
STARFISH: A PROTOTYPE FOR UNIVERSAL PREPROCESSING AND TEXT-EMBEDDED PROGRAMMING

A PREPRINT

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ABSTRACT

We present a **novel concept of universal text preprocessing and text-embedded programming** (PTEP). Preprocessing and text-embedded programming has been widely used in programming languages and frameworks in a fragmented and mutually isolated way. The PTEP ideas can be found in the implementation of the \TeX typesetting system; they are prominent in PHP and similar web languages, and finally they are used in the Jupyter data science framework. This paper presents this area of research and related work in a more unified framework, and we describe the implemented system Starfish that satisfies the following novel principles of PTEP: universality, update and replace modes, flexibility, configurability, and transparency. We describe the operating model and design of Starfish, which is an open-source system implementing universal preprocessing and text-embedded programming in Perl. The system is transparent and its design allows direct implementation in other programming languages as well.

Keywords Preprocessing and Text-Embedded Programming (PTEP) · Software Development · Web Engineering · Data Science · Text Processing

1 Introduction

There is a wide need in computer science for *text Preprocessing* and *Text-Embedded Programming (PTEP)*. Transparency and ubiquity of textual representation, similarly to the universality of natural language, creates a widespread and uniform need to transform and automatically manipulate text that we write before being processed in some domain-specific way, such as programming language compilation, document typesetting or visual rendering, and similar.

We define *text preprocessing* as any operation that takes text as input and produces a similar text as output; and it serves as a way to automate manual editing of text. It is called “preprocessing,” since there is normally some standard use of that type of text that would be called “processing,” such as compilation or interpretation of a programming language, rendering of an HTML page, and similar. A typical example of a preprocessor is the C programming language preprocessor [4], which is mostly used for simple text inclusions or exclusions based on some configuration parameters and simple text replacements, before the C program code is passed to the compiler.

Text-embedded programming is a related but generally different concept than text processing. We define *text-embedded programming* as any form of computer programming where code is embedded in an arbitrary text, and can be executed in-place, in that text context. One of the first examples of text-embedded programming can be considered the \TeX typesetting system by Donald Knuth, released in 1978 [13]. \TeX has its own language of annotating text to prepare it for typesetting and printing in form of papers, books, and similar documents. The \TeX language also includes a macro language for text transformation in-place, before the final preparation of the output pages. This macro part of

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the language is a form of preprocessing, but also text-embedded programming because it is Turing-complete, and one can write a general-purpose program in this language. The \TeX book [13] contains a famous example of a table of prime numbers, generated in the \TeX macro programming language, written by Knuth.

The second, more obvious example of text-embedded programming is the PHP programming language [18]. A PHP program file is usually an HTML file with the snippets of PHP code inserted in the file. The file is processed, or we could say preprocessed, before being delivered to the HTML browser in such way that the PHP snippets are replaced with their output produced using the command `echo`. The snippets are delimited with the strings `<?php` and `?>`, or simply with `<?` and `?>`. This model is particularly convenient for fast development of web apps, where we can start with a static (pure) HTML page and incrementally replace pieces with PHP snippets that will produce dynamic PHP-generated HTML text. A similar approach was used in ASP (Active Server Pages) [25] engine or JSP (JavaServer Pages) [24], both of which use `<%` and `%>` delimiters for code snippets.

The third example of text-embedded programming is the project Jupyter [9], formed in 2015 by Fernando Pérez [26], which supports inclusion of Python, Julia, or R programming language snippets in a file called Jupyter Notebook. Although this example of text-embedded programming is not transparent in the sense that a Jupyter Notebook is not a plain text file, it is still very close to a text file (it is in the JSON format), marked in a language called Markdown, which gets translated into HTML, and it allows inclusion of arbitrary code in Python (or other allowed language), that can be executed. The result of the execution is shown in the notebook itself. This is a novelty, compared to PHP for example, that we will call the *update mode*, vs. the *replace mode* used in PHP, ASP, JSP, and similar template languages.

