A Brief History of Modularity in Programming
“Programming in the Large” Steps

Design & Implement

- Program & programming style (done)
- Common data structures and algorithms (done)
- Modularity ← we are here
- Building techniques & tools (done)

Debug

- Debugging techniques & tools (done)

Test

- Testing techniques (done)

Maintain

- Performance improvement techniques & tools
Goals of this Lecture

Help you learn:
- The history of modularity in computer programming
- A rational reconstruction of the development of programming styles, with a focus on modularity

Why? Modularity is important
- Abstraction is a powerful (the only?) technique available for understanding large, complex systems
- A power programmer knows how to find the abstractions in a large program
- A power programmer knows how to convey a large program’s abstractions via its modularity

And also… History is important
- Only by understanding the past can we fully appreciate the present
Agenda

Non-modular programming

Structured programming (SP)

Abstract object (AO) programming

Abstract data type (ADT) programming
Non-Modular Programming

Example languages
- Machine languages
- Assembly languages
- FORTRAN (Formula Translating System)
- BASIC (Beginners All-Purpose Symbolic Instruction Code)
Non-Modular Example

Example program
- Dr. Dondero’s first computer program
- 1971
- Teletype terminal
- Survived on paper

Functionality
- Help fellow algebra students learn how to expand polynomials
- Name: POLLY.BAS

Design
- BASIC language
- Don’t be concerned with details…
POLLY.BAS

5 PRINT "IF YOU NEED INSTRUCTIONS TYPE 0."; (1)
7 INPUT X (2)
8 IF X=0 THEN 10 (3)
9 IF X#0 THEN 60
10 PRINT "HELLO! THIS PROGRAM IS DESIGNED TO GIVE YOU PRACTICE" (4)
11 PRINT "IN EXPANDING, THROUGH THE USE OF THE DISTRIBUTIVE" (5)
12 PRINT "PROPERTY. IT WILL ALSO HELP YOU TO OVERCOME THE" (6)
13 PRINT "FRESHMAN MISTAKE. PLEASE RESPOND TO EACH QUESTION" (7)
14 PRINT "BY TYPING THE NUMBER OF THE ANSWER CORRESPONDING TO" (8)
15 PRINT "THAT QUESTION." (9)
27 PRINT (10)
28 PRINT (11)
29 PRINT (12)
30 PRINT TAB(21)"LIST OF ANSWERS" (13)
40 PRINT "********************************************************************" (14)
50 PRINT TAB(1)"1. -4A^2 - 2A^2 + 2A^2B"; (15)
51 PRINT TAB(36)"4. -4A^2 + 2A^2 + 2A^2B" (16)
52 PRINT TAB(1)"2. -4A^2 -2A^2 -2A^2B"; (17)
53 PRINT TAB(36)"5. 4A^2 - 2A^2 -2A^2B" (18)
54 PRINT TAB(1)"3. -A^2 - A - AB"; (19)
55 PRINT TAB(36)"6. -2A^2 + 2a + 2AB" (20)
POLLY.BAS (cont.)

56 PRINT (21)
57 PRINT (22)
58 PRINT (23)
60 PRINT "OK! HERE WE GO!!!" (24)
61 PRINT (25)
62 PRINT (26)
63 PRINT (27)
70 PRINT "EXPAND:"; (28)
71 GOSUB 8000 (29)
72 GOTO 90 (32)
73 GOSUB 8010 (54 end trace)
74 GOTO 141
75 GOSUB 8020
76 GOTO 170
77 GOSUB 8030
78 GOTO 200
79 GOSUB 8040
80 GOTO 300
81 GOSUB 8050
82 GOTO 400

