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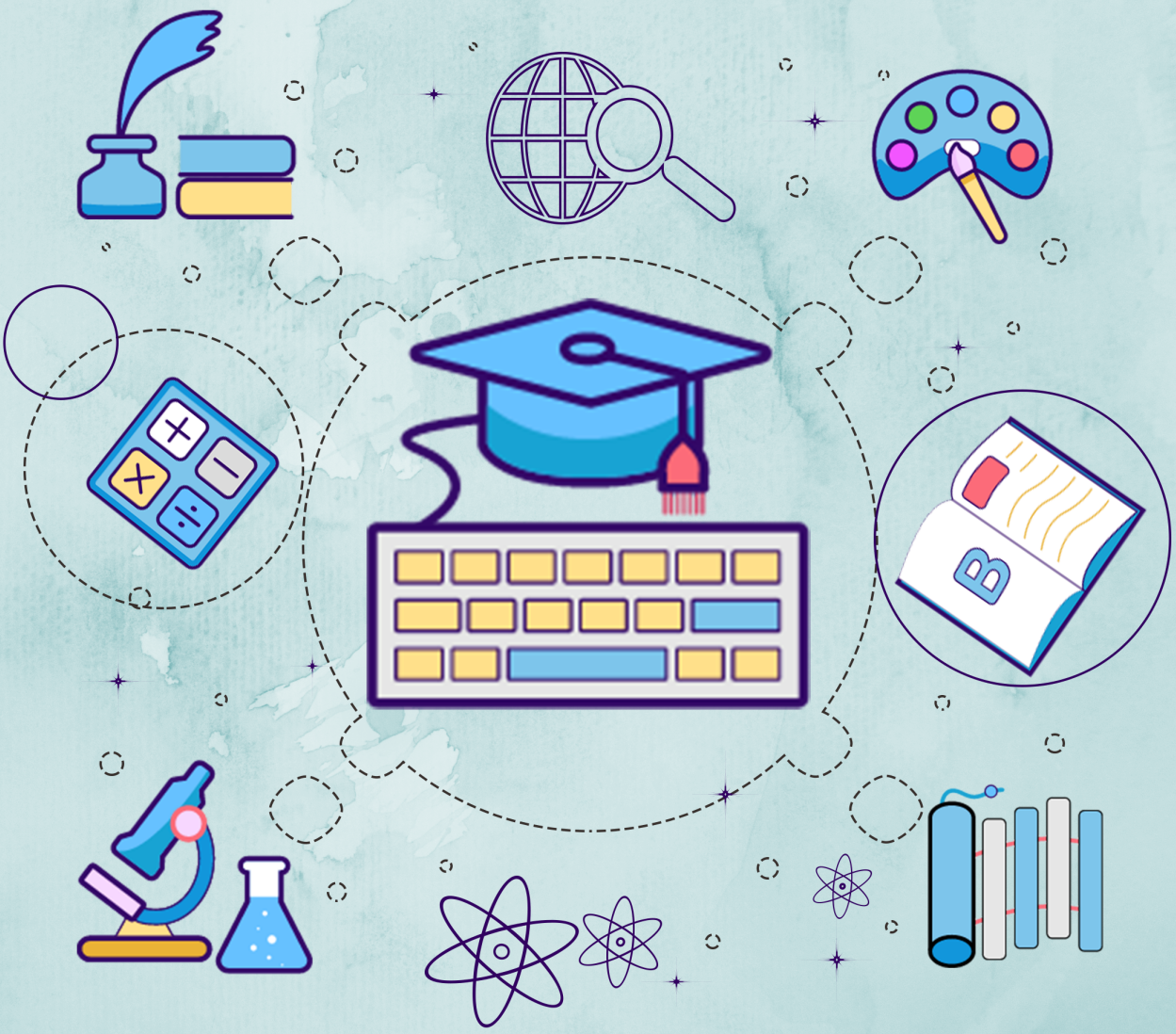

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MODULE 5

MACRO PROCESSOR

A *Macro* represents a commonly used group of statements in the source programming language.

- A macro instruction (macro) is a notational convenience for the programmer
  - It allows the programmer to write shorthand version of a program (module programming)
- The macro processor replaces each macro instruction with the corresponding group of source language statements (*expanding*)
  - Normally, it performs no analysis of the text it handles.
  - It does not concern the meaning of the involved statements during macro expansion.
- The design of a macro processor generally is *machine independent!*
- Two new assembler directives are used in macro definition
  - **MACRO:** identify the beginning of a macro definition
  - **MEND:** identify the end of a macro definition
- Prototype for the macro
  - Each parameter begins with '&'
    - name MACRO parameters
      :
      body
      :
      MEND
  - Body: the statements that will be generated as the expansion of the macro.

5.1 Basic Macro Processor Functions:

- Macro Definition and Expansion
- Macro Processor Algorithms and Data structures

5.1.1 Macro Definition and Expansion:

- Consider the example of an SIC/XE program using macro instructions. This program defines and uses two macro instructions , RDBUFF and WRBUFF.

- The functions and logic of RDBUFF macro are similar to RDREC subroutine.

```
 5      COPY      START   0                 COPY FILE FROM INPUT TO OUTPUT
10      RDBUFF    MACRO   &INDEV,&BUFADR,&RECLTH
15      .
20      .         MACRO TO READ RECORD INTO BUFFER
25      .
30                CLEAR   X                 CLEAR LOOP COUNTER
35                CLEAR   A
40                CLEAR   S
45               +LDT     #4096            SET MAXIMUM RECORD LENGTH
50                TD      =X'&INDEV'       TEST INPUT DEVICE
55                JEQ     *-3              LOOP UNTIL READY
60                RD      =X'&INDEV'       READ CHARACTER INTO REG A
65                COMPR   A,S              TEST FOR END OF RECORD
70                JEQ     *+11             EXIT LOOP IF EOR
75                STCH    &BUFADR,X        STORE CHARACTER IN BUFFER
80                TIXR    T                LOOP UNLESS MAXIMUM LENGTH
85                JLT     *-19               HAS BEEN REACHED
90                STX     &RECLTH          SAVE RECORD LENGTH
95                MEND
```

```
100       WRBUFF    MACRO    &OUTDEV,&BUFADR,&RECLTH
105       .
110       .         MACRO TO WRITE RECORD FROM BUFFER
115       .
120                 CLEAR    X                CLEAR LOOP COUNTER
125                 LDT      &RECLTH
130                 LDCH     &BUFADR,X        GET CHARACTER FROM BUFFER
135                 TD       =X'&OUTDEV'      TEST OUTPUT DEVICE
140                 JEQ      *-3              LOOP UNTIL READY
145                 WD       =X'&OUTDEV'      WRITE CHARACTER
150                 TIXR     T                LOOP UNTIL ALL CHARACTERS
155                 JLT      *-14               HAVE BEEN WRITTEN
160                 MEND
165       .
170       .         MAIN PROGRAM
175       .


180       FIRST     STL      RETADR           SAVE RETURN ADDRESS
190       CLOOP     RDBUFF   F1,BUFFER,LENGTH  READ RECORD INTO BUFFER
195                 LDA      LENGTH           TEST FOR END OF FILE
200                 COMP     #0
205                 JEQ      ENDFIL           EXIT IF EOF FOUND
210                 WRBUFF   05,BUFFER,LENGTH  WRITE OUTPUT RECORD
215                 J        CLOOP            LOOP
220       ENDFIL    WRBUFF   05,EOF,THREE     INSERT EOF MARKER
225                 J        @RETADR
230       EOF       BYTE     C'EOF'
235       THREE     WORD     3
240       RETADR    RESW     1
245       LENGTH    RESW     1                LENGTH OF RECORD
250       BUFFER    RESB     4096             4096-BYTE BUFFER AREA
255                 END      FIRST
```

Figure 4.1 Use of macros in a SIC/XE program.