1.1 Research Goals of Universal PTEP

The main motivation for *Universal PTEP* (Preprocessing and Text-Embedded Programming) is an initiative for creating a prototype of universal system that could be easily used and adapted for an arbitrary text. Beside some major examples, such as \TeX , PHP, and Jupyter, as mentioned, which have dedicated languages or are actually centered around text-embedded programming, it would be beneficial to have a system ready-to-be-used in an arbitrary text language, or *style*, as we will call it, such as Makefiles, procmail recipes, Xfig files, shell scripts, and many other text styles. The approach is also attended to be used for any programming language, web languages (e.g., HTML, CSS), data formats (e.g., JSON), and typesetting languages (e.g., \TeX , \LaTeX). Some ideas of this prototype were implemented starting from 1998, with the system Starfish being named and released in 2001 [10]. It has been further developed since then, and as of now, I am not aware of a similar effort in this area.

The main features that are the goal of this proposal and the Starfish system are:

- **Universal Preprocessing and Text-Embedded Programming (PTEP):** This is the goal of creating a universal system that can be used for PTEP for various types of text files (e.g., HTML, LaTeX, Java, Makefile, etc.)
- **Update and Replace Modes:** Starfish supports two modes of operation: the *replace mode* — similarly to PHP or C preprocessor, where the snippets are replaced with the snippet output and the complete output is saved in the output file or produced to the standard output; or the *update mode* — similarly to Jupyter, where the snippet output is appended to the snippet in the updated source file.
- **Flexible PTEP:** Starfish is flexible, in the sense that we can modify the patterns that are used to detect active code (snippets) in text. The basic pattern used to detect and execute code snippets, can be generalized to make active “hooks” from any string, pair of delimiters, or regular expression pattern. Starfish also provides flexibility in defining the way snippets are evaluated.
- **Configurable PTEP:** Starfish allows user-defined configuration per directory, and it uses directory hierarchy for a more wide hierarchical configuration specification.
- **Transparent PTEP:** Starfish provides transparency in the sense that when a file with Starfish snippets is processed, assuming it is a static file, we do not need Starfish any more to use it. For example, an HTML file is still an HTML file viewable by a browser, a \LaTeX file is still a \LaTeX file processable by \LaTeX , and so on. As a comparison of a less transparent approach, a Jupyter file is a special-format JSON file, which needs to be processed to produce HTML, \LaTeX , or other forms usable by a user.
- **Embedded Perl:** Even though the main principles of Starfish could be implemented in many languages, Perl is particularly convenient for both Starfish implementation, use in code snippets, and configuration. As a comparison, \TeX uses its own language for PTEP and it is difficult to use since its paradigm and notation style are so different from the main main-stream languages. The C preprocessor works well for C, but in attempts to use it in other systems, like Imake for the Makefiles, it was not widely adopted due to its restrictive

nature and a significantly different context than C programs. Using a known, general-purpose language for specifying preprocessing steps and in the text-embedded snippets has clear advantages, and Perl succinctness and expressiveness in working with strings makes it an excellent candidate.

After this introduction, we will introduce main terminology and some background on PTEP and related work in Section 2. In Section 3, we will present a case study of a Java preprocessor functionality achieved using Starfish system, which we use to describe fundamental modes of operation of Starfish. Section 4 describes how we achieve universal PTEP by using modifiable parameters such as delimiters and line comments. We use example of Makefile and HTML styles to illustrate these different contexts. Finally, we give a conclusion with some ideas about vision of PTEP for future work in Section 5.

2 Background and Related Work

We will describe in this section some background information on Preprocessing and Text-Embedded Programming (PTEP), and some existing related work in this area. The PTEP area does not exist as a recognized coherent area, but there has been a lot of fragmented related work within the context of different programming languages, and applied areas of Computer Science, such as in the web systems development (PHP, ASP, JSP), software development (C preprocessor, make, imake), electronic publishing (T_EX, L^AT_EX), and machine learning and data science (Jupyter).

Text and text files: We define *text* to be any string of characters, generally including the new-line character, and it will typically be saved in a file, which we call a *text file*. We will assume characters to come from the ASCII set, but they may include extended ASCII (i.e., numerical values from 0 to 255), or they may have UTF-8 encoding, so characters may be from the Unicode set. A text is usually created manually in a plain-text editor, such as *emacs* or *vi* in Linux or other Unix-like systems, or *notepad* in Windows OS. If the text follows certain formal rules (grammar), we will say that text is in certain *style*. Otherwise, if we do not recognize a particular formal grammar of the text, we will say that text has a *default style*. It could be, for example, a general natural language text, such as English, or any kind of text that is not on our list of recognized styles. We will also talk about specific styles, such as the C-program style, if the text is a program in the C programming language, a Java style, an HTML style, L^AT_EX style, and similar.