90 PRINT "WHAT IS YOUR ANSWER? "; (33)
100 INPUT A (34) (43)
110 IF A=1 THEN 550 (35) (44)
115 IF A=2 THEN 550 (45)
120 IF A=3 THEN 780 (46)
125 IF A=4 THEN 550
130 IF A=5 THEN 550
135 IF A=6 THEN 550
140 IF A#6 THEN 9990
141 PRINT "WHAT IS YOUR ANSWER? ";
150 INPUT B
155 IF B=1 THEN 580
156 IF B=2 THEN 580
158 IF B=3 THEN 580
160 IF B=4 THEN 580
162 IF B=5 THEN 580
164 IF B=6 THEN 800
166 IF B#6 THEN 9990
PRINT "WHAT WILL IT BE THIS TIME? ";
INPUT C
IF C=1 THEN 620
IF C=2 THEN 820
IF C=3 THEN 620
IF C=4 THEN 620
IF C=5 THEN 620
IF C=6 THEN 620
IF C#6 THEN 9990
PRINT "WHAT IS YOUR GUESS? ";
INPUT D
IF D=1 THEN 660
IF D=2 THEN 660
IF D=3 THEN 660
IF D=4 THEN 840
IF D=5 THEN 660
IF D=6 THEN 660
IF D#6 THEN 9990
PRINT "WHAT IS YOUR ANSWER? ";
INPUT E
IF E=1 THEN 860
IF E=2 THEN 700
IF E=3 THEN 700
IF E=4 THEN 700
IF E=5 THEN 700
IF E=6 THEN 700
IF E#6 THEN 9990
PRINT "WHAT WILL IT BE? ";
INPUT F
IF F=1 THEN 740
IF F=2 THEN 740
IF F=3 THEN 740
IF F=4 THEN 740
IF F=5 THEN 880
IF F=6 THEN 740
IF F#6 THEN 9990
Non-Modular Example

POLLY.BAS (cont.)

<table>
<thead>
<tr>
<th>Line</th>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>550</td>
<td>GOSUB 9000</td>
<td></td>
</tr>
<tr>
<td>570</td>
<td>GOTO 100</td>
<td>(42)</td>
</tr>
<tr>
<td>580</td>
<td>GOSUB 9000</td>
<td></td>
</tr>
<tr>
<td>600</td>
<td>GOTO 150</td>
<td></td>
</tr>
<tr>
<td>620</td>
<td>GOSUB 9000</td>
<td></td>
</tr>
<tr>
<td>640</td>
<td>GOTO 175</td>
<td></td>
</tr>
<tr>
<td>660</td>
<td>GOSUB 9000</td>
<td></td>
</tr>
<tr>
<td>680</td>
<td>GOTO 210</td>
<td></td>
</tr>
<tr>
<td>700</td>
<td>GOSUB 9000</td>
<td></td>
</tr>
<tr>
<td>720</td>
<td>GOTO 310</td>
<td></td>
</tr>
<tr>
<td>740</td>
<td>GOSUB 9000</td>
<td></td>
</tr>
<tr>
<td>760</td>
<td>GOTO 410</td>
<td></td>
</tr>
<tr>
<td>780</td>
<td>GOSUB 9010</td>
<td>(47)</td>
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<tr>
<td>785</td>
<td>GOSUB 9020</td>
<td>(50)</td>
</tr>
<tr>
<td>790</td>
<td>GOTO 73</td>
<td>(53)</td>
</tr>
<tr>
<td>800</td>
<td>GOSUB 9010</td>
<td></td>
</tr>
<tr>
<td>805</td>
<td>GOSUB 9020</td>
<td></td>
</tr>
<tr>
<td>810</td>
<td>GOTO 75</td>
<td></td>
</tr>
<tr>
<td>820</td>
<td>GOSUB 9010</td>
<td></td>
</tr>
<tr>
<td>825</td>
<td>GOSUB 9020</td>
<td></td>
</tr>
<tr>
<td>830</td>
<td>GOTO 77</td>
<td></td>
</tr>
<tr>
<td>840</td>
<td>GOSUB 9010</td>
<td></td>
</tr>
<tr>
<td>845</td>
<td>GOSUB 9020</td>
<td></td>
</tr>
<tr>
<td>850</td>
<td>GOTO 79</td>
<td></td>
</tr>
<tr>
<td>860</td>
<td>GOSUB 9010</td>
<td></td>
</tr>
<tr>
<td>865</td>
<td>GOSUB 9020</td>
<td></td>
</tr>
<tr>
<td>870</td>
<td>GOTO 81</td>
<td></td>
</tr>
<tr>
<td>880</td>
<td>GOSUB 9010</td>
<td></td>
</tr>
<tr>
<td>890</td>
<td>GOTO 9998</td>
<td></td>
</tr>
<tr>
<td>8000</td>
<td>PRINT &quot;-A(A + 1 + B)&quot;</td>
<td>(30)</td>
</tr>
<tr>
<td>8001</td>
<td>RETURN</td>
<td>(31)</td>
</tr>
<tr>
<td>8010</td>
<td>PRINT &quot;-2A(A - 1 - B)&quot;</td>
<td></td>
</tr>
<tr>
<td>8011</td>
<td>RETURN</td>
<td></td>
</tr>
<tr>
<td>8020</td>
<td>PRINT &quot;-2A(2A + A + AB)&quot;</td>
<td></td>
</tr>
<tr>
<td>8021</td>
<td>RETURN</td>
<td></td>
</tr>
<tr>
<td>8030</td>
<td>PRINT &quot;-2A(2A - A - AB)&quot;</td>
<td></td>
</tr>
<tr>
<td>8031</td>
<td>RETURN</td>
<td></td>
</tr>
<tr>
<td>8040</td>
<td>PRINT &quot;-(4A^2 + 2A^2 -2A^2B)&quot;</td>
<td></td>
</tr>
<tr>
<td>8041</td>
<td>RETURN</td>
<td></td>
</tr>
<tr>
<td>8050</td>
<td>PRINT &quot;-A(-4A + 2A + 2AB)&quot;</td>
<td></td>
</tr>
<tr>
<td>8051</td>
<td>RETURN</td>
<td></td>
</tr>
<tr>
<td>9000</td>
<td>PRINT &quot;YOUR ANSWER IS INCORRECT.&quot;</td>
<td>(37)</td>
</tr>
<tr>
<td>9005</td>
<td>PRINT &quot;LOOK CAREFULLY AT THE SAME PROBLEM AND GIVE&quot;</td>
<td>(38)</td>
</tr>
<tr>
<td>9006</td>
<td>PRINT &quot;ANOTHER ANSWER.&quot;</td>
<td>(39)</td>
</tr>
<tr>
<td>9007</td>
<td>PRINT &quot;WHAT WILL IT BE? &quot;;</td>
<td>(40)</td>
</tr>
<tr>
<td>9008</td>
<td>RETURN</td>
<td>(41)</td>
</tr>
<tr>
<td>9010</td>
<td>PRINT &quot;YOUR ANSWER IS CORRECT.&quot;</td>
<td>(48)</td>
</tr>
<tr>
<td>9015</td>
<td>RETURN</td>
<td>(49)</td>
</tr>
<tr>
<td>9020</td>
<td>PRINT &quot;NOW TRY THIS ONE.&quot;</td>
<td>(51)</td>
</tr>
<tr>
<td>9030</td>
<td>RETURN</td>
<td>(52)</td>
</tr>
<tr>
<td>9990</td>
<td>PRINT &quot;THAT'S NOT A REASONABLE ANSWER.&quot;</td>
<td></td>
</tr>
<tr>
<td>9991</td>
<td>PRINT &quot;COME BACK WHEN YOU GET SERIOUS.&quot;</td>
<td></td>
</tr>
<tr>
<td>9992</td>
<td>GOTO 9999</td>
<td></td>
</tr>
<tr>
<td>9998</td>
<td>PRINT &quot;SORRY, THIS IS THE END OF THE PROGRAM.&quot;</td>
<td></td>
</tr>
<tr>
<td>9999</td>
<td>END</td>
<td></td>
</tr>
</tbody>
</table>
What’s wrong?
  • From programmer’s viewpoint?