- Two new assembler directives (Macro and MEND) are used in macro definitions. The keyword macro identifies the beginning of the macro definition. The symbol in the label field (RDBUFF) is the name of the macro and entries in the operand field identify the parameters of the macro. Each parameter begins with the character & which helps in the substitution of parameters during macro expansion. Following the macro directive are the statements that make up the body of the macro definition. These are the statements that will be generated as the expansion of the macro. The MEND directive marks the end of the macro.
- Macro invocation or call is written in the main program. In macro invocation the name of the macro is followed by the arguments. Output of the macroprocessor is the expanded program.

```
  5     COPY     START   0                 COPY FILE FROM INPUT TO OUTPUT
180     FIRST    STL     RETADR            SAVE RETURN ADDRESS
190     .CLOOP   RDBUFF  F1,BUFFER,LENGTH  READ RECORD INTO BUFFER
190a    CLOOP    CLEAR   X                 CLEAR LOOP COUNTER
190b             CLEAR   A
190c             CLEAR   S
190d            +LDT     #4096             SET MAXIMUM RECORD LENGTH
190e             TD      =X'F1'            TEST INPUT DEVICE
190f             JEQ     *-3               LOOP UNTIL READY
190g             RD      =X'F1'            READ CHARACTER INTO REG A
190h             COMPR   A,S               TEST FOR END OF RECORD
190i             JEQ     *+11              EXIT LOOP IF EOR
190j             STCH    BUFFER,X          STORE CHARACTER IN BUFFER
190k             TIXR    T                 LOOP UNLESS MAXIMUM LENGTH
190l             JLT     *-19                HAS BEEN REACHED
190m             STX     LENGTH            SAVE RECORD LENGTH
195              LDA     LENGTH            TEST FOR END OF FILE
200              COMP    #0
205              JEQ     ENDFIL            EXIT IF EOF FOUND
```

Expanded Program

- Another simple example is given below:
- Program with macro

```
EX1       MACRO     &A,&B
          LDA       &A
          STA       &B
          MEND

SAMPLE    START     1000
          EX1       N1,N2
N1        RESW      1
N2        RESW      1

          END
```

Expanded program

```
SAMPLE    START     1000

.         EX1       N1,N2
          LDA       N1
          STA       N2
N1        RESW      1
N2        RESW      1
```

Macro expansion

- Macro definition statements have been deleted since they are no longer required after the macros are expanded. Each macro invocation statement has been expanded into the statements that form the body of the macro with the arguments from the macro invocation is substituted for the parameters in the macro definition. Macro invocation statement is included as a comment line in the expanded program.

- After macroprocessing the expanded file can be used as input to the assembler.

- Differences between macro and subroutine: The statements that form the expansion of a macro are generated and (assembled) each time the macro is invoked. Statements in a subroutine appear only once, regardless of how many time the subroutine is called.

5.1.2 Macro Processor Algorithm and Data Structure:

- It is easy to design a two pass macro processor in which all macro definitions are processed during the first pass and all macro invocation statements are expanded during the second pass.

- But such a two pass macro processor would not allow the body of one macro instruction to contain definitions of other macros.

```
1   MACROS    MACRO       {Defines SIC standard version macros}
2   RDBUFF    MACRO       &INDEV,&BUFADR,&RECLTH
                .
                .         {SIC  standard version}
                .
3             MEND        {End of RDBUFF}
4   WRBUFF    MACRO       &OUTDEV,&BUFADR,&RECLTH
                .
                .         {SIC standard version}
                .
5             MEND        {End of WRBUFF}
                .
                .
                .
6             MEND        {End of MACROS}
```

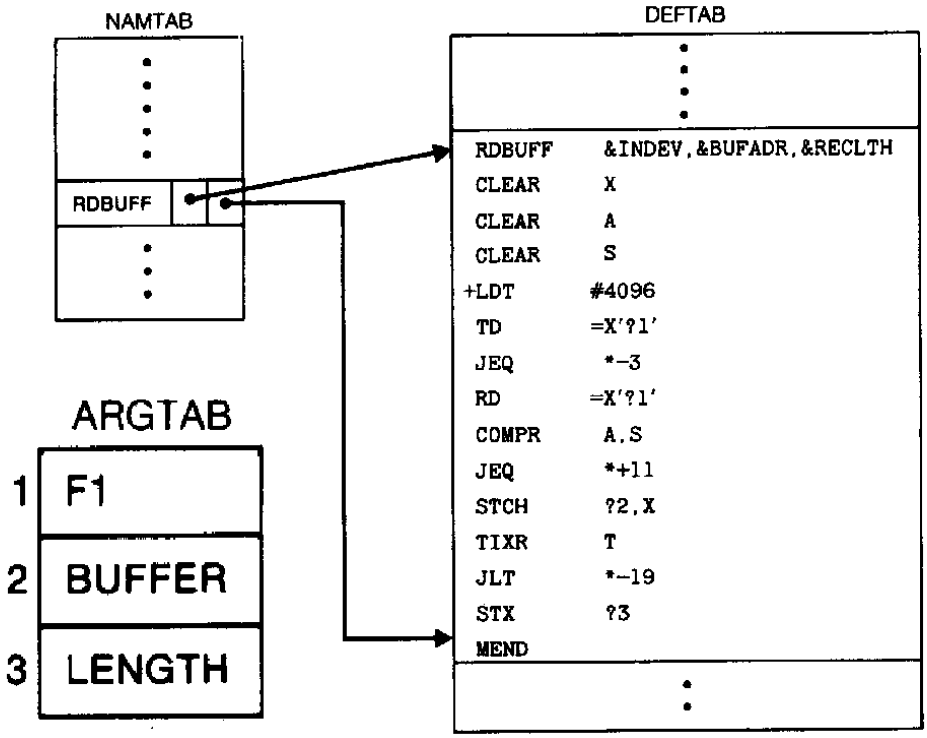
```
1   MACROX    MACRO       {Defines  SIC/XE macros}
2   RDBUFF    MACRO       &INDEV,&BUFADR,&RECLTH
                .
                .         {SIC/XE version}
                .
3             MEND        {End of RDBUFF}
4   WRBUFF    MACRO       &OUTDEV,&BUFADR,&RECLTH
                .
                .         {SIC/XE version}
                .
5             MEND        {End of WRBUFF}
                .
                .
                .
6             MEND        {End of MACROX}
```

(b)

Figure 4.3 Example of the definition of macros within a macro body.