Text preprocessing: We define *text preprocessing* to be an operation that takes text as input and produces a similar text as output, and it serves as a way to automate manual editing of the text. Again, this is not a very precise definition, and we will have to rely on some of our common sense and experience in recognizing what constitutes preprocessing. The name “preprocessing” comes from the idea that this operations does not change the main style of the text, and it is done before any proper *processing* designed for this style of text, such as compilation of a C program, rendering of an HTML page, or translating a LaTeX text into a PDF document. A typical representative preprocessor is the C programming language preprocessor [4, 27].

The generic potential of the C preprocessor has been recognized and it was used independently of the C compiler; for example, in the Imake system [2, 28]. Darren Miller [17] made available Filepp—a generic file preprocessor, following closely the C preprocessor syntax, with a number of generalizations. The Filepp preprocessor is written in Perl with intention to be used on general text files and support for the HTML files.

2.1 Text-Embedded Programming

We define *text-embedded programming* as a form of computer programming where programming source code is embedded in text of arbitrary style, and this code can be executed in place; i.e., in the original embedded context.

One could argue that any programming source code is embedded, since code is generally mixed with documentation comments, but there is a significant conceptual difference in thinking about a text file as a program with comments, rather than a text of arbitrary style, with some code snippets inserted. We also leave some freedom in how the code snippets are executed, to what purpose, or how they interact with the surrounding text. We will see soon some typical usages for such snippets.

In text-embedded programming, programming source code is embedded in text as a sequence of continuous text segments. These segments are sometimes called *code snippets*, *active code*, *live code*, or *embedded code*. We call the text outside the segments the *outer text*. The code snippets are usually easily recognizable by defined text delimiters, but depending on the rules that we use, any text can be recognized as a snippet. This is why the name *active code* is very appropriate: The TeX system uses a labeling of all characters at run-time that can denote any character to be an ‘active’ character, and as such initiate special processing after the system reads this character. This character is also

Table 1: Escape Strings in Some Systems

| System | Escape Strings | | System | Escape Strings | |
|----------------|----------------|----------|-------------------------|----------------|------------|
| | Begin | End | | Begin | End |
| PHP | <? <?php | ?> ?> | HTML::EP | <ep-perl> | </ep-perl> |
| ASP | <% | %> | Starfish (default) | <? | !> |
| JSP | <% | %> | Starfish (HTML style) | <!--<? | !>--> |
| ePerl | <? | !> | Starfish (user defined) | <?sfish | !> |
| Text::Template | { | } | Starfish (user defined) | : | : |
| Text::Oyster | <? | ?> | | | |

sometimes called an *escape* character. A similar generalized approach is adopted in Starfish, in which the active code is recognized by *hooks*, which can be strings, pairs of begin-end strings, or regular expressions.

One of the first examples of text-embedded programming was the \TeX typesetting system developed by Knuth, released in 1978 [13]. The system processes text and prepares it for typesetting pages for print, but in the process it recognizes \TeX commands by detecting the *escape* backslash character (\backslash), i.e., an *active* character, which triggers special execution behaviour based mostly on macro expansions. This macro expansion model can be regarded as a computation model; i.e., a model for code execution, but it is difficult to learn for programming purposes as indicated by the author itself. There were approaches to developing \TeX preprocessors in other languages such as Lisp, as published by Iwesaki in 2002 [8].

Text-Embedded Programming is particularly popular and useful in the context of HTML documents. The HTML language was after its design mostly used for creation of static documents, viewable and browsable by users, and a very natural way to make the documents dynamic through programming is by inserting code snippets in HTML pages. Before serving the page for viewing and browsing, the snippets are executed and replaced with their textual output, and the resulting page is sent to the browser. This model is used in the very popular PHP language [18], and also in ASP (Active Server Pages) [25] and JSP (JavaServer Pages) [24].

