CSED601
Dependable Computing
Lecture 7

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POSTECH

Review of Previous Lecture

- Software redundancy
- Fault-avoidance in software
  - Software engineering techniques
- Fault-masking in software
  - N-version programming
- Fault-tolerance in software
  - Algorithm construction
  - Forward error recovery
  - Backward error recovery
    - Checkpointing
    - Journaling
    - Recovery blocks

Information redundancy

- Concept
  - Addition of redundant information to data to allow fault detection, fault masking, or possible fault tolerance.
  - Eg.: Error detection and error correction codes

Terminology

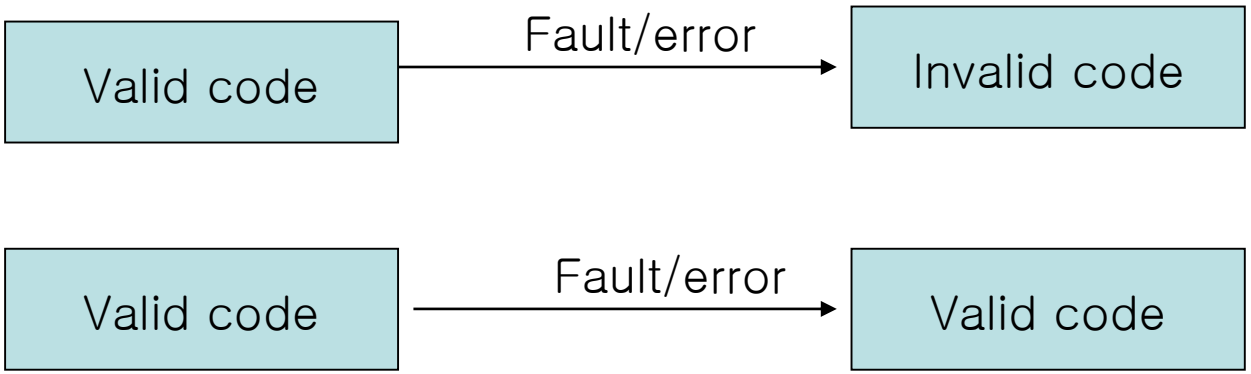
- Terminology
  - Code: A means of representing information, or data using a well-defined set of rules
  - Code word: A collection of symbols, often called a digit if the symbols are numbers.
  - Binary code: One in which the symbols forming each code word consist of only digits 0 or 1
  - Encoding process: The process of determining the corresponding code word for a particular data item
  - Decoding process: The process of recovering the original data item and represent it as a code word using the rules of a code
  - Error detecting code: A specific representation allowing errors introduced into a code word to be deleted.
  - Error correcting code: Allow coding scheme to correct errors.

Code distance

- Hamming distance
  - The hamming distance between any two binary words is the number of bit positions in which two words differ.
- Code distance
  - The minimum hamming distance between any two valid code words.
- Valid / Invalid code
  - Code is valid if any data has the valid code form after encoding process. Otherwise, the code word is invalid.

Concept of error handling with code

- Concept
  - Error detection: Any valid code word should be changed to invalid code word if there is a fault in the code word.
  - Error correction: Any valid code word should be changed to invalid code word such that the original code word is known when there is a fault in the code word.



Code distance and error handling

- Example
  - Code distance = 2 ➔ single-error detectable
  - Code distance = 3 ➔ single/double bit error detectable
    single error correctable
  - Code can correct c-bit and detect d additional bit
    iff $c + d + 1 <= Hd$
- Separable code
  - A code is separable in which the original information is appended with new information to form the code word, thus allowing the decoding process to consist of simply removing the unwanted information and keeping the original data.

Types of code

- Coding types
  - Parity code
  - M-out-of-N code
  - Duplication code
  - Checksums
  - Cyclic code
  - Arithmetic code
  - Berger code
  - Horizontal and vertical parity
  - Hamming error-correcting code

Parity code

- Concept
  - Add parity to detect or correct errors.
  - Single-bit parity code = addition of one extra code
  - Let $A = (a_{n-1}, a_{n-2}, \ldots\ldots, a_0, a_c)$

    where a_c is a parity bit and a_c = xor a_c (even) or 1 xor a_c (odd).
  - Separable code
  - Commonly used in many applications

M-out-of-N code

- Concept
  - Define code words that are n-bits in length and contain exactly m 1's.
  - Error status : code have not having m 1's
- Characteristics
  - Advantage: simplicity, easy to visualize the error detecting process.
  - Disadvantage: encoding, decoding, and detection process is very extremely difficult ➔ counting number of 1's in code
- Implementation
  - Simple construction method: i-out-of-2i code
    - Information : i-bit
    - Add i-bit to make m 1's.
    - Overhead 100% and separable code
  - 2-out-of-5 code
    - Non-separable code.

Duplication code

- Concept
  - Completely duplicating the original information to form the code word.
- Characteristics
  - Advantage of the duplication code: simplicity.
  - Disadvantage: overhead
- Implementation
  - Simple duplication
  - Duplicate transmission
    - Used in the communication
  - Complemented duplication
    - Advantageous when the original information and its duplicate must be processed by the same hardware.
  - Swap & compare
    - Maintain two copies of the original information
    - Used to detect memory bit slice error

Checksums

- Concept
  - Add the quantity of information for all block of data to help detect errors.
  - Another form of separable code
  - Applicable when blocks of data are to be transferred.
- Implementation
  - Depends on the way in which the summation is generated
  - Methods
    - Single precision
    - Double precision
    - Honeywell
    - Residue

Single/Double precision

- Single precision
  - All data blocks are added with single precision computation.
  - Cannot detect some types of errors (MSB stuck-fault)
  - Why? : the ignorance of overflow
- Double precision
  - Use double precision checksum
  - Can detect MSB stuck-fault.

Honeywell/Residue

- Honeywell checksum
  - Concatenate consecutive words to form a collection of double length words
  - Generate 2n-bit checksum
  - Similar to double precision
- Residue checksum
  - Almost same with single precision
  - If there is overflow, add it to the checksum in an end-around carry fashion.

Cyclic codes

- Concept
  - Any end-around shift of a code word will produce another code word.
  - Frequently used to sequential access devices such as tapes, bubble memory, and disks.
  - Encoding operation can be implemented using simple shift registers with feedback connections.
  - Characterized by its generator polynomial G(X), which is a polynomial of degree n-k or greater.
  - The n bits are contained in the complete code word and k bits are in the original information to be encoded.
  - A cyclic code with a G(X) of degree n-k is called a (n, k) cyclic code.
  - Can detect all single errors and all multiple adjacent errors affecting fewer than (n-k) bits.
  - Very important in communication where burst error can occur.