- Here defining MACROS does not define RDBUFF and WRBUFF. These definitions are processed only when an invocation of MACROS is expanded.
- A one pass macro processor that can alternate between macro definition and macro expansion is able to handle these type of macros.
- There are 3 main data structures:-

- DEFTAB- The macro definitions are stored in a definition table(DEFTAB) which contain the macro definition and the statements that form the macro body. References to the macro instruction parameters are converted to positional notation.
- NAMTAB- Macro names are entered into NAMTAB, which serves as an index to DEFTAB. For each macro instruction defined , NAMTAB contains pointers to the beginning and end of the definition in DEFTAB.
- ARGTAB- is used during the expansion of the macro invocation. When a macro invocation statement is recognized the arguments are stored in argument table. As the macro is expanded arguments from ARGTAB are substituted for the corresponding parameters in the macro body.
- Eg



Macro processor algorithm

```
begin {macro processor}
    EXPANDING := FALSE
    while OPCODE ≠ 'END' do
        begin
            GETLINE
            PROCESSLINE
        end {while}
end {macro processor}


procedure PROCESSLINE
    begin
        search NAMTAB for OPCODE
        if found then
            EXPAND
        else if OPCODE = 'MACRO' then
            DEFINE
        else write source line to expanded file
    end {PROCESSLINE}
```

Figure 4.5 Algorithm for a one-pass macro processor.

```
procedure DEFINE
    begin
        enter macro name into NAMTAB
        enter macro prototype into DEFTAB
        LEVEL  := 1
        while LEVEL > 0 do
            begin
                GETLINE
                if this is not a comment line then
                    begin
                        substitute positional notation for parameters
                        enter line into DEFTAB
                        if OPCODE = 'MACRO' then
                            LEVEL := LEVEL + 1
                        else if OPCODE = 'MEND' then
                            LEVEL  := LEVEL - 1
                    end {if not comment}
            end {while}
        store in NAMTAB pointers to beginning and end of definition
    end {DEFINE}

procedure EXPAND
    begin
        EXPANDING  := TRUE
        get first line of macro definition {prototype} from DEFTAB
        set up arguments from macro invocation in ARGTAB
        write macro invocation to expanded file as a comment
        while not end of macro definition do
            begin
                GETLINE
                PROCESSLINE
            end {while}
        EXPANDING := FALSE
    end {EXPAND}


procedure GETLINE
    begin
        if EXPANDING then
           begin
                get next line of macro definition from DEFTAB
                substitute arguments from ARGTAB for positional notation
           end {if}
        else
            read next line from input file
    end {GETLINE}
```

Figure 4.5 (*cont'd*)

- Procedure DEFINE which is called when the beginning of a macro definition is recognized makes the appropriate entries in DEFTAB and NAMTAB.
- EXPAND is called to set up the argument values in ARGTAB and expand a *Macro Invocation* statement.
- Procedure GETLINE is called to get the next line to be processed either from the DEFTAB or from the input file .
- Handling of macro definition within macro:- When a macro definition is encountered it is entered in the DEFTAB. The normal approach is to continue entering till MEND is encountered. If there is a program having a Macro defined within another Macro.While defining in the DEFTAB the very first MEND is taken as the end of the Macro definition. This does not complete the definition as there is another outer Macro which completes the definition of Macro as a whole. Therefore the DEFINE procedure keeps a counter variable LEVEL.Every time a Macro directive is encountered this counter is incremented by 1. The moment the innermost Macro ends indicated by the directive MEND it starts decreasing the value of the counter variable by one. The last MEND should make the counter value set to zero. So when LEVEL becomes zero, the MEND corresponds to the original MACRO directive.

5.3Machine-independent Macro-Processor Features.

The design of macro processor doesn't depend on the architecture of the machine. We will be studying some extended feature for this macro processor. These features are:

- Concatenation of Macro Parameters
- Generation of unique labels
- Conditional Macro Expansion
- Keyword Macro Parameters

5.3.1Concatenation of Macro parameters:

- Most macro processor allows parameters to be concatenated with other character strings. Suppose that a program contains a series of variables named by the symbols XA1, XA2, XA3,…, another series of variables named XB1, XB2, XB3,…, etc. If similar processing is to be performed on each series of labels, the programmer might put this as a macro instruction.
- The parameter to such a macro instruction could specify the series of variables to be operated on (A, B, etc.). The macro processor would use this parameter to construct the symbols required in the macro expansion (XA1, XB1, etc.).

- Suppose that the parameter to such a macro instruction is named &ID. The body of the macro definition might contain a statement like
  - LDA X&ID1

- & is the starting character of the macro instruction; but the end of the parameter is not marked. So in the case of &ID1, the macro processor could deduce the meaning that was intended.

- If the macro definition contains &ID and &ID1 as parameters, the situation would be unavoidably ambiguous.
- Most of the macro processors deal with this problem by providing a special **concatenation operator.** In the SIC macro language, this operator is the character →. Thus the statement LDA X&ID1 can be written as

  LDA X&ID→1

```
1   SUM MACRO   &ID
2       LDA     X&ID→ 1
3       ADD     X&ID→ 2
4       ADD     X&ID→ 3
5       STA     X&ID→ S
6       MEND
```

```
SUM     A
 ↓
LDA     XA1
ADD     XA2
ADD     XA3
STA     XAS
```

```
SUM     BETA
 ↓
LDA     XBEATA1
ADD     XBEATA2
ADD     XBEATA3
STA     XBEATAS
```

- The above figure shows a macro definition that uses the concatenation operator as previously described. The statement SUM A and SUM BETA shows the invocation statements and the corresponding macro expansion.

5.3.2Generation of Unique Labels

- it is not possible to use labels for the instructions in the macro definition, since every expansion of macro would include the label repeatedly which is not allowed by the assembler.
- We can use the technique of generating unique labels for every macro invocation and expansion.
- During macro expansion each $ will be replaced with $XX, where xx is a two- character alphanumeric counter of the number of macro instructions expansion.

For example,

XX = AA, AB, AC…

This allows 1296 macro expansions in a single program.

The following program shows the macro definition with labels to the instruction.

```
25        RDBUFF   MACRO    &INDEV, &BUFADR, &RECLTH
30                 CLEAR    X                  CLEAR LOOP COUNTER
35                 CLEAR    A
40                 CLEAR    S
45                 +LDT     #4096              SET MAXIMUM RECORD LENGTH
50        $LOOP    TD       =X'&INDEV'         TEST INPUT DEVICE
55                 JEQ      $LOOP              LOOP UNTIL READY
60                 RD       =X'&INDEV'         READ CHARACTER INTI REG A
65                 COMPR    A, S               TEST FOR END OF RECORD
70                 JEQ      $EXIT              EXIT LOOP IF EOR
75                 STCH     &BUFADR, X         STORE CHARACTER IN BUFFER
80                 TIXR     $LOOP              HAS BEEN REACHED
90        $EXIT    STX      &RECLTH            SAVE RECORD LENGTH
                   MEND
```

The following figure shows the macro invocation and expansion first time.

```
.          RDBUFF   F1, BUFFER, LENGTH

30                  CLEAR    X              CLEAR LOOP COUNTER
35                  CLEAR    A
40                  CLEAR    S
45                 +LDT      #4096          SET MAXIMUM RECORD LENGTH
50         $AALOOP  TD       =X'F1'         TEST INPUT DEVICE
55                  JEQ      $AALOOP        LOOP UNTIL READY
60                  RD       =X'F1'         READ CHARACTER INTI REG A
65                  COMPR    A, S           TEST FOR END OF RECORD
70                  JEQ      $AAEXIT        EXIT LOOP IF EOR
75                  STCH     BUFFER, X      STORE CHARACTER IN BUFFER
80                  TIXR     T              LOOP UNLESS MAXIMUM LENGTH
85                  JLT      $AALOOP        HAS BEEN REACHED
90         $AAEXIT  STX      LENGTH         SAVE RECORD LENGTH
```

- If the macro is invoked second time the labels may be expanded as $ABLOOP $ABEXIT.