The code snippets are marked in text with starting and ending delimiters, which are arbitrary small strings. Other than simple markers for snippets, we can think of them as escape sequences that toggle on and off code processing. Table 1 shows the live code (snippet) delimiters in some systems. For example, the string delimiters are “<?” and “?” or “<?php” and “?” in PHP, “<%” and “%>” in ASP, and “<?” and “!>” in ePerl. For example, in PHP, we could prepare an HTML document such as:

```
<html><head><title>PHP Test</title></head>
<body>
  <?php echo ' <p>Hello World</p>'; ?> </body></html>
```

where we show snippet delimiters in red, and the snippet itself in blue color. After processing with the PHP interpreter, the following output would be produced:

```
<html><head><title>PHP Test</title></head>
<body>
  <p>Hello World</p>
</body></html>
```

where we show the generated output in the green color. Embedding the code in this way is sometimes called *escaping* because a starting delimiter, such as “<?” serves as an escape sequence, triggering special processing of the snippet. Another kind of escaping, referred to as the *advanced escaping* in PHP is illustrated with the following example:

```
Good <?php if ($hour < 12) { ?> Morning <?php} else { ?> Evening <?php }
?>
```

We will refer to this kind of escaping as *inverted escaping*. Inverted escaping can be interpreted in the following way: The complete input text is treated as code in which the plain text, i.e., the non-code text or *outer text*, is embedded between ‘?’ and ‘<?php’ delimiters and it is translated into an ‘echo “string” ;’ statement; and similarly, any part of the form ‘?’ plain text ‘<?’ is interpreted as the statement:

```
echo " plain text ";
```

An implicit delimiter ‘?’ is assumed at the beginning of the text and an implicit delimiter ‘<?php’ is assumed at the end of text. Although this type of escaping is relatively easy to implement, we do not use inverted escaping in Starfish since its benefits are not very clear. On the other hand, inverted escaping does not follow the principle that each snippet should be a well-defined block of code. If we want large pieces of outer text to be conditionally included or excluded, Perl offers many string delimiting options for large text segments, such as `q/.../` and `<<'EOT'`, which can be used in place of inverted escaping.

2.2 Perl-based Embedded Programming

The universal PTEP proposal is programming language independent, and the prototype is easily adaptable to work with any programming language. Any higher-level language that provides easy manipulation of strings, automated memory management, and run-time evaluation of code are very suitable for PTEP. The Perl programming language is particularly suitable due to its string-processing efficiency and expressive string-processing functionalities. For this reason, there has always been many Perl implementations of preprocessing and some forms of text-embedded programming, including templating modules. Even the core Perl language always included simple template-based string generation with interpolated strings, in which a string such as

```
"The flight $flightid arrives at $time."
```

is evaluated to: `"The flight AC806 arrives at 11:26."` if the variables `$flightid` and `$time` have values:

```
$flightid = "AC806";
$time     = "11:26";
```

An early system for embedded Perl in a fashion similar to PHP was ePerl (Embedded Perl Language) by Ralf S. Engelshall [3]. The language ePerl was developed in the period from 1996 to 1998. The system was a binary package based on modified code of the Perl interpreter, and as such had a relatively large memory footprint, or was a “heavy-weight” implementation as sometimes called [15]. This approach had some other disadvantages such as need for recompilation for each platform, and not keeping with the evolution of the Perl language, unless regularly maintained. These issues are addressed by implementing the system as a Perl module; i.e., a language extension in Perl terminology. For example, David Ljung Madison developed an “ePerl hack” [15] which is a Perl script of some 1400 lines that has functionality similar to ePerl. In comparison to Starfish, in addition to the “heavy-weight” implementation, ePerl does not support the update mode and is not designed for a universal PTEP.

`Text::Template` [1] by Mark Jason Dominus is another Perl module with similar functionality. It is a very popular module designed to “expand template text with embedded Perl”, created in 1995 or 1996 and maintained with contributions by many users until now. An interesting and probably independent similarity is that Starfish uses `$O` as the output variable, while `$OUT` is used in `Text::Template`. The default embedded code delimiters in `Text::Template` are ‘{’ and ‘}’, with an additional condition that braces have to be properly nested. For example, ‘{{{“abc”}}}' is a valid snippet with delimiters. The module allows the user to change the default delimiters to other alternative delimiters. The philosophy of `Text::Template` module has a lot of similarity with Starfish, however the `Text::Template` module is primarily meant to be used in templating style; which means that a template file is created as a more passive object and it always requires a handling Perl script to generate the output target file. An additional difference is that the `Text::Template` module does not support the update mode. The use of default delimiters creates issues with JavaScript code, although there are workarounds. The system is not applied to many text styles other than plain text and HTML.

