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Intermediate Language Translator for Execution of Java Programs in .NET Platform

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ABSTRACT

This paper presents the java bytecode-to-.NET MSIL intermediate language translator which enables the execution of the java program in .NET environments without JVM(Java Virtual Machine), translating bytecodes produced by compiling java programs into MSIL codes. Java, one of the most widely used programming languages recently, is the language invented by James Gosling at Sun Microsystems, which is the next generation language independent of operating systems and hardware platforms. Java source code is compiled into bytecode as intermediate code independent of each platform by compiler, and also executed by JVM. .NET language such as C# and .NET platform in Microsoft Corp. has been developed to meet the needs of programmers, and cope with Java and JVM platform of Sun Microsystems. After compiling, a program written in .NET language is converted to MSIL code, and also executed by .NET platform but not in JVM platform. For this reason, we designed and implemented the java bytecode-to-.NET MSIL translator system for programs written in java language to be executed in the.NET platform without JVM. This work improves the execution speed of programs, enhances the productivity, and provides a environment for programmers to develop application programs without limitations of programming languages.

Keywords: Bytecode, MSIL, Intermediate Language, Translator, JVM, .NET Platform

1. INTRODUCTION

Java, one of the most widely used programming languages recently, is the language invented by James Gosling at Sun Microsystems, which is the next generation language independent of operating systems and hardware platforms. Java is a language that generates execution files through compiling. The generated files are in the bytecode form, which is interpreted and executed by JVM(Java Virtual Machine), the Java interpreter. Therefore, Java programming language is both complier and interpreter language, but more universal than normal compilers and runs faster and more efficiently than usual interpreters[2,5,8].

On the other, C# language provided by Microsoft .NET platform is offered as a platform-independent language like Java of Sun Microsystems, the development of components by C# is becoming widespread. C# is a language based on the characteristics of high coding convenience and easy maintenance of Microsoft Visual Basic and flexibility and intensity of C++ which enables much faster and easier development of COM++ and web services[1,3,4,14].

On the other hand, one of studies about a translator is about an intermediate language translator[19-22] that generates a native code of the

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target machine from bytecode for improving an execution speed of java applications. It, however, can not be used in other computer environments because of being dependent on a target machine.

Microsoft has developed the JLCA translator[23] which converts a java program into a C# program in a source language level. With the iNET translator[24] the Halcyon Soft generates java source program from .NET MSIL code, an intermediate code of .NET programming languages. The Remotesoft, on the contrary, has developed the Java. NET translator[25] which translates a java source program into a .NET MSIL code.

It can't guarantee the security of source programs that a source program is translated into an intermediate code like JCLA or Java.NET. It also takes more time, and is hard to have good performance and is difficult to overcome the semantic gap, bacause translating an intermediate code into a source program such as iNET should have several translation steps.

On this environment of .NET platform, we can create any code that, once converted to MSIL, can generate an execution file optimized for the target platform regardless of the language used. Therefore, by converting the java bytecode to .NET MSIL, we can run the java programs on the Windows .NET platform even without JVM.

In summary, this paper presents a method to translate java bytecode to .NET MSIL code using a mapping table and the macro translation method, to construct a platform independent information system. Indeed, we designed and implemented a translator using this method, and translate a java bytecode program to MSIL code to run it on the .NET platform without JVM.

2. BYTECODE AND MSIL CODE

2.1 Bytecode

Bytecode can be considered as a machine language for JVM(Java Virtual Machine). It is acquired in the stream format for each method within a class when JVM loads a class file. At this time, the stream is in the binary stream format of a 8-bit byte. Furthermore, a bytecode basically has a stack-oriented structure, originally intended for being used through an interpreter. In other words, it is either interpreted by JVM, or compiled when the class is loaded[2,5,8,15,16].

JVM(Java Virtual Machine) saves and executes the source code by java programming language using class file format. Since the class file is in binary format, it is very difficult to analyze and modify. On the other hand, Oolong code, another type of java intermediate language, is much easier to read and write compared to class file format. Oolong code is based on Jasmin language of John Meyer, and designed to work in the level of bytecode[5,13].

Fig. 1 schematically shows the process of extraction of Oolong code from class file. In order to obtain an assembly format file as an input for the translator from the class file acquired by java compiler, javac, we used the Oolong decompiler, Gnoloo. Gnoloo carries out the function to extract only the source code-related contents from the various data in the class file.