Think about
  • Flow of control
Bőhm and Jacopini

Any algorithm can be expressed as the nesting of only 3 control structures: sequence, selection, repetition

Corrado Bőhm and Guiseppe Jacopini.
"Flow diagrams, Turing machines and languages with only two formation rules."
Toward SP (Bőhm & Jacopini)

Sequence

Statement 1

Statement 2

Selection

TRUE

Statement 1

Statement 2

FALSE

Repetition

TRUE

Statement

FALSE
Toward SP (Dijkstra)

Paraphrasing (quotes in Appendix 1) …

A program
- Is a static entity
- Has no time dimension

A process
- Is a program in execution
- Is a dynamic entity
- Has a time dimension
- Can be understood only in terms of its time dimension

People understand static things better than they understand dynamic things

So the static structure of a program should be similar to its dynamic structure
Toward SP (Dijkstra)

Or, in other words…

Suppose:

• We have program written on paper 1
• Each time computer executes a statement, we write that statement on paper 2

Then consider the correspondence between paper 1 and paper 2

• Conditionals interfere, but only slightly
• Function calls interfere
• Iterations interfere

Nevertheless, for the sake of clarity…
Paper 2 should be similar to paper 1
  • The **dynamic** rep of the program should be similar to the **static** rep of the program

And ...  
  • If the static rep of the program contains goto statements, then paper 2 will be dissimilar to paper 1

So avoid goto statements
Bőhm & Jacopini:
- Any program \textit{can} be expressed as the nesting of only 3 control structures

Bőhm & Jacopini + Dijkstra
- Any program \textit{should} be expressed as the nesting of only 3 control structures
Agenda

Non-modular programming

Structured programming (SP)

Abstract object (AO) programming

Abstract data type (ADT) programming
Structured Programming

Key ideas:
• Programming using only the nesting of the 3 elementary control structures: sequence, selection, iteration
• (Arguably) occasional exceptions are OK
• Define functions/procedures/subroutines liberally

Example languages:
• Pascal
• C

Example program…
• (Don’t be concerned with details)
rev.c

Functionality
• Read numbers (doubles) from stdin until end-of-file
• Write to stdout in reverse order

Design
• Use a stack (LIFO data structure) of doubles
• Represent stack as an array
• To keep things simple…
  • Assume max stack size is 100
  • (See precept examples for more realistic implementations)
#include <stdio.h>
#include <stdlib.h>
#include <assert.h>

enum {MAX_STACK_ITEMS = 100}; /* Arbitrary */

int push(double *stack, int *top, double d)
{
    assert(stack != NULL);
    assert(top != NULL);
    if (*top >= MAX_STACK_ITEMS)
        return 0;
    stack[*top] = d;
    (*top)++;
    return 1;
}

double pop(double *stack, int *top)
{
    assert(stack != NULL);
    assert(top != NULL);
    assert(*top > 0);
    (*top)--;
    return stack[*top];
}
int main(void)
{
    double stack[MAX_STACK_ITEMS];
    int top = 0;
    double d;
    while (scanf("%lf", &d) == 1)
        if (!push(stack, &top, d))
            return EXIT_FAILURE;
    while (top > 0)
        printf("%g\n", pop(stack, &top));
    return 0;
}
Toward AO Programming

What's wrong?
  • From programmer's viewpoint?

Think about:
  • Design decisions
  • Modularity
Toward AO Programming

David Parnas

David Parnas
"On the Criteria to be Used in Decomposing Systems into Modules."
Agenda

Non-modular programming
Structured programming
Abstract object (AO) programming
Abstract data type (ADT) programming
Abstract Object Programming

Key ideas:
• Design modules to encapsulate important design decisions
• Design modules to hide info from clients

Example languages
• Ada
• C (with some discipline)

Example program…
AO Programming Example

stack.h (interface)

```c
#ifndef STACK_INCLUDED
#define STACK_INCLUDED

int    Stack_init(void);
void   Stack_free(void);
int    Stack_push(double d);
double Stack_pop(void);
int    Stack_isEmpty(void);

#endif
```
#include "stack.h"
#include <stdio.h>
#include <stdlib.h>

int main(void)
{
    double d;
    Stack_init();
    while (scanf("%lf", &d) == 1)
    {
        Stack_push(d);
    }
    while (! Stack_isEmpty())
    {
        printf("%g\n", Stack_pop());
    }
    Stack_free();
    return 0;
}

For simplicity, error handling code is omitted.
#include "stack.h"
#include <assert.h>

enum {MAX_STACK_ITEMS = 100};

static double stack[MAX_STACK_ITEMS];
static int top;
static int initialized = 0;

int Stack_init(void)
{  assert(! initialized);
   top = 0;
   initialized = 1;
   return 1;
}

void Stack_free(void)
{  assert(initialized);
    initialized = 0;
}

int Stack_push(double d)
{  assert(initialized);
    if (top >= MAX_STACK_ITEMS)
        return 0;
    stack[top] = d;
    top++;
    return 1;
}

double Stack_pop(void)
{  assert(initialized);
    assert(top > 0);
    top--;
    return stack[top];
}

int Stack_isEmpty(void)
{  assert(initialized);
    return top == 0;
}
Notes:

• One Stack **object**
• The Stack object is **abstract**
  • Major design decision (implementation of Stack as array) is hidden from client
  • Client doesn’t know Stack implementation
  • Change Stack implementation => need not change client
• Object state is implemented using global variables
  • Global variables are **static** => clients cannot access them directly
Toward ADT Programming

What’s wrong?
  • From programmer’s viewpoint?

Think about
  • Flexibility
Toward ADT Programming

Barbara Liskov
"An abstract data type defines a class of abstract objects which is completely characterized by the operations available on those objects. This means that an abstract data type can be defined by defining the characterizing operations for that type."