5.3.3Conditional Macro Expansion

- IF ELSE
- WHILE loop

- We can modify the sequence of statements generated for a macro expansion depending on conditions.

IF ELSE ENDIF structure

- Consider the following example.

```
25    RDBUFF    MACRO    &INDEV,&BUFADR,&RECLTH,&EOR,&MAXLTH
26              IF       (&EOR NE '')
27    &EORCK    SET      1
28              ENDIF
30              CLEAR    X               CLEAR LOOP COUNTER
35              CLEAR    A
38              IF       (&EORCK EQ 1)
40              LDCH    =X'&EOR'         SET EOR CHARACTER
42              RMO      A,S
43              ENDIF
44              IF       (&MAXLTH EQ '')
45             +LDT     #4096            SET MAX LENGTH = 4096
46              ELSE
47             +LDT     #&MAXLTH         SET MAXIMUM RECORD LENGTH
48              ENDIF
50    $LOOP     TD      =X'&INDEV'       TEST INPUT DEVICE
55              JEQ      $LOOP           LOOP UNTIL READY
60              RD      =X'&INDEV'       READ CHARACTER INTO REG A
63              IF       (&EORCK EQ 1)
65              COMPR    A,S             TEST FOR END OF RECORD
70              JEQ      $EXIT           EXIT LOOP IF EOR
73              ENDIF
75              STCH     &BUFADR,X       STORE CHARACTER IN BUFFER
80              TIXR     T               LOOP UNLESS MAXIMUM LENGTH
85              JLT      $LOOP             HAS BEEN REACHED
90    $EXIT     STX      &RECLTH         SAVE RECORD LENGTH
95              MEND
```

(a)

```
.           RDBUFF   F3,BUF,RECL,04,2048


30              CLEAR    X               CLEAR LOOP COUNTER
35              CLEAR    A
40              LDCH    =X'04'           SET EOR CHARACTER
42              RMO      A,S
47             +LDT     #2048            SET MAXIMUM RECORD LENGTH
50    $AALOOP   TD      =X'F3'           TEST INPUT DEVICE
55              JEQ      $AALOOP         LOOP UNTIL READY
60              RD      =X'F3'           READ CHARACTER INTO REG A
65              COMPR    A,S             TEST FOR END OF RECORD
70              JEQ      $AAEXIT         EXIT LOOP IF EOR
75              STCH     BUF,X           STORE CHARACTER IN BUFFER
80              TIXR     T               LOOP UNLESS MAXIMUM LENGTH
85              JLT      $AALOOP           HAS BEEN REACHED
90    $AAEXIT   STX      RECL            SAVE RECORD LENGTH
```

(b)

Figure 4.8 Use of macro-time conditional statements.

- Here the definition of RDBUFF has two additional parameters. &EOR(end of record) &MAXLTH(maximum length of the record that can be read)
- The macro processor directive SET – The statement assigns a value 1 to &EORCK and &EORCK is known as macrotime variable. A **macrotime variable** is used to store working values during the macro expansion. Any symbol that begins with & and that is not a macro instruction parameter is assumed to be a macro time variable. All such variables are initialized to a value 0.
- Implementation of Conditional macro expansion- Macro processor maintains a symbol table that contains the values of all macrotime variables used. Entries in this table are made when SET

statements are processed. The table is used to look up the current value of the variable.

- Testing of Boolean expression in IF statement occurs at the time macros are expanded. By the time the program is assembled all such decisions are made and conditional macro instruction directives are removed.
- IF statements are different from COMPR which test data values during program expansion.

Looping-WHILE

- Consider the following example.

```
 25   RDBUFF    MACRO    &INDEV,&BUFADR,&RECLTH,&EOR
 27   &EORCT    SET      %NITEMS(&EOR)
 30             CLEAR    X              CLEAR LOOP COUNTER
 35             CLEAR    A
 45            +LDT      #4096          SET MAX LENGTH = 4096
 50   $LOOP     TD       =X'&INDEV'     TEST INPUT DEVICE
 55             JEQ       $LOOP         LOOP UNTIL READY
 60             RD       =X'&INDEV'     READ CHARACTER INTO REG A
 63   &CTR      SET       1
 64             WHILE     (&CTR LE &EORCT)
 65             COMP     =X'0000&EOR[&CTR]'
 70             JEQ       $EXIT
 71   &CTR      SET       &CTR+1
 73             ENDW
 75             STCH      &BUFADR,X     STORE CHARACTER IN BUFFER
 80             TIXR      T             LOOP UNLESS MAXIMUM LENGTH
 85             JLT       $LOOP           HAS BEEN REACHED
 90   $EXIT     STX       &RECLTH       SAVE RECORD LENGTH
100             MEND
```

(a)

```
.          RDBUFF   F2,BUFFER,LENGTH,(00,03,04)


30             CLEAR    X              CLEAR LOOP COUNTER
35             CLEAR    A
45            +LDT      #4096          SET MAX LENGTH = 4096
50   $AALOOP   TD       =X'F2'         TEST INPUT DEVICE
55             JEQ       $AALOOP       LOOP UNTIL READY
60             RD       =X'F2'         READ CHARACTER INTO REG A
65             COMP     =X'000000'
70             JEQ       $AAEXIT
65             COMP     =X'000003'
70             JEQ       $AAEXIT
65             COMP     =X'000004'
70             JEQ       $AAEXIT
75             STCH      BUFFER,X      STORE CHARACTER IN BUFFER
80             TIXR      T             LOOP UNLESS MAXIMUM LENGTH
85             JLT       $AALOOP         HAS BEEN REACHED
90   $AAEXIT   STX       LENGTH        SAVE RECORD LENGTH
```

(b)

- Here the programmer can specify a list of end of record characters.
- In the macro invocation statement there is a list(00,03,04) corresponding to the parameter &EOR. Any one of these characters is to be considered as end of record.
- The WHILE statement specifies that the following lines until the next ENDW are to be generated repeatedly as long as the condition is true.
- The testing of these condition and the looping are done while the macro is being expanded.The conditions do not contain any runtime values.
- %NITEMS is a macroprocessor function that returns as its value the number of members in an argument list. Here it has the value 3. The value of &CTR is used as a subscript to select the proper member of the list for each iteration of the loop. &EOR[&CTR] takes the values 00,03,04 .
- Implementation- When a WHILE statement is encountered during a macro expansion the specified Boolean expression is evaluated , if the value is false the macroprocessor skips ahead in DEFTAB until it finds the ENDW and then resumes normal macro expansion(not at run time).