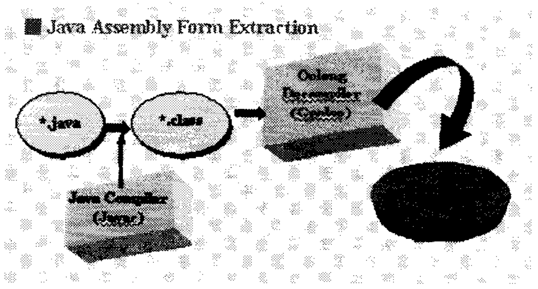


Fig. 1. Oolong Code Extracting Process

2.2 MSIL Code

MSIL(MicroSoft Intermediate Language) is an intermediate language of .NET language such as C#, comprising a set of stack-based instructions designed to be easily generated from source codes through a compiler or other tools. The instructions are classified into arithmetic/logical operations, flow control, DMA, exception handling, and method calling. In addition, the virtual method calling, field access, array access, object allocation and initialization, which affect the programming structure, are also types of instructions directly supported by MSIL. The MSIL instruction set searches data types in stacks, and is directly interpreted.

Furthermore, MSIL is independent of hardware and platform, and was originally designed for JIT. Unlike Java, it was designed to be language independent of the first and targeted at generic programming. Consequently, the language adapts very well to the change of program functions and structures[1,3,6,7,9,11,13].

Fig. 2 illustrates the extraction of an MSIL code in reverse order to find out the resulting format of the translator.

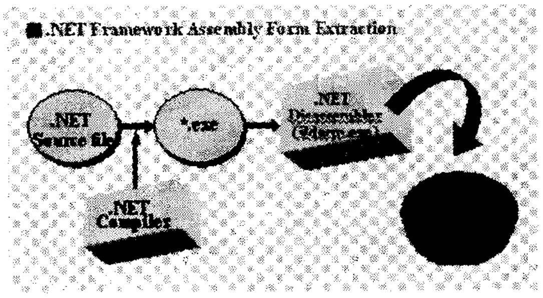

■ .NET Framework Assembly Form Extraction
.NET Source file
*.exe
.NET Disassembler (Ildasm.exe)
.NET Compiler

Fig. 2. MSIL Extracting Process

3. CODE GENERATION AND CODE CONVERSION METHODS

3.1 Code Generation Method

In general, there are two methods for generation of object codes from an intermediate language: using code expander or code generator.

The code expander method uses the routine to convert an intermediate code to the concrete target machine code. The benefit of this method is that it can generate a target machine code within a short time. However, the quality of the generated code is lower than the code generator method [3,7,17,18].

The code generator method is to generate codes through pattern matching technique referencing the code generation rules described in the target machine code table(MDT: Machine Description Table). The benefit of using this method is that we can get high-quality target machine codes. On the other hand, its disadvantage is that there is a time delay while generating a target machine code through pattern matching techniques[3,7,17,18].

In this paper, we used the code generator to convert codes through a pattern matching technique with the intermediate language instruction code table.

3.2 Code Conversion Method

The code conversion method is to generate codes by using the routine of converting the intermediate code to a concrete target machine code. The code conversion method utilizes the macro conversion. The macro definition format consists of a macro name, parameters, and the macro definition part to be expanded between '{' and '}'.

Table 1. Macro definition format

```
macro's name [ ( _parameter | parameter { ,argument } ) ]
        {       definition of the macro
                call for another macro
        }
```

The following is an example of macro definition of an MSIL code for a bytecode instruction.

istore_2	iadd

iconst_2
{
ldc.i4.2
} //push 2 onto the stack as i4
	iadd
	{
	add
	} //add to values, returning a new value

4. JAVA BYTECODE-TO-.NET MSIL IL TRANSLATOR

For the translation system from Java bytecode to .NET MSIL code to construct a platform independent information system, we designed and implemented the code translator by using the mapping table and the macro conversion method. We must convert the matching between codes through the mapping table so that the instruction mapping part and the function format structure conversion part, which are the main components of the translator, would become functionally equivalent to the relationship between bytecode and MSIL code. Furthermore, in the actual implementation, we will refer to the table corresponding to each of the codes by using the macro conversion method.

4.1 System Configuration

Fig. 3 shows the system configuration of the translator from Java bytecode, namely Oolong code, to .NET MSIL code. For the process of extracting the Oolong code from class file, with the class file as an input, the Oolong disassember, Gnoloo, was used to output the Oolong code in the text assembly format. Next, with the code converter, we generated an MSIL code from the Oolong code used as the input file. Finally, we created an *.exe file from the MSIL code through ilasm.exe provided by the .NET platform.

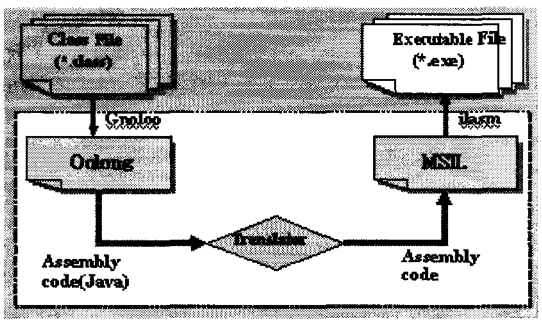


Fig. 3. System Configuration

4.2 Java Bytecode-to-.NET MSIL Translator

With the extracted Oolong code as an input to the translator, we used the instruction mapping table and the function format structure conversion table to generate MSIL code, which is the resulting code of the translator. As shown in Fig. 4, we obtained an MSIL code from the Oolong code through the extraction process, and the result is generated from the two processes of mapping and conversion.

The development environment for the translator is divided into the JDK and Oolong part to create and disassemble the java class file to be input to the translator, and the .NET platform SDK part to convert the translated MSIL file into a *.exe file.

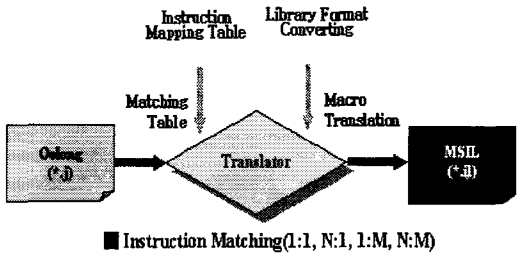

Instruction Mapping Table
Library Format Converting
Matching Table
Macro Translation
Oolong (*.j)
Translator
MSIL (*.il)
Instruction Matching(1:1, N:1, 1:M, N:M)

Fig. 4. Internal System Configuration of Translator

4.2.1 Data Type Mapping Table

This is the table for the basic data type mapping used by the translator for conversion(Table 2). There are some basic data types for Oolong code, which are included in the 17 data types used by MSIL.

Table 2. Data Type Mapping Table

Oolong	MSIL	Description
iadd, fadd, ladd, dadd	add	addition
imul, fmul, lmul, dmul	mul	multiplication
...	...	...
newarray	newarr	creating array
string	string	unicode string
...	...	...

Table 2. Continued

byte	int8	signed 8-bit integer
short	int16	unsigned 16-bit integer
int	int32	unsigned 32-bit integer
long	int64	unsigned 64-bit integer
···	···	···

4.2.2 Instruction Mapping Table

Table 3 lists only the basic instructions. The instructions are classified based on the MSIL, to which the corresponding Oolong instructions are mapped.

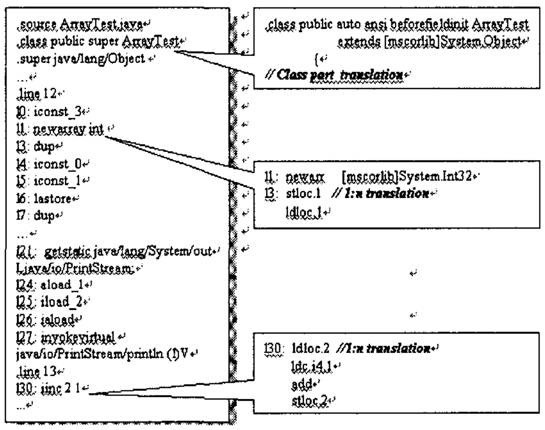
Table 3. Instruction Mapping Table

Oolong	MSIL	Description
iload.0	ldarg.0	load the argument number 0 on the stack.
···		···
istore_0	stloc.0	store a value in local variable number 0 on the stack
···		···
iadd	add	addition
imul	mul	multiplication
ifnonnull ifne	btrue	branch if <value> is nonzero.
putfield	stfld	store into a field of an object.
getfield	ldfld	load a field of an object.
···	···	···

5. EXPERIMENTAL RESULTS AND ANALYSIS

The followings are the example of java array program. Program 1 below depicts the extraction of Oolong code from java program source. The translator used the extracted Oolong code as its input, and translated the .NET MSIL code corresponding to each Java Oolong code through the mapping table and macro conversion within the translator, which is exactly the case for program 2.

```
Public class ArrayTest {
 public static void main()
 {      int m[]={1,2,3};
        for (int i=0; i<3; ++i)
             system.out.println(m[i]);
 }
}
```



```
.source ArrayTest.java
.class public super ArrayTest
.super java/lang/Object
...
.line 12
l0: iconst_3
l1: newarray int
l3: dup
l4: iconst_0
l5: iconst_1
l6: lastore
l7: dup
...
l21:  getstatic java/lang/System/out
Ljava/io/PrintStream;
l24: aload_1
l25: iload_2
l26: iaload
l27: invokevirtual
java/io/PrintStream/println (I)V
.line 13
l30: iinc 2 1
...
```

```
.class public auto ansi beforefieldinit ArrayTest
          extends [mscorlib]System.Object
       {
// Class part translation
```

```
l1:  newarr    [mscorlib]System.Int32
l3:  stloc.1   // 1:n translation
     ldloc.1
```

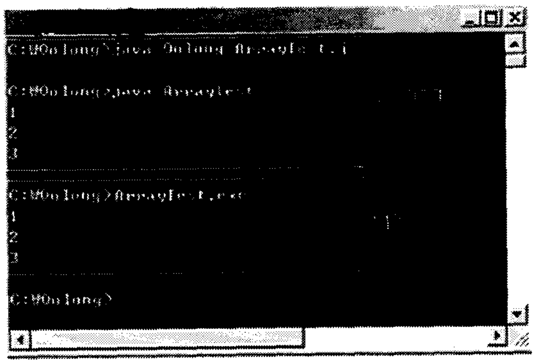
```
l30: ldloc.2  //1:n translation
      ldc.i4.1
      add
      stloc.2
```

Program 1. Java Program, Extracted Oolong Code and Corresponding MSIL Code

```
.assembly extern mscorlib
{
 .publickeytoken = (B7 7A 5C 56 19 34 E0 89)
 .ver 1:0:3300:0
}
:
.class public auto ansi beforefieldinit ArrayTest
extends [mscorlib]System.Object
{
 .method public hidebysig specialname
  rtspecialname instance void .ctor() cil managed
 {
 .maxstack 1
 l0: ldarg.0
 l1: call instance void [mscorlib]
        System.Object::.ctor()
 l4: ret
 }
.method public hidebysig static void Main()
 cil managed
 {
 .entrypoint
 .maxstack 4
 .locals init (int32 V_0, int32[] V_1, int32 V_2)
 l0: ldc.i4.3
 l1: newarr [mscorlib]System.Int32
 l3: stloc.1
     ldloc.1
 l4: ldc.i4.0
 l5: ldc.i4.1
 l6: stelem.i4
 l7: ldloc.1
 l8: ldc.i4.1
 l9: ldc.i4.2
 l10: stelem.i4
 l11: ldloc.1
 l12: ldc.i4.2
 l13: ldc.i4.3
 l14: stelem.i4
 l15: nop
 l16: ldc.i4.0
 l17: stloc.2
 l18: br l33
 l21: nop
 l24: ldloc.1
 l25: ldloc.2
 l26: ldelem.i4
 l27: call void [mscorlib]System.Console
 ::WriteLine(int32)
 l30: ldloc.2
 ldc.i4.1
 add
 stloc.2
 l33: ldloc.2
 l34: ldc.i4.3
 l35: blt l21
 l38: ret
 }
}
```

Program 2. MSIL Code Generated by Translator

Fig. 5 shows the result of the execution after translating the java Oolong program to .NET MSIL program and converting it into executable file. It shows the same results from the execution of ArrayTest.j extracted by the Oolong disassembler from the class file generated by the Java compiler and the execution of MSIL file ArrayTest.exe generated by the translator with ArrayTest.j file as input.



```
C:₩Oolong>java Oolong ArrayTest.j

C:₩Oolong>java ArrayTest
1
2
3

C:₩Oolong>ArrayTest.exe
1
2
3

C:₩Oolong>
```

Fig. 5. Execution Result

Table 4 shows the result of performance evaluation between java bytecode program in JVM and MSIL code program in .NET platform.

Table 4. The result of Performance Evaluation

Program	Java Bytecode	.NET MSIL
If Statement	335ms	171ms
While Statement	333ms	170ms
For Statement	339ms	171ms
While Statement	335ms	172ms
Class	338ms	165ms
Extended Class	363ms	173ms
Exception Handling	336ms	274ms
Thread	342ms	165ms

As the table displayed, it takes little time for .NET programs. to be executed rather than java programs, double speed on average. Therefore, java programs can be executed in .NET platform without JVM with this bytecode-to-MSIL translator, it improve the execution speed of java applications, and provides an environment for programmers to develop application programs without limitations of programming languages.

6. CONCLUSIONS

After compiling, a program written in java language is converted to bytecode, and also executed by JVM platform but not in .NET platform. For this reason, we designed and implemented the Java bytecode-to-.NET MSIL translator system for java programs to be executed in the.NET platform without JVM. This work improves the execution speed of programs, enhances the productivity, and provides an environment for programmers to develop application programs without limitations of programming languages.

We are currently researching on the optimization method to generate the better codes to speed up and to be able to convert the entire code format for large programs as well.

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