenience of the people, the electronic health card has more and more advantages in the whole life cycle of residents, such as uniform identity and authentication of health identity, real name system for medical treatment, reduction of issuance costs of physical cards, health and privacy protection of residents, promotion of regional medical business collaboration, integration and sharing of health medical data and so on. At present, it has been gradually applied in 28 provinces. Popularizing the application of electronic health card, without increasing the burden of patients, to realize "one card (code) connection" of medical and health services, is conducive to the full implementation of the real name system for medical treatment, and to solve the blocking problem of "one hospital, one card, repeated issuance of cards and mutual exclusion" in medical and health institutions, and supporting the sharing of the whole people's health information platform, so as to better play the role of "Internet + medical health" in the convenience for the people. It is of great significance to promote the construction of a healthy China, deepen the implementation of medical reform policies, help targeted poverty alleviation, promote the "three medical linkage" and comprehensive supervision, and improve the ability and level of industrial governance[1][2][3]. Based on the FSM, this paper optimizes the process of issuing and
using the electronic health card, and greatly promotes the efficiency of the electronic health card for the convenience and benefit of the people.

2. Development mode based on FSM

2.1. Finite state machine

The Finite State Machine[4](Finite State Machine, FSM for short) is a mathematical model used to represent finite states and the behaviors of transitions and actions between these states[5]. FSM is divided into two types: deterministic and non-deterministic. According to whether the state output is related to the input, they are divided into Moore and Mearly. Any FSM M can be formally described as a five-element tuple[6], as shown in Figure 1.

\[ M = (S_0, \sum a, S, F, \delta) \]  \hspace{1cm} (1)

Among them:
- \( S = [S_0, S_1, \ldots, S_n] \), a finite set of states;
- \( S_0 \), the starting state;
- \( \sum a \), a finite, nonempty input alphabet;
- \( \delta = [\delta_0, \delta_1, \ldots, \delta_n] \), a series of transition functions, single value mapping from \( S \times \sum a \) to \( S \);
- \( F = [F_0, F_1, \ldots, F_n] \in S \), the set of final states.

The FSM must have four characteristics: first, state \( S \) is finite; second, at any time, it can only be in one state of \( S \) or \( F \); third, when state \( S_i \) satisfies a certain input \( \sum a \) and \( \delta \), state transition will occur and become a new state \( S_j \); fourth, each FSM has a start state \( S_0 \) and a stop state \( F_i \), as well as several intermediate states \( S_i \).

2.2. Development mode based on FSM

In traditional procedure-based development mode, each branch needs to add different judgment conditions. If there are new conditions or conditions updates, the original program package will be destroyed during development, and even the existing business logic errors will be caused, resulting in system execution failure. It can be seen from the characteristics of the FSM that the new development mode avoids the drawbacks, and completes the design of all possible states of the system. When a new state occurs, it only needs to add a new state, without destroying the existing state package, so it is more flexible and fault tolerance.

Firstly, the execution process of the FSM gives an initial state \( S_0 \). Secondly, which state \( S_i \) to transfer to is determined by the input condition \( \sum a \) and the state transfer function \( \delta \). Finally, system will terminates in one state in \( F \) after one or more state transitions; Conversely, if any state in \( S \) cannot
be obtained after the state transition from any state $S_i$, it indicates that the state machine is executed incorrectly. This is determined by the state completeness of the state machine, unless there is an incomplete design in the state machine design. At this point, you should add a new state or keep the current state unchanged.

3. System design

3.1. Functional composition of electronic health card system

Electronic health card system mainly includes card issue, card using and personal health archives query, etc. Individual users will be issued a card firstly, and then they can query their own family, health profile and electronic medical records through the personal electronic health card. The system functions are shown in Figure 2.

![Figure 2. Functional composition of electronic health card system.](image)

3.2. System architecture design

Due to historical reasons, there are many medical and health information business systems like chimneys, which form more information isolated islands. The electronic health card system involves multiple business systems, and the interconnection between the various business systems mostly adopts the mesh interconnection mode. This mode has a drawback. When there are many interactions between business systems or third-party visits, there will be problems such as out of control interaction, low efficiency, high cost of transformation and development, due to the lack of unified authentication and management. In order to avoid this prominent problem, the development mode of the application open platform came into being. The application open platform adopts the bus-type design. The application open platform provides unified interface and application services for docking back-end business systems. Communications between applications can only be done through the open platform. The open platform provides a complete authentication management solution for the access organizations, applications and interfaces. Through the application of the open platform for opening data and application management, the evolution from traditional point-to-point mesh interconnection to platform-oriented service bus-type interconnection is realized. Based on the application open platform, the electronic health card system is different from the traditional three-level architecture design, and uses the development mode of “micro service + open platform + light application”. The architecture is shown in Figure 3.
Figure 3. Five-tier architecture design of electronic health card system environment transformation.