5.3.4Keyword Macro Parameters

- All the macro instruction definitions used positional parameters. Parameters and arguments are matched according to their positions in the macro prototype and the macro invocation statement.
- The programmer needs to be careful while specifying the arguments. If an argument is to be omitted the macro invocation statement must contain a null argument mentioned with two commas.
- Positional parameters are suitable for the macro invocation. But if the macro invocation has large number of parameters, and if only few of the values need to be used in a typical invocation, a different type of parameter specification is required.
- Eg: Consider the macro GENER which has 10 parameters, but in a particular invocation of a macro only the third and nineth parameters are to be specified. If positional parameters are used the macro invocation will look like

GENER , , DIRECT, , , , , , 3,

- But using keyword parameters this problem can be solved. We can write

GENER TYPE=DIRECT, CHANNEL=3

```
25    RDBUFF    MACRO    &INDEV=F1,&BUFADR=,&RECLTH=,&EOR=04,&MAXLTH=4096
26              IF       (&EOR NE '')
27    &EORCK    SET      1
28              ENDIF
30              CLEAR    X              CLEAR LOOP COUNTER
35              CLEAR    A
38              IF       (&EORCK EQ 1)
40              LDCH    =X'&EOR'        SET EOR CHARACTER
42              RMO      A,S
43              ENDIF
47             +LDT      #&MAXLTH       SET MAXIMUM RECORD LENGTH
50    $LOOP     TD       =X'&INDEV'     TEST INPUT DEVICE
55              JEQ      $LOOP          LOOP UNTIL READY
60              RD       =X'&INDEV'     READ CHARACTER INTO REG A
63              IF       (&EORCK EQ 1)
65              COMPR    A,S            TEST FOR END OF RECORD
70              JEQ      $EXIT          EXIT LOOP IF EOR
73              ENDIF
75              STCH     &BUFADR,X      STORE CHARACTER IN BUFFER
80              TIXR     T              LOOP UNLESS MAXIMUM LENGTH
85              JLT      $LOOP            HAS BEEN REACHED
90    $EXIT     STX      &RECLTH        SAVE RECORD LENGTH
95              MEND

      .         RDBUFF   BUFADR=BUFFER,RECLTH=LENGTH

30              CLEAR    X              CLEAR LOOP COUNTER
35              CLEAR    A
40              LDCH     =X'04'         SET EOR CHARACTER
42              RMO      A,S
47             +LDT      #4096          SET MAXIMUM RECORD LENGTH
50    $AALOOP   TD       =X'F1'         TEST INPUT DEVICE
55              JEQ      $AALOOP        LOOP UNTIL READY
60              RD       =X'F1'         READ CHARACTER INTO REG A
65              COMPR    A,S            TEST FOR END OF RECORD
70              JEQ      $AAEXIT        EXIT LOOP IF EOR
75              STCH     BUFFER,X       STORE CHARACTER IN BUFFER
80              TIXR     T              LOOP UNLESS MAXIMUM LENGTH
85              JLT      $AALOOP          HAS BEEN REACHED
90    $AAEXIT   STX      LENGTH         SAVE RECORD LENGTH
```

(b)

Figure 4.10 Use of keyword parameters in macro instructions.

Keyword parameters

- Each argument value is written with a keyword that names the corresponding parameter.
- Arguments may appear in any order.
- Null arguments no longer need to be used.
- It is easier to read and much less error-prone than the positional method.

5.4 Macro Processor Design Options

5.4.1 Recursive Macro Expansion

- We have seen an example of the *definition* of one macro instruction by another. But we have not dealt with the *invocation* of one macro by another. The following example shows the invocation of one macro by another macro.

```
10      RDBUFF  MACRO   &BUFADR, &RECLTH, &INDEV
15      .
20      .       MACRO TO READ RECORD INTO BUFFER
25      .
30              CLEAR   X               CLEAR LOOP COUNTER
35              CLEAR   A
40              CLEAR   S
45              +LDT    #4096           SET MAXIMUN RECORD LENGTH
50      $LOOP   RDCHAR  &INDEV          READ CHARACTER INTO REG A
65              COMPR   A, S            TEST FOR END OF RECORD
70              JEQ     &EXIT           EXIT LOOP IF EOR
75              STCH    &BUFADR, X      STORE CHARACTER IN BUFFER
80              TIXR    T               LOOP UNLESS MAXIMUN LENGTH
85              JLT     $LOOP           HAS BEEN REACHED
90      $EXIT   STX     &RECLTH         SAVE RECORD LENGTH
95              MEND
```

```
5    RDCHAR      MACRO   &IN
10   .
15   .    MACROTO READ CHARACTER INTO REGISTER A
20   .
25                TD      =X'&IN'                 TEST INPUT DEVICE
30                JEQ      *-3                    LOOP UNTIL READY
35                RD      =X'&IN'                 READ CHARACTER
40                MEND
```

Problem of Recursive Expansion

- Previous macro processor design cannot handle such kind of recursive macro invocation and expansion
    - The procedure EXPAND would be called recursively, thus the invocation arguments in the ARGTAB will be overwritten.
    - The Boolean variable EXPANDING would be set to FALSE when the "inner" macro expansion is finished, *i.e.*, the macro process would forget that it had been in the middle of expanding an "outer" macro.

The procedure EXPAND would be called when the macro was recognized. The arguments from the macro invocation would be entered into ARGTAB as follows:

Parameter	Value
1	BUFFER
2	LENGTH
3	F1
4	(unused)
-	-

The Boolean variable EXPANDING would be set to TRUE, and expansion of the macro invocation statement would begin. The processing would proceed normally until statement invoking RDCHAR is processed. This time, ARGTAB would look like

Parameter	Value
1	F1

2	(Unused)
--	--

At the expansion, when the end of RDCHAR is recognized, EXPANDING would be set to FALSE. Thus the macro processor would 'forget' that it had been in the middle of expanding a macro when it encountered the RDCHAR statement. In addition, the arguments from the original macro invocation (RDBUFF) would be lost because the value in ARGTAB was overwritten with the arguments from the invocation of RDCHAR.

- Solutions
    - Write the macro processor in a programming language that allows recursive calls, thus local variables will be retained.
    - If you are writing in a language without recursion support, use a stack to take care of pushing and popping local variables and return addresses.

5.4.2General-Purpose Macro Processors

- Macro processors that do not dependent on any particular programming language, but can be used with a variety of different languages
- **Pros**
    - Programmers do not need to learn many macro languages.
    - Although its development costs are somewhat greater than those for a language specific macro processor, this expense does not need to be repeated for each language, thus save substantial overall cost.
- **Cons**
    - Large number of details must be dealt with in a real programming language
        - Situations in which normal macro parameter substitution should not occur, e.g., comments.
        - Facilities for grouping together terms, expressions, or statements. Eg: some languages use begin and end . Some use { and }
        - Tokens, e.g., identifiers, constants, operators, keywords
        - Syntax used for macro definition and macro invocation statement is different.