Another well-known Perl module `HTML::Mason` [19], authored by Jonathan Swartz, Dave Rolsky, and Ken Williams, can also be seen as an embedded Perl system. It is a larger system with the major design objective to be a high-performance, dynamic, web-site authoring system.

A relatively minimalistic approach is used in development of the module `Text::Oyster` [16] by Steve McKay in the period 2000–3. The module is template module for evaluating Perl embedded in text between delimiters ‘<?’ and ‘?’.

`HTML::EP` [20] is another Perl module for embedding Perl into HTML. Its specific approach is that code delimiters are HTML-like tags that start with ‘ep-’. For example, comments are delimited by `<ep-comment>` and `</ep-comment>`, and active code is delimited with tags `<ep-perl>` and `</ep-perl>`. The last value in the embedded code is the generated string. The module is meant to be used in a dynamic way over the Apache web server and the use of Apache module `mod-perl`, so the documentation gives a nice overview of how to set up a Perl module that supports embedded programming to run efficiently in this setting. The set of tags is further extended, so it includes `<ep-email>`

for generating emails from a web page, `<ep-database>` and `<ep-query>` for working with a database, `<ep-list>` for generating HTML lists, then conditionals, and so on. It is an interesting idea that in text embedding like this we can modify the language to be simpler in some situations than Perl, but it is still not clear that it is justified to introduce all these new constructs, when equivalent Perl code constructs exist.

Starfish is a lighter-weight system than `eperl` or `Mason`, but it is more flexible and universal than `Text::Template`, the `ePerl` hack, and `HTML::EP`. Starfish covers a larger set of text styles than other systems, provides other unique innovations, such as more flexibility in defining active code detection patterns, per-directory configuration, update mode, and full embedding when compared to the other systems. Under *full embedding* we refer to capability that all functionality and customizability, such as adaptation of patterns, can be achieved with code inside the snippets embedded in a text file.

2.3 PTEP in the Update Mode

We can have different ways in which embedded code is executed and how its output is used. For example, even the concept of Literate Programming [23] introduced by Knuth in 1984 [14] can be considered to be text-embedded programming, although the code is only executed after it is automatically gathered into the source files, and then compiled.

All the systems discussed in this section so far support the execution model that we call the *replace mode* of execution. In the *replace mode*, the code snippets are replaced with the output of those snippets, and the file produced in this way is either sent over internet to a browser to be viewed, or saved into a target file. The Starfish system was designed to support a new mode of operation, called the *update mode*, in addition to the *replace mode*, from its initial release in 2001 [10]. This mode was briefly described in a Perl Journal article in 2005 [12]. The main property of the update mode is that rather than replacing the code snippets with their output, the output is appended to snippets. This has several advantages: (1) we are not required to setup a translation process from source files to target files, which makes the project management simpler; (2) it provides an easy inspection of the embedded code and the output it produces, which is very convenient in prototyping, for example; and (3) it provides an easy way for the system to be used as a preprocessor for text files of arbitrary style. We will describe in more detail the update mode, but we mention it in the related work section since a well-known system Jupyter [9, 26], released in 2015, operates in the update mode. The Jupyter system works on files called Jupyter Notebooks, which are JSON-type files with a mixture of plain text and embedded Python code. The execution of the notebook appends the output of embedded code immediately to the code. This is used to create documents in which the code and results of code execution are intermixed. We would describe this as text-embedded programming with the update mode, with a minor exception that Jupyter Notebook itself is not in plan-text format but needs a viewer software to be presented in that way.

After this summary of related work, we can introduce Starfish by using a case of Java preprocessor functionality.

3 Case Study: Java Preprocessor

In this section, we will use the Java style example to describe details of the Starfish model, and how Starfish can be directly used in Java preprocessing. As we mentioned before, a preprocessing example is the C preprocessor, which is a useful and unique feature of the C programming language. It is a part of the C compiler package, but it is a simple language in its own, which does simple text manipulation before feeding it to the proper C compiler. One use of the preprocessor is inclusion or exclusion of parts of code depending on values of some configuration variables. It preprocesses C source code as a general text, without a detailed use of C syntax or semantics. It is sometimes criticized for not using deeper semantics of the language, and it is also praised for the same reason because it is very clear what it does and it can be used on text other than C programs. For example, it was used in the Imake system [28, 2] for preprocessing `Makefiles` [6, 21]. Java does not have a preprocessor and it would be useful in some situations.

