An Improved SFMEA Method Integrated with Assistive Techniques

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Outline

- Introduction
- The principle of the improved SFMEA
- The process of The improved SFMEA
- Case study
- Conclusion
1. Introduction

- Conventional SFMEA
  - The difficulties to identify failure modes, causes, and effects.
  - Low efficiency, heavy workload...

- Improved SFMEA in recent years
  - Combining SFMEA with other analysis techniques, such as SFTA, UML...
  - Integrating with some assistive approaches, such as forward and backward approach, failure modes database...

- This paper discusses an new improved SFMEA integrated with assistive techniques
2. The principle of the improved SFMEA

- The structure of the improved SFMEA with assistive techniques
2. The principle of the improved SFMEA

A. Functional structure

- Software system
  - Function 1
    - Function 2.1
      - Function 2.1.1
      - Function 2.1.2
  - Function 2
    - Function 2.2
      - Function 2.2.1
      - Function 2.2.2
  - Function 3
    - Function 2.3
      - Function 2.3.1
      - Function 2.3.2
2. The principle of the improved SFMEA

- The relation between adjacent layers in SFMEA
2. The principle of the improved SFMEA

B. Data flow diagram

- Trace the higher effects to the system level
- Trace the identified effects to the higher layer
- Identify the affected modules basing on the data interaction in the same layer
- Analyze the data interaction among modules in the lower layer to find causes
2. The principle of the improved SFMEA

C. Control flow diagram
2. The principle of the improved SFMEA

D. SFTA

SFMEA

<table>
<thead>
<tr>
<th>Module</th>
<th>Failure modes</th>
<th>Failure causes</th>
<th>Failure effects</th>
<th>Severity</th>
<th>Corrective actions</th>
</tr>
</thead>
</table>

SFTA

Top event → Middle event → Basic event → Minimum cut set

Supplement failure causes

Supplement corrective actions
3. The process of The improved SFMEA

- **Step 1:** Define the system
- **Step 2:** Build the functional structure
- **Step 3:** Choose one layer to analyze
- **Step 4:** Identify the failure modes of the modules
  - Through analyzing the functions that a module will fulfill, and referring to some general failure modes
  - Through the assistance of functional structure
- **Step 5:** Identify the failure causes
  - Use functional structure
  - DFD helps to identify through data flow the possible functional modules in the lower layer, which will cause the failure modes being analyzed
- CFD helps for the further analysis through the control flow in the lower layer

**Step 6:** Analyze the failure effects

- Analyze the effects on each of the affected modules in the local layer identified with DFD
- Find the path through which failure passes in the local layer, and analyze the effects on the modules of the path with CFD
- Identify the higher and system level effects in similar ways

**Step 7:** Define the severity of failure effects

**Step 8:** Supplement the failure causes by SFTA

**Step 9:** Propose the corrective actions
4. Case study

- The Fly-By-Wire (FBW) flight control system
  - Flight control computer system
  - Servo actuator system
  - Sensor system
  - Control and display system
**Step 1:** Define the system

- Main function of the flight control computer system
  - collect the input signals from different input channels
  - calculate the control law
  - output the command to the actuator according to the control law

- Main functional modules
  - The control law
  - The redundancy management
  - BIT
4. Case study

**Step 2:** Build the functional structure

![Diagram showing the functional structure of a flight control computer system]

**Step 3:** Choose one layer to analyze

- Calculation of the control law
- Redundancy management of the input
- Redundancy management of the output
- Redundancy management of computer
- Control law of control and augmentation
- Model control
- Redundancy management
- Channel monitoring
- Signal voting
- Reconfiguration
- Fault managing
- Failure recovery
- BIT
  - IFBIT
  - MBIT
  - PBIT
Step 4: Identify the failure modes of the modules

The failure modes were identified basing on the functionality and the general failure modes

- There is no voting result of the input signal produced;
- The voting result of the input signal is incorrect;
- ....
4. Case study

- **Step 5:** Identify the failure causes

  - Identify failure causes directly by analyzing the input and output of the module
    - The input data is invalid
    - ......

  - Adopt the hierarchical DFD to assist the identification of failure causes
    - Invalid channels are judged to be valid
    - ......
4. Case study

The data flow diagram of the system including the module analyzed.
4. Case study

**Step 6:** Analyze the failure effects

- The local effect of this failure mode is null
- The higher effect -- May lead to a fault in the calculation of the control law.
- The system effect -- The flight control computer system may produce wrong command to the actuator and thus may lead to a dangerous state of the airplane.

**Step 7:** Define the severity of failure effects

- We adopted a four-level criteria (1, 2, 3, 4) to define the severity of the failure effects, which represent disastrous, fatal, general and mild failure effects respectively.
- The failure effect we discussed may be defined as severity level 2 (fatal).
4. Case study

- **Step 8:** Supplement the failure causes by SFTA

  - The voting result of the input signal is incorrect
    - The monitoring of the input is incorrect
      - The hardware failure
      - The flag of the channel switches from 0 to 1
    - Defects in the voting algorithm
      - No algorithm reconfiguration after the fault recovery
      - Deviation in the input signal when only one valid channel left
4. Case study

- Step 9: Propose the corrective actions
  - The failure causes identified ---- The corrective actions for each failure modes

  - The failure cause with “AND” gate
    - the “hardware failure” and “the flag of the channel switches from 0 to 1”-----The flag of the channel should contain two or more bits.
## 4. Case study

### TABLE I. SFMEA of the Module “The Redundancy Management of Input Signal”

<table>
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<tr>
<th>Module</th>
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<th>Corrective actions</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>No voting result of the input signal produced</td>
<td>The input signal of the module cannot be identified.</td>
<td>No input signal for the calculation of the control law.</td>
<td>1</td>
<td>Implement the monitoring of the signal to find the failure in time.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>......</td>
<td></td>
<td></td>
<td>......</td>
</tr>
<tr>
<td>The redundancy management of the input signal</td>
<td>Invalid channels are judged to be valid.</td>
<td></td>
<td></td>
<td></td>
<td>Strengthen the unit test.</td>
</tr>
<tr>
<td></td>
<td>Valid channels are judged to be invalid.</td>
<td></td>
<td></td>
<td></td>
<td>Strengthen the unit test.</td>
</tr>
<tr>
<td></td>
<td>The algorithm does not reconfigure after the fault recovery.</td>
<td></td>
<td></td>
<td></td>
<td>Improve the fault management to update the state and revise the algorithm.</td>
</tr>
<tr>
<td></td>
<td>Deviation in the input signal when only one valid channel left.</td>
<td></td>
<td></td>
<td></td>
<td>When there is only one valid channel, the voting result should be the average value of the previous-cycle signal and the current signal.</td>
</tr>
<tr>
<td></td>
<td>The “hardware failure” and “the flag of the channel switches from 0 to 1” occur simultaneously.</td>
<td></td>
<td></td>
<td></td>
<td>The flag of the channel should contain two or more bits, e.g. 01 represents the invalid state and 10 represents the valid state.</td>
</tr>
</tbody>
</table>
5. Conclusion

- By integrating the functional structure, DFD, CFD, and SFTA into the conventional SFMEA, the improved method can help to alleviate the difficulties and improve the efficiency while applying SFMEA to complex systems.

- The feasibility of this approach has been verified through the case study.

- For the future work, we hope to integrate the assistive techniques into the SFMEA tool, so that the improved approach can be carried out with the assistance of computer.
Thank You!