Agenda

Non-modular programming
Structured programming
Abstract object (AO) programming
Abstract data type (ADT) programming
ADT Programming

Key ideas:
- A module should be **abstract**
  - As in AO programming
- A module can (and often should) be a **data type**!!!
  - Data type consists of data and operators applied to those data
  - Program can create as many objects of that type as necessary

Example languages
- CLU (ALGOL, with **clusters**)
- C++, Objective-C, C#, Java, Python
- C (with some discipline)

Example program…
#ifndef STACK_INCLUDED
#define STACK_INCLUDED

enum {MAX_STACK_ITEMS = 100};

struct Stack {
    double items[MAX_STACK_ITEMS];
    int top;
};

struct Stack *Stack_new(void);
void          Stack_free(struct Stack *stack);
int           Stack_push(struct Stack *stack, double d);
double        Stack_pop(struct Stack *stack);
int           Stack_isEmpty(struct Stack *stack);

#endif
#include <stdio.h>
#include <stdlib.h>
#include "stack.h"

int main(void)
{
    double d;
    struct Stack *stack1;
    stack1 = Stack_new();
    while (scanf("%lf", &d) == 1)
        Stack_push(stack1, d);
    while (! Stack_isEmpty(stack1))
        printf("%g\n", Stack_pop(stack1));
    Stack_free(stack1);
    return 0;
}
#include <stdlib.h>
#include <assert.h>
#include "stack.h"

struct Stack *Stack_new(void)
{
    struct Stack *stack;
    stack = (struct Stack*)malloc(sizeof(struct Stack));
    if (stack == NULL)
        return NULL;
    stack->top = 0;
    return stack;
}

void Stack_free(struct Stack *stack)
{
    assert(stack != NULL);
    free(stack);
}
int Stack_push(struct Stack *stack, double d)
{
    assert(stack != NULL);
    if (stack->top >= MAX_STACK_ITEMS)
        return 0;
    stack->items[stack->top] = d;
    (stack->top)++;
    return 1;
}

double Stack_pop(struct Stack *stack)
{
    assert(stack != NULL);
    assert(stack->top > 0);
    stack->top--;
    return stack->items[stack->top];
}

int Stack_isEmpty(struct Stack *stack)
{
    assert(stack != NULL);
    return stack->top == 0;
}
What’s wrong?
  • From programmer’s viewpoint?

Think about
  • Encapsulation

See next lecture!
Summary

A rational reconstruction of the history of modularity in computer programming

• Non-modular programming
• Structured programming (SP)
• Abstract object (AO) programming
• Abstract data type (ADT) programming

More recently:

• Object-oriented programming
  • Smalltalk, Objective-C, C++, C#, Java
• Logic-based programming
  • Prolog
• Functional programming
  • LISP, OCaml
• …
Edsger Dijkstra.  
"Go To Statement Considered Harmful."  
*Communications of the ACM, Vol. 11,*  
"My first remark is that, although the programmer's activity ends when he has constructed a correct program, the process taking place under control of his program is the true subject matter of his activity, for it is this process that has to accomplish the desired effect; it is this process that in its dynamic behavior has to satisfy the desired specifications. Yet, once the program has been made, the 'making' of the corresponding process is delegated to the machine."

"My second remark is that our intellectual powers are rather geared to master **static relations and that our powers to visualize** processes evolving in time are relatively poorly developed. For that reason we should do (as wise programmers aware of our limitations) our utmost to shorten the conceptual gap between the static program and the dynamic process, to **make the correspondence between the program (spread out in text space) and the process (spread out in time) as trivial as possible.**"

Edsger Dijkstra.  
"Go To Statement Considered Harmful."  

Use of the **goto** statement makes the correspondence between the program and the process non-trivial
Toward AO Programming

David Parnas
"In the first decomposition the criterion used was to make each major step in the processing a module. One might say that to get the first decomposition one makes a flowchart. This is the most common approach to decomposition or modularization."

David Parnas
"On the Criteria to be Used in Decomposing Systems into Modules."
"The second decomposition was made using 'information hiding' as a criterion. The modules no longer correspond to steps in the processing... Every module in the second decomposition is characterized by its knowledge of a design decision which it hides from all others. Its interface or definition was chosen to reveal as little as possible about its inner workings."

David Parnas
"On the Criteria to be Used in Decomposing Systems into Modules."
Toward ADT Programming

Barbara Liskov
"We believe that the above concept captures the fundamental properties of abstract objects. When a programmer makes use of an abstract data object, he is concerned only with the behavior which that object exhibits but not with any details of how that behavior is achieved by means of an implementation."

"Abstract types are intended to be very much like the built-in types provided by a programming language. The user of a built-in type, such as integer or integer array, is only concerned with creating objects of that type and then performing operations on them. He is not (usually) concerned with how the data objects are represented, and he views the operations on the objects as indivisible and atomic when in fact several machine instructions may be required to perform them."

Appendix 2: SP Example 2

polly.c

```c
#include <stdio.h>
#include <stdlib.h>

static void printInstructions(void)
{
    printf("HELLO! THIS PROGRAM IS DESIGNED TO GIVE YOU PRACTICE\n");
    printf("IN EXPANDING, THROUGH THE USE OF THE DISTRIBUTIVE\n");
    printf("PROPERTY. IT WILL ALSO HELP YOU TO OVERCOME THE\n");
    printf("FRESHMAN MISTAKE. PLEASE RESPOND TO EACH QUESTION\n");
    printf("BY TYPING THE NUMBER OF THE ANSWER CORRESPONDING TO\n");
    printf("THAT QUESTION.\n");
    printf("\n\n\n");
    printf("LIST OF ANSWERS\n");
    printf("******************************************************************************");
    printf("******************************************************************************\n");
    printf("1. -4A^2 - 2A^2 + 2A^2B  4. -4A^2 + 2A^2 + 2A^2B\n");
    printf("2. -4A^2 -2A^2 -2A^2B  5. 4A^2 - 2A^2 -2A^2B\n");
    printf("3. -A^2 - A - AB  6. -2A^2 + 2a + 2AB\n");
    printf("\n\n\n");
}
```
static void handleSillyAnswer(void)
{  printf("THAT'S NOT A REASONABLE ANSWER.\n");
    printf("COME BACK WHEN YOU GET SERIOUS.\n");
    exit(EXIT_FAILURE);
}

static void handleWrongAnswer(void)
{  printf("YOUR ANSWER IS INCORRECT.\n");
    printf("LOOK CAREFULLY AT THE SAME PROBLEM AND GIVE\n");
    printf("ANOTHER ANSWER.\n");
    printf("WHAT WILL IT BE? ");
}
static int readAnswer(int minAnswer, int maxAnswer)
{
    int answer;
    if (scanf("%d", &answer) != 1)
        handleSillyAnswer();
    if ((answer < minAnswer) || (answer > maxAnswer))
        handleSillyAnswer();
    return answer;
}

static void readCorrectAnswer(int correctAnswer)
{
    enum {MIN_ANSWER = 1, MAX_ANSWER = 6};
    int answer;
    answer = readAnswer(MIN_ANSWER, MAX_ANSWER);
    while (answer != correctAnswer)
    {
        handleWrongAnswer();
        answer = readAnswer(MIN_ANSWER, MAX_ANSWER);
    }
    printf("YOUR ANSWER IS CORRECT.\n");
}
int main(void)
{
    int answer;

    printf("IF YOU NEED INSTRUCTIONS TYPE 0. OTHERWISE TYPE 1.\n");
    answer = readAnswer(0, 1);
    if (answer == 0)
        printInstructions();

    printf("OK! HERE WE GO!!!\n");
    printf("\n\n");

    printf("EXPAND:\n");
    printf("-A(A + 1 + B)\n");
    printf("WHAT IS YOUR ANSWER? ");
    readCorrectAnswer(3);

    printf("NOW TRY THIS ONE\n");
    printf("-2A(A - 1 - B)\n");
    printf("WHAT IS YOUR ANSWER? ");
    readCorrectAnswer(6);
```c
printf("NOW TRY THIS ONE\n");
printf("-2A(2A + A + AB)\n");
printf("WHAT WILL IT BE THIS TIME? ");
readCorrectAnswer(2);

printf("NOW TRY THIS ONE\n");
printf("-2A(2A - A - AB)\n");
printf("WHAT IS YOUR GUESS? ");
readCorrectAnswer(4);

printf("NOW TRY THIS ONE\n");
printf("-(4A^2 + 2A^2 -2A^2B)\n");
printf("WHAT IS YOUR ANSWER? ");
readCorrectAnswer(1);

printf("NOW TRY THIS ONE\n");
printf("-A(-4A + 2A + 2AB)\n");
printf("WHAT WILL IT BE? ");
readCorrectAnswer(5);

printf("SORRY, THIS IS THE END OF THE PROGRAM.\n");
return 0;
```