When developing code in Java, we may need two versions of the source code: a test version to be used for testing and development, and a release version to be the production release. The test version could carry around a lot of meta information on data structures, be able to produce verbose debug code, make additional expensive run-time checks, and similar, while the release version would be efficient and slim in code size and running time. This means that at various places in the source code, we need to write two versions of code snippets: a test version and a release version, and the appropriate version would be included everywhere based on the value of some global variable. This could be simulated using Java constructs, but the release code would be unnecessarily bloated, and running-time efficiency of the code would likely be negatively affected.

As an example, let us consider the following simple Java code:

```

/**
 * A simple Java file.
 */

public class simple {

    public static int main(String[] args) {

        System.out.println("Test version");
        System.out.println("Release version");

        return 0;
    }
}

```

where the red line would be included in the test version of the code, and the blue line would be included in the release version of the code.

One solution would be to use the C preprocessor. However, the C preprocessor is a part of the C compiler and it is not meant and not convenient to use independently. Its functionality is tailored to the C language, and it is not as easy to use for general and more flexible text processing that we may want to have. We would argue that it is more convenient to write a new text preprocessor from scratch in a language like Perl, than to rely on the C preprocessor for this purpose. That leads to the second solution: we could write an independent preprocessor from scratch in text-friendly high-level language like Perl. An even more flexible idea is to have a general-purpose preprocessing system. The system `m4` [5, 22] is one such system, but it is limited to general-purpose macro processing, has its own, specific syntax, and it does not support the update mode of operation.

3.1 Fully-Embedded Preprocessor

One approach to our preprocessing task is to implement a program similar to the C preprocessor, which would read our Java source files and produce other files to be used for compilation. To distinguish these two files, we would have the original, *meta-source* file, and produced *target source* Java file. One issue with this approach is that we must now manage two files for each Java source file, and the second issue is that this preprocessor would be one-off program with its own syntax, and a more general solution would be applicable to a wider set of situations. We could emulate the functionality of the C preprocessor, but designing a new universal preprocessor would allow us to think bigger and aim at a more open-ended general functionality. Both of the issues are addressed with a *fully-embedded preprocessor*, which combines preprocessing instructions and the preprocessing result in the same file, and allows for a quite general Perl preprocessing code.

The Starfish system provides this functionality. Our example Java file could be written in the following way using the Starfish conventions:

```

/**
 * A simple Java file.
 */
// Uncomment version:
//<? $Version = 'Test'; !>
//<? # $Version = 'Release'; !>

public class simple {

    public static int main(String[] args) {

        //<? $0 = "    " . ($Version eq 'Test' ?
        // 'System.out.println("Test version");' :
        // 'System.out.println("Release version");' );
        //!>

        return 0;
    }
}

```

Starfish code is embedded Perl code found between delimiters `<? and !>`, and it is commented out using the Java line comment notation `//`. The blue and red lines are used to choose version of the software that we want to produce. The red line contains code commented out in Perl, so that chosen version is the “Test” version. The green snippet code shows how we can select the appropriate line of Java and produce it. The Perl variable `$0` is used as a special variable to specify the generated code. Starfish has also a command `echo` that effectively appends to this variable.

If the name of the Java source file is `simple.java` then we can process it in Starfish by running the command (`$` is a shell prompt):

```
$ starfish simple.java
```

As the result of preprocessing, we do not create a new file, but the source file is updated. This is what we call the *update mode*, which is the default mode of Starfish operation. The reason why we call Starfish a *fully-embedded preprocessor* is that all necessary preprocessing code, including even customization of delimiters and snippet evaluations, can be done within the snippets themselves. After running the above command, the contents of the file `simple.java` is now:

```
/**
 * A simple Java file.
 */
// Uncomment version:
//<? $Version = 'Test';    !>
//<? # $Version = 'Release'; !>

public class simple {

    public static int main(String[] args) {

        //<? $0 = "    " . ($Version eq 'Test' ?
        // 'System.out.println("Test version");' :
        // 'System.out.println("Release version");' );
        //!>//+
        System.out.println("Test version");//-

        return 0;
    }
}
```

We can see that the desired line of code has been generated and inserted in the file (magenta-colored part). The generated part is delimited with strings `//+` and `//-`, so if we run the `starfish` again on the file, the file will not be changed because the generated part would be replaced with the same generated string. If by coincidence our output code contains the string `//-`, Starfish will insert a number in the delimiters; e.g., `//3+` and `//3-`, so that the ending delimiter does not conflict with accidental match in the generated code.