The data layer relies on the database of each independent system, and the business data is separated from each other without crossover. The layer solves the problem that the service data is stored independently and does not cross at the storage layer.

The atomic business layer involves the provision of atomic services in systems, such as electronic health card management services, birth medical certificate query services, entry and exit empirical verification services, electronic medical record query services, population family information query services and public health information query services. This layer adopts the micro-service "water compartment" design mode to separate the services provided by each business system and solve the independence problem of each micro service. Each atomic business system service is deployed and operated independently without affecting each other. When a service is interrupted or stopped, it will not affect the normal operation of other services.

The application open platform layer mainly solves the problems of data opening and application management. The open platform provides core services, such as unified data gateway, configuration center, load balancing, register center and log center, which provide guarantee for the opening and operation of micro services. Meanwhile, the functional modules include website portal, institute management, application management, interface management, authority control, technical support center, developer center, personal center, statistical analysis and other functions to support the integration of light applications and open data services.

The light application layer is organized on the data and services provided by the application development platform. Light applications easily provide services for users without downloading and installing. At present, the card issue H5 page of electronic health card mainly provides the card issue and card using service; the personal health archives query mainly provides personal authorization to query the population family, health archives and electronic medical records and other information. The user layer mainly includes service consumer, service provider and platform manager. The service consumers are medical institutions that use data and services; The service providers are companies that provide data and light application services; The service managers are health management department at all levels.

4. Optimization of empirical verification process of electronic health card

4.1. State definition

The electronic health card mainly solves the problem of “one card (code) connection”. It must obtain an empirical card, including children and adults (mainland Chinese residents, Hong Kong residents, Macao residents, Taiwan residents and foreigners). Different people have different verification methods, such as ID card verification need to be verified by the public security system. If
children less than one year old and without ID card need to be verified by the birth medical certificate system. In order to avoid the appearance of an electronic health card that cannot be issued, the state machine must have the design completeness. In addition to the final state, the remaining states should be consistent with the inclusion relationship and cover all possible states of empirical verification. It can be seen that the state of the empirical verification of the electronic health card includes one initial state $S_0$, two primary states $S_1$-$S_2$, two secondary states $S_3$-$S_4$, four tertiary states $S_5$-$S_8$, six fourth state $S_9$-$S_{14}$, six fifth state $S_{15}$-$S_{20}$, four sixth state $S_{21}$-$S_{28}$ and three final states $F_1$-$F_3$, a total of 31 states. See the states’ name in Figure 4 for details.

4.2. State transition

The state transition of the FSM is accomplished by the input condition $\sum a_n$ and the transfer function $\delta$. When the electronic health card system is in a certain state $S_i$, and at the same time receiving an input value $a_n$, the next state $(S_j, a_n)$ can be inferred by the function $\delta$, as shown in Figure 4. All state transitions in the figure must follow a unified specifications, which can be described formally as follows:

- There is one and only one state is running:
  \[ \forall i, \text{count}(S_i = \text{runtime}) = 1 \]

- After all states have undergone one or more state transitions, they will enter the final state:
  \[ \forall S_i, S = (S_i, a_n) \Rightarrow F_j \in F \]

- Each state transition can only be moved in one direction:
  \[ \forall \text{count}(S_i = S \neq F) = 1 \]

![Figure 4. State transition diagram of electronic health card.](attachment:figure4.png)

4.3. State recovery and monitoring

Due to the stability of network and system, the electronic health card system may be disconnected, reconnected or faulty during the process of card issue and card using. Therefore, the system must provide a complete state monitoring and recovery mechanism, which is solved by the FSM.
In a FSM system, the system is in a certain state $S_i$ at any time. On the one hand, all states can be monitored; on the other hand, all states are recorded in real time. When the system is restarted, first, the system obtains the current state $S_i$ from the database, and continues the state transition according to the current input condition $\sum a_i$ and the transfer function $\delta_i$ until the final state $F_i$. The FSM effectively resolves the problem that the electronic health card system can recover quickly after the failure restart, and continue to execute from the interrupted state without the need to re-execute from the initial state $S_0$.

5. System practical application

At present, the electronic health card system based on FSM has been applied to the public of various medical institutions. It provides services such as card issue, card using and personal health archives query for adults and children. The system interface conforms to national regulations, and runs smoothly, as shown in Figure 5.

![Figure 5. Electronic health card issue, card using and personal health archives query diagram.](image)

6. Conclusion

From the perspective of health and benefit for people, the electronic health card is the “golden key” for enriching the application of healthy and convenient services[9]. The technology innovation of FSM is widely used in the electronic health card system. It has a positive effect in establishing real-time data interaction for cross-domain main index, providing residents with a good medical experience, one card (code) connection, and querying personal health archives of cross-medical institutions, through the association of electronic health card.

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