CEC Continuing Education Center

DesignNews

Expert C Techniques to Master Baremetal Programming

DAY 4 : Assertions and Validation Techniques for Baremetal Programming

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THE SPEAKER

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Beningo Embedded Group – CEO / Founder

Focus: Software Architecture, Processes, and Dev Skills

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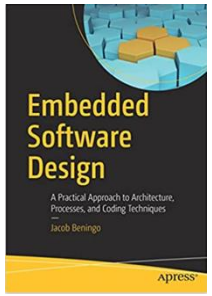

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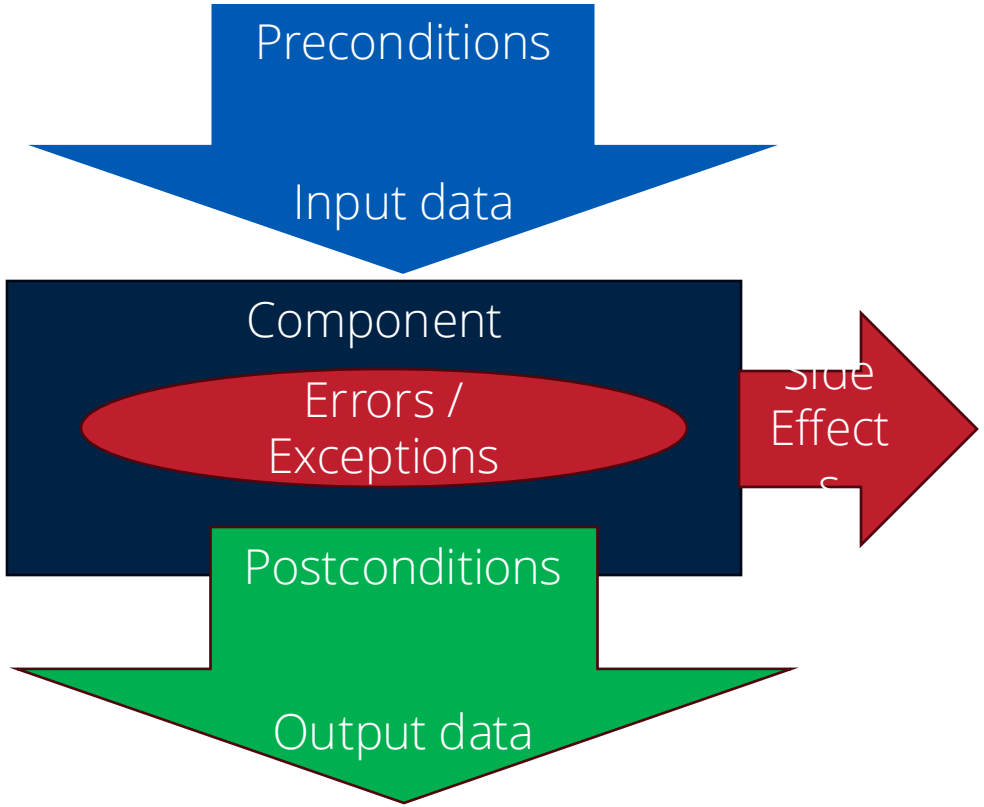
Design-by-Contract

01

Design-by-Contract

Definition



Design-by-Contract (DbC) is a software development methodology that defines clear, formalized agreements (or "contracts") between different parts of a program to ensure correct and predictable behavior. These contracts specify the obligations, benefits, and constraints for software components, such as functions, classes, or modules, promoting robust and reliable software.

Design-by-Contract

More Definitions

Preconditions:

Conditions that must be true before a method or function is executed. These are obligations the caller must fulfill for the function to execute correctly.

- Example: A function that calculates the square root might require the precondition that the input must be non-negative.

Postconditions:

Conditions that are guaranteed to be true after a method or function executes, provided the preconditions are met. These are the guarantees the function offers to the caller.

- Example: After a withdraw(amount) method is called on a bank account object, the account balance must be reduced by amount.

Invariants:

Conditions that must always hold true during the lifetime of an object or while a program is running. These often define the consistency rules for a class or system.

- Example: In a BankAccount class, the invariant might ensure that the balance is always non-negative.

Design-by-Contract

Example

```
/* Invariant Condition: DataBuffer must remain in a consistent state and not be accessed
* concurrently without proper synchronization to prevent race conditions */
int ProcessSensorData(float * restrict DataBuffer, size_t DataLength)
{
/* PreCondition: DataBuffer must not be NULL */
/* PreCondition: DataLength must be greater than 0 and less than MAX_BUFFER_SIZE */
/* PreCondition: DataBuffer elements must contain valid floating-point values */

/* PostCondition: Return value is 0 if all data processed successfully */
/* PostCondition: Return value is -1 if invalid data is encountered */
/* PostCondition: DataBuffer contents are normalized to the range [0.0, 1.0] */
}
```

Audience POLL Question

What is an invariant?
A) A condition that must hold true before a function is executed.
B) A condition that must hold true after a function is executed.
C) A condition that must always hold true throughout the lifetime of a program or object.
D) A condition that determines whether a loop terminates correctly.

Assertions

02

Assertions

Assertion Fundamentals

Definition: An assertion is a Boolean expression at a specific point in a program that will be true unless there is a bug in the program.

Pros for assert()

- improve testing
- bugs are easier to detect
- execution stops at them
- can serve as executable comments
- improve code quality
- can be turned on and off

Cons for assert()

- slow down code execution
- commonly misunderstood
- used improperly for error handling
- use string that require RAM/ROM
- require printf and a terminal
- can be turned on and off

What is the difference between a bug and an error condition?

Assertions

Example Uses

Assertion conditions:

- If the expression is true, execution continues normally
- If the expression is false, whatever happens is “undefined”

Proper Use:

```
void CalculateDistance (uint32_t Velocity)
{
  assert (Velocity < 10);
}
```

Improper Use:

```
int result = Open("MyFile.txt", 'r');
assert (result != NULL);
```

Side Effects (Mistakes!):

```
assert (result = 14);
assert (VelocitySet(100) < VELOCITY_MAX);
```

Assertions

Implementation

Must match the function definition in assert.h!

```
288  void __aeabi_assert(const char *expr, const char *file, int line)
289  {
290    Uart_printf(UART1, "Assertion failed in %s at line %d\n", file, line);
291
292    for(;;);
293  }
```

Wait forever?

What should happen?

- Print to terminal
- Entry in log file
- etc

Audience POLL Question

What are the potential problems with assertions?

A) They immediately halt the system if an assertion is hit
B) Compiling them out can change real-time performance
C) They use CPU cycles to evaluate the expression
D) All the above
E) None of the above

Real-time Assertions

03

Real-time Assertions

Definition

Definition: A real-time assertion is a Boolean expression at a specific point in a program that will be true unless there is a bug in the program and will have minimal impact on the real-time performance if triggered.

```
void __aeabi_assert(const char * expr, const char * file, int line)
{
  // Log the assertion file and line number

  // Handle Real-time Behaviors?

  // Safe Restart Sequence?
}
```

No wait forever!

Real-time Assertions

Where to Log the Bug?

- Print to a terminal
  - IDE Terminal (ITM, etc)
  - External (UART, etc)
- Store in a RAM buffer
  - Printed at start-up or when full
- Write to non-volatile memory
  - SD card
  - Flash
  - EEPROM

Real-time Assertions

Defining Real-time Assertions

```
typedef enum
{
  ASSERT_SEVERITY_MINOR,
  ASSERT_SEVERITY_MODERATE,
  ASSERT_SEVERITY_CRITICAL,

ASSERT_SEVERITY_MAX_COUNT
}AssertSeverity_t
```

```
void assert_failed(const char expr, const char *file, int line, AssertSeverity_t Severity)
{
  #if ASSERT_UART == TRUE
    Uart_printf(UART1, "Assertion failed in %s at line %d\n", file, line);
  #elif
    Log_Append(ASSERT, Assert_String, file, line);
  #endif

  # Pull the I/O line Low to turn on the LED and signal an assertion.
  Dio_ChannelWrite(LED_Assert, LOW);

  App_Notify(Severity);
}
```

Real-time Assertions

Defining Real-time Assertions

```
void Distance_Calculate (uint32_t Velocity)
{
   assert (Velocity < 10, ASSERT_SEVERITY_MINOR);
   assert (Velocity > 300, ASSERT_SEVERITY_CRITICAL);

   // Functional code goes here ...
}
```

Audience POLL Question

What is the primary purpose of real-time assertions in embedded systems?
A) To document the purpose of a function for future developers.
B) To dynamically verify that critical conditions are met during the execution of real-time code.
C) To ensure a program compiles successfully before deployment.
D) To optimize the performance of time-sensitive algorithms.

Next Steps

04

Going Further

https://beningo.mykajabi.com/

Download Function Pointer Example Code:

- Additional Video on Baremetal Scheduling
- Scheduling Lab Instructions
- Scheduler Source Code

Additional Resources

Please consider the resources below:

- Jacob's Blogs
- Jacob's CEC courses
- Embedded Software Academy

- Embedded Bytes Newsletter
  - http://bit.ly/1BAHYXm

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Next Steps

- Mastering Function Pointers for Baremetal Systems
- Building Cooperative Schedulers and Command Parsers
- Baremetal Performance Analysis and Architecture Design
- Assertions and Validation Techniques for Baremetal
- Managing Interrupts in Baremetal Systems

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