If we comment out the “Test” line and uncomment the “Release” line in the new `simple.java` file as follows:

```
/**
 * A simple Java file.
 */
// Uncomment version:
//<? # $Version = 'Test';    !>
//<? $Version = 'Release'; !>

public class simple {

    public static int main(String[] args) {

        //<? $0 = "    " . ($Version eq 'Test' ?
        // 'System.out.println("Test version");' :
        // 'System.out.println("Release version");' );
        //!>//+
        System.out.println("Test version");//-
```



```

        return 0;
    }
}

```

and run:

```
$ starfish simple.java
```

again, the file `simple.java` file will look as follows:

```

/**
 * A simple Java file.
 */
// Uncomment version:
//<? # $Version = 'Test';    !>
//<?  $Version = 'Release'; !>

public class simple {

    public static int main(String[] args) {

        //<? $0 = "    " . ($Version eq 'Test' ?
        // 'System.out.println("Test version");' :
        // 'System.out.println("Release version");' );
        //!>//+
        System.out.println("Release version");//-

        return 0;
    }
}

```

Since we can include arbitrary Perl code in the snippets, including imports of external libraries and code, this framework provides a very general way of code preprocessing. Starfish includes a few more features to support wider management of code base within a directory, which we will discuss in the next two subsections.

3.2 Preprocessing Multiple Files

If we want to preprocess a number of Java files in a project, it would be tedious and error-prone to modify each of them to set them to the appropriate Test or Release version. There are several ways how this problem could be solved and we will describe three of them:

- (1) using Perl `require` command,
- (2) using Make and Starfish `-e` option, and
- (3) using the Starfish `starfish.conf` configuration file.

(1) Using Perl `require` command: We can have one `$Version` parameter controlling many files by simply having a Perl file called `configuration.pl` with the following content:

```

#!/usr/bin/perl
$Version = 'Test'; # Test or Release
1;

```

and one of the first lines in each Java source file would be:

```
//<? require 'configuration.pl' !>
```

In this way, we would have one point of control for the Test or Release version of all files.

(2) Using Make and the Starfish `-e` option: Starfish has the option `-e` for an initial Perl code execution, somewhat similar to Perl, and we can use it to set the Version variable. For example, if we use a Makefile to compile all Java files in a project, we could add a preprocessing command for each of them in the following way in the Makefile:

```

VERSION=Test
#VERSION=Release

simple.class: simple.java
    starfish -e='$$Version="$VERSION"' $<
    javac $<

```

We would again have one point of version control, this time in the Makefile.

(3) Using the Starfish `starfish.conf` configuration file: The idea of using a Perl configuration file, as shown in (1), is so common in many situations that we use a standard name for the configuration file called `starfish.conf` to include this information. Similarly to (1), the contents of the file `starfish.conf` would be:

```

#!/usr/bin/perl
$Version = 'Test'; # Test or Release
1;

```

and one of the first lines in each Java source file would be:

```
//<? read_starfish_conf !>
```

This is the common way to represent per-directory configuration in Starfish. One important difference between this approach and the earlier approach with the standard Perl configuration file (1) is that `read_starfish_conf` behaves in a special way. Namely, the command `read_starfish_conf` will look for a file named `starfish.conf` in the current directory; if found, it will then look for the same named file in the parent directory. Again, if it is found, it will look into the parent of the parent directory and so on until it cannot find a file with that name, or until it reaches the top directory in the file system. After that, it will execute, or more precisely *require* in the Perl terminology, all found files `starfish.conf` from top to bottom. Each file is executed in its own directory as the current directory. This provides for a hierarchical per-directory configuration, with natural process of parameter inheritance and override option in sub-directories. A similar process is used sometimes in the system of Makefile in a project with multiple directories [7], and in the Imake system for Makefile generation.[2, 28]