5.4.3Macro Processing within Language Translators

- The macro processors we discussed are called “Preprocessors”.
  - Process macro definitions
  - Expand macro invocations
  - Produce an expanded version of the source program, which is then used as input to an assembler or compiler
- You may also combine the macro processing functions with the language translator:
  - Line-by-line macro processor
  - Integrated macro processor

Line-by-Line Macro Processor

- Used as a sort of input routine for the assembler or compiler
  - Read source program
  - Process macro definitions and expand macro invocations
  - Pass output lines to the assembler or compiler
- Benefits
  - Avoid making an extra pass over the source program.
  - Data structures required by the macro processor and the language translator can be combined (e.g., OPTAB and NAMTAB)
  - Utility subroutines can be used by both macro processor and the language translator.
    - Scanning input lines
    - Searching tables
    - Data format conversion
  - It is easier to give diagnostic messages related to the source statements

Integrated Macro Processor

- An integrated macro processor can potentially make use of any information about the source program that is extracted by the language translator.
  - Ex (blanks are not significant in FORTRAN)
    - DO 100 I = 1,20
      - a DO statement

    - DO 100 I = 1
        - An assignment statement
        - DO100I: variable (blanks are not significant in FORTRAN)
- An integrated macro processor can support macro instructions that depend upon the context in which they occur.

- Disadvantages- They must be specially designed and written to work with a particular implementation of an assembler or compiler.. Cost of development is high.

EDITORS AND DEBUGGING SYSTEMS

An Interactive text editor has become an important part of almost any computing environment. Text editor acts as a primary interface to the computer for all type of "knowledge workers" as they compose, organize, study, and manipulate computer-based information.

An interactive debugging system provides programmers with facilities that aid in testing and debugging of programs. Many such systems are available during these days. Our discussion is broad in scope, giving the overview of interactive debugging systems – not specific to any particular existing system.

5.1 Text Editors:

- An Interactive text editor has become an important part of almost any computing environment. Text editor acts as a primary interface to the computer for all type of "knowledge workers" as they compose, organize, study, and manipulate computer- based information.
- A text editor allows you to edit a text file (create, modify etc…). For example the Interactive text editors on Windows OS - Notepad, WordPad, Microsoft Word, and text editors on UNIX OS - vi, emacs , jed, pico.
- Normally, the common editing features associated with text editors are, Moving the cursor, Deleting, Replacing, Pasting, Searching, Searching and replacing, Saving and loading, and, Miscellaneous(e.g. quitting).

5.1.1 Overview of the editing process

- An interactive editor is a computer program that allows a user to create and revise a target document. Document includes objects such as computer diagrams, text, equations tables, diagrams, line art, and photographs. In text editors, character strings are the primary elements of the target text.

- Document-editing process in an interactive user-computer dialogue has four tasks:
    1) Select the part of the target document to be viewed and manipulated
    2) Determine how to format this view on-line and how to display it
    3) Specify and execute operations that modify the target document
    4) Update the view appropriately

- The above task involves traveling, filtering and formatting.
    - Traveling – To locate the area of interest. This is done by operations such as next screenful, bottom and find pattern.
    - Filtering- extracts the relevant subset of the target document.
    - Formatting- How the result of filtering will be seen as a visible representation(the view) on a display screen.
    - Editing- The target document is created or altered with a set of operations such as insert, delete, replace, move and copy.
- There are two types of editors. Manuscript-oriented editor and program oriented editors. Manuscript-oriented editor is associated with characters, words, lines, sentences and paragraphs. Program-oriented editors are associated with identifiers, keywords, statements. User wish – what he wants – formatted.
- So in overall the user might travel to the end of the document. A screenful of text would be filtered, this segment would be formatted, and the view would be displayed on an output device. The user could then edit the view.

5.1.2User Interface:

- Conceptual model of the editing system provides an easily understood abstraction of the target document and its elements. For example, Line editors – simulated the world of the key punch – 80 characters, single line or an integral number of lines, Screen editors – Document is represented as a quarter-plane of text lines, unbounded both down and to the right.
- The user interface is concerned with, the input devices, the output devices and, the interaction language. The input devices are used to enter elements of text being edited, to enter commands. The output devices, lets the user view the elements being edited and the

results of the editing operations and, the interaction language provides communication with the editor.

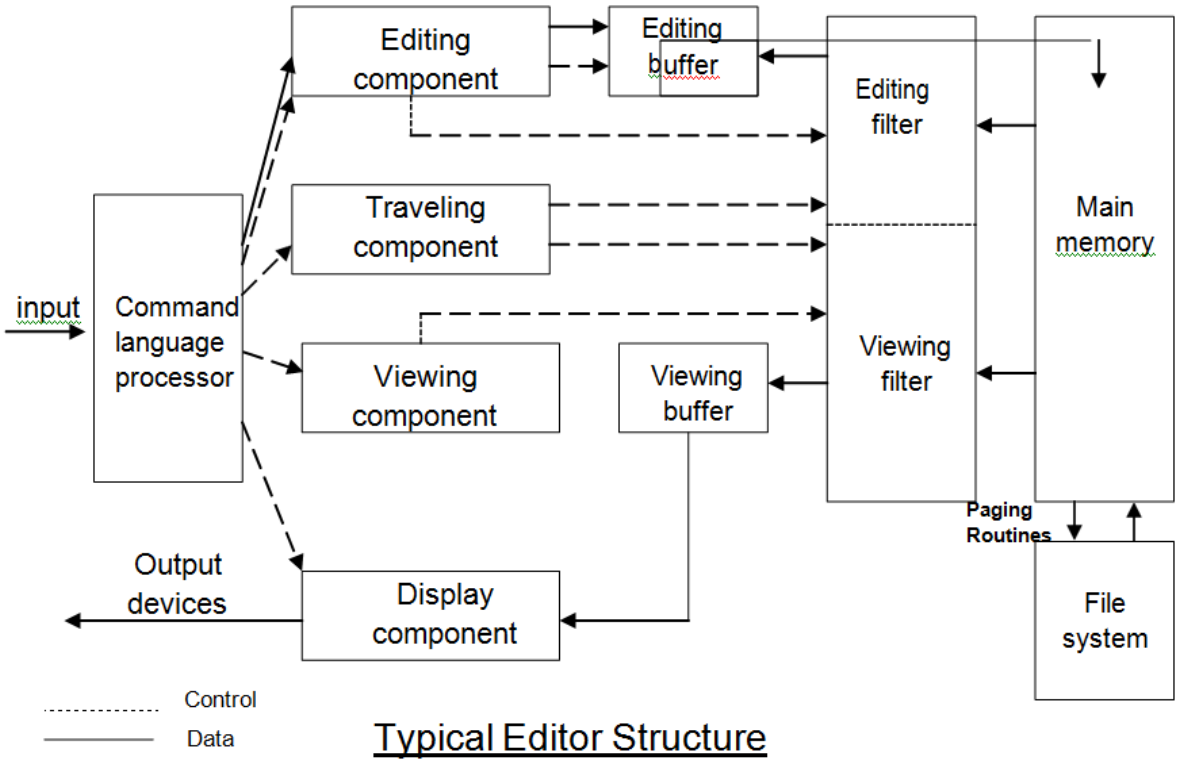
- **Input Devices** are divided into three categories:
    - text devices- are type writer like key boards on which a user presses and releases keys sending a unique code for each key.
    - button or choice devices- generate an interrupt causing an invocation of an associated application program action. They include a set of function keys. Buttons can be simulated in software.
    - Locator devices – are two dimensional analog to digital converters that position a cursor symbol on the screen by observing the user's movement of the device. Eg: mouse, data tablet. Returns the coordinates of the position of the device. Text devices with arrow keys can be used as locator devices . Arrow shows left, right , up or down.
    - Voice input devices- Translates spoken words to their textual equivalent.

- **Output Devices** lets the user view the elements being edited and the results of the editing operations. CRT terminals use hardware assistance for such features as moving the cursor , inserting and deleting characters and lines etc.
- **The interaction language** is one of the common types.
    - **Typing or text command oriented-** the user communicates with the editor by typing text strings both for command names and for operands.These strings are sent to the editor and echoed to the output device.This requires the user to remember the commands.
    - **Function key oriented-** In this each command is associated with a marked key on the user's keyboard.
    - **Menu oriented systems-** A menu is a multiple choice set of text strings or icons which are graphic symbols that represent object or operations. The user can perform actions by selecting items from the menu. Some systems have the most used functions on a main command menu and have secondary menus to handle the less frequently used functions.

5.1.3Editor Structure:

Most text editors have a structure similar to that shown in the following figure. That is most text editors have a structure similar to shown in the figure regardless of features and the computers

Command language Processor accepts command, uses semantic routines – performs functions such as editing and viewing. The semantic routines involve traveling, editing, viewing and display functions.



Typical Editor Structure

- The **command language processor** accepts input from the user's input devices and analyses the tokens and syntactic structure of the commands. That is, it function like lexical and syntactic phases of a compiler. It invokes the semantic routines directly. The command language processor also produces an intermediate representation of the desired editing operations. This representation is decoded by an interpreter that invokes the appropriate semantic routines.

- **Editing Component** - In editing a document, the start of the area to be edited is determined by the current editing pointer maintained by the editing component. Editing component is a collection of modules dealing with editing tasks. Current editing pointer can be set or reset due to next paragraph, next screen, cut paragraph, paste paragraph etc..,.

  - **Travelling component** – performs the setting of the current editing and viewing pointers and thus determines the point at which the viewing/editing filtering begins.
  - **Editing filter**- When the user issues an editing command the editing component invokes the editing filter. This component filters the document to generate a new **editing buffer** based on the current editing pointer as well as on the editing filter parameters.

  - **Filtering** consists of selection of continuous characters beginning at the current point.

  - **Viewing component**- thee start of the area to be viewed is determined by the viewing pointer. This pointer is maintained by the viewing component. When the display need to be updated the viewing component invokes the **viewing filter**. This component filters the document to generate a new **viewing buffer**.

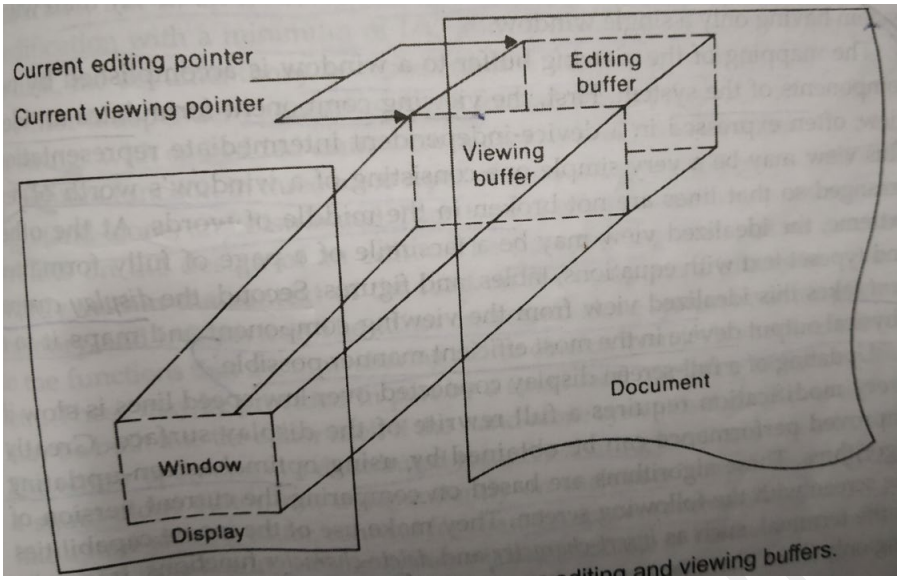
  - **Display component**- The viewing buffer is then passed to the display component which produces a display by mapping the buffer to a rectangular subset of the screen called window.

  - The editing and viewing buffers can be independent or overlapped.

  - The mapping of viewing buffer to window is accomplished by two components.

    1. Viewing component- formulates an ideal view

    2. Display component – takes this ideal view from viewing component and maps it to the output device.



Simple relationship between editing and viewing buffers

- The components of the editor deal with a user document on two levels: In main memory and in the disk file system. Loading an entire document into main memory may be infeasible – only part is loaded – demand paging is used – uses editor paging routines.
- Documents may not be stored sequentially as a string of characters. Uses separate editor data structure that allows addition, deletion, and modification with a minimum of I/O and character movement.
- Many editors use terminal control database. They can call terminal independent library routines such as scroll down, or read cursor positions.
- Types of editors based on computing environment: Editors function in three basic types of computing environments:

    1. Time sharing
    2. Stand-alone
    3. Distributed.

    Each type of environment imposes some constraints on the design of an editor.

- In time sharing environment, editor must function swiftly within the context of the load on the computer's processor, memory and I/O devices.
- In stand-alone environment, editors on stand-alone system are built with all the functions to carry out editing and viewing operations – The help of the OS may also be taken to carry out some tasks like demand paging.
- In distributed environment, editor has both functions of stand-alone editor; to run independently on each user's machine and like a time sharing editor, contend for shared resources such as files.

Interactive Debugging Systems:

An interactive debugging system provides programmers with facilities that aid in testing and debugging of programs. Many such systems are available during these days. Our discussion is broad in scope, giving the overview of interactive debugging systems – not specific to any particular existing system.

Here we discuss

- Introducing important functions and capabilities of IDS

- Relationship of IDS to other parts of the system

- Debugging methods

Debugging Functions and Capabilities:

- One important requirement of any IDS is unit test functions specified by the programmer. Such functions deal with execution sequencing , which is the observation and control of the flow of program execution.Eg: The program may be suspended after a fixed number of instructions are executed. The programmer can define break points. After the program is suspended debugging commands can be used to diagnose errors.
- A Debugging system should also provide functions such as tracing and trace back

- Tracing can be used to track the flow of execution logic and data modifications. The control flow can be traced at different levels of detail – procedure, branch, individual instruction, and so on.
- Trace back can show the path by which the current statement in the program was reached. It can also show which statements have modified a given variable or parameter. The statements are displayed rather than as hexadecimal displacements.
- Program-Display capabilities. A debugger should have good program-display capabilities.
    - Program being debugged should be displayed completely with statement numbers.
    - The program may be displayed as originally written or with macro expansion.
    - Keeping track of any changes made to the programs during the debugging session. Support for symbolically displaying or modifying the contents of any of the variables and constants in the program. Resume execution – after these changes.

- A debugging system should consider the language in which the program being debugged is written. A single debugger – many programming languages – language independent. The debugger- a specific programming language– language dependent.
- The debugging system should be able to deal with optimized code. Many optimizations involve rearrangement of code in the program.Eg: Separate loops can be combined into single loop.
- Storage of variables- When a program is translated the compiler assigns a home location in memory for each variables. Variable values can be temporarily held in registers to improve speed of access. If a user changes the value of a variable in home location while debugging the modified value might not be used by the program.
- The debugging of optimized code requires cooperation from optimized compiler.

Relationship with Other Parts of the System:

- The important requirement for an interactive debugger is that it always be available. Must appear as part of the run-time environment and an integral part of the system.
- When an error is discovered, immediate debugging must be possible. The debugger

must communicate and cooperate with other operating system components such as interactive subsystems.

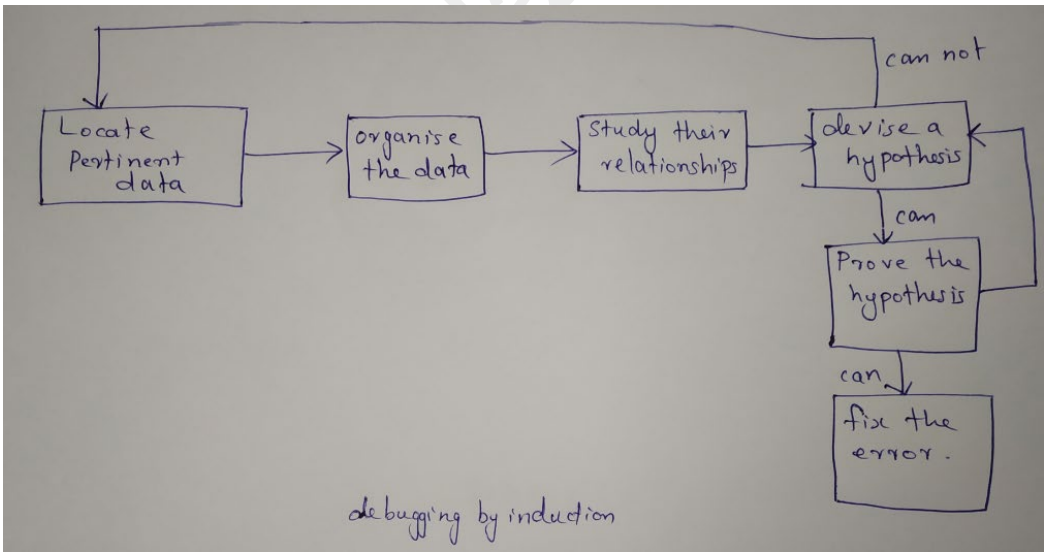
- Debugging is more important at production time than it is at application-development time. When an application fails during a production run, work dependent on that application stops.
- The debugger must also exist in a way that is consistent with the security and integrity components of the system.
- The debugger must coordinate its activities with those of existing and future language compilers and interpreters.

Debugging Methods

1. Debugging by Induction
2. Debugging by Deduction
3. Debugging by Backtracking

Debugging by Induction

- In induction one proceeds from the particulars to the whole.ie, By starting with the symptoms of the error in the result of one or more test cases and looking for relationships among the symptoms.



1. Locate the pertinent data: Consider all the available data or symptoms about the problems

2. Organise the data: Pertinent data is structured to allow one to observe patterns of particular importance and search for contradictions. One such organization structure can be a table.

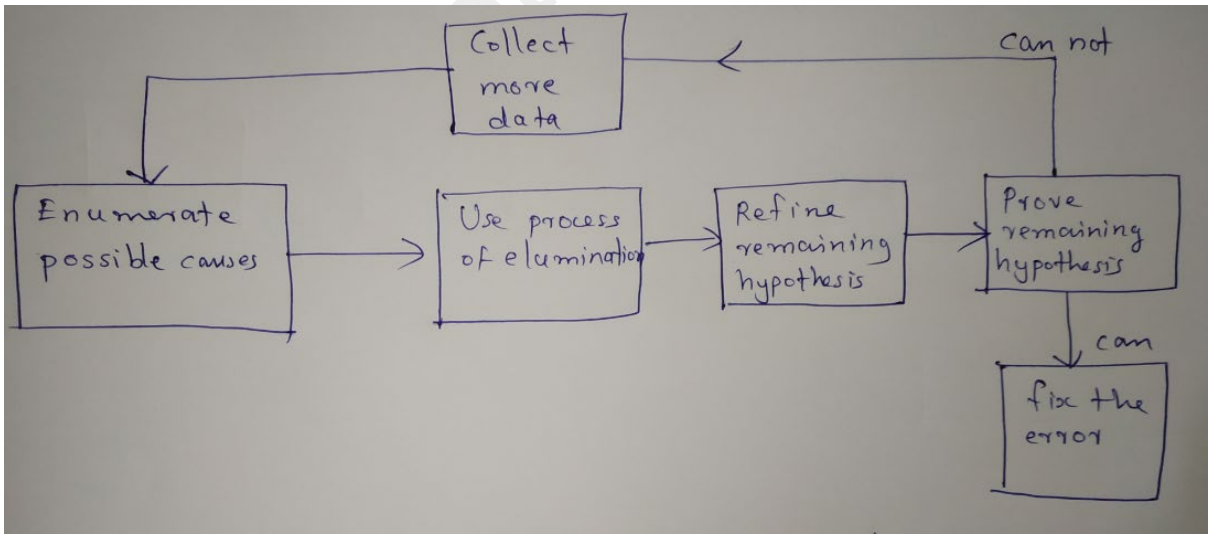
3. Devise a hypothesis: In this step study the relationship between the clues and devise using patterns, one or more hypothesis about the cause o the error.

4. Prove the hypothesis: Prove the reasonableness of the hypothesis before proceeding. A failure to this, results in the fixing of only one symptom of the problem.

Debugging by Deduction

- Is a process of proceeding from general theories or premises to arrive at a conclusion.
    1. Enumerate all possible cases- The first step is to develop all causes of the error.
    2. Use the data to eliminate possible causes- By careful analysis of data particularly by looking for contradictions attempt to eliminate all possible causes except one.
    3. Refine the remaining hypothesis- The possible causes at this point may be correct. But refine it to be more specific.

    4. Prove the remaining hypothesis.



Debugging by Back Tracking

- For small programs the method of backtracking is more effective to locate errors.
- To use this method start at the place in the program where an incorrect result was produced and go backwards in the program one step at a time. That is executing the program in reverse order to derive the values of all variables in the previous step. Then the error can be localized.

Device Driver

Learn from PPT