3.3 Replace Mode

Finally, if we want to produce a version of Java code without preprocessing code, we can use the Starfish *replace mode*. In this mode, the preprocessing code is removed as well as markup around the generated code. We must specify an output file in the replace mode because we normally do not want to permanently loose the preprocessing code. For example, if we run the following command:

```
$ starfish -replace -o=release/simple.java simple.java
```

on the above file in which `$Version` variable is set to the value "Release", the resulting file `release/simple.java` would contain the following contents:

```

/**
 * A simple Java file.
 */
// Uncomment version:

public class simple {

    public static int main(String[] args) {

        System.out.println("Release version");

        return 0;
    }
}

```

With this, we conclude this Java preprocessor case study of general PTEP as implemented in the Starfish system.

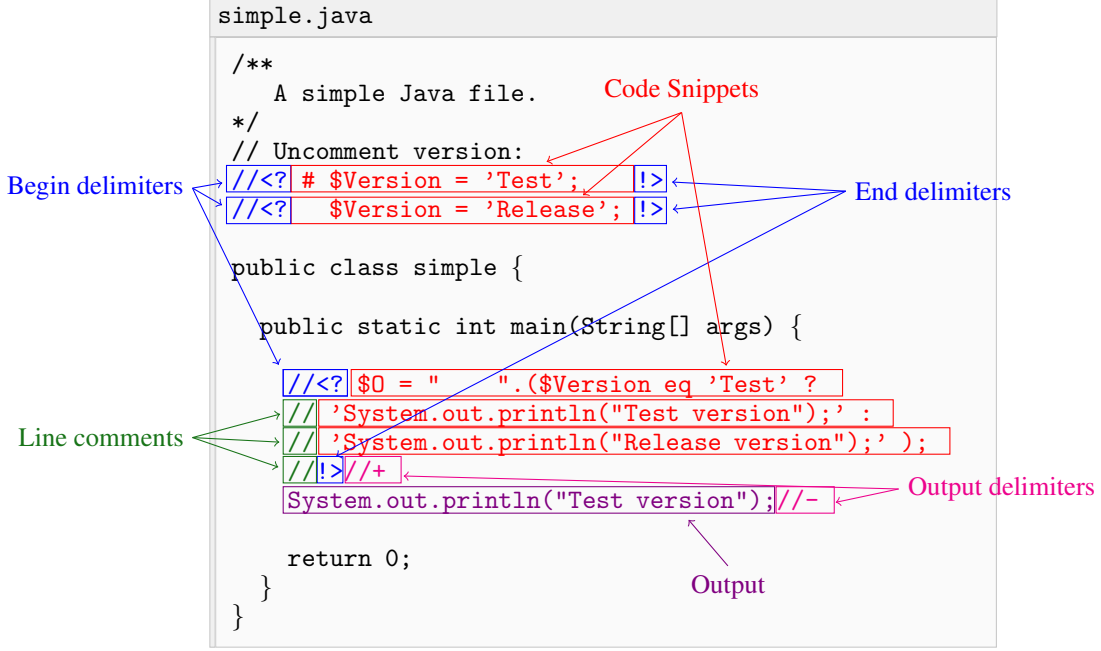


Figure 1: Illustration of Starfish parameters in Java code with active Starfish code

4 Universal PTEP: Modifying Active Patterns and Evaluation

A universal PTEP feature of Starfish is implemented by allowing run-time change of patterns for detecting active code and the model of its evaluation. For example, Figure 1 shows active elements of the Java code used in the previous section, with emphasized strings used or generated by Starfish. First, in order to detect active code (code snippets), Starfish relies on the *begin* and *end delimiters* of the code snippets, which we call *hooks*. In Figure 1, the begin-end hook consists of the strings ('//<?', '!>'). In addition to this hook, there is another hook ('<?', '!>'), which is not used in this example. Even though the first hook seems redundant, it is needed for the replace mode, where we want the snippet output to replace the line comment as well. Starfish operates with a list of hooks, which can be modified at any time. In addition to the begin-end delimiter pairs, hooks can also be expression hooks, which provide more flexibility. Starfish is implemented in the object-oriented way, so during text processing there is always a current Starfish-type object, accessible as the variable `$Star`, which contains the current state of parsing, the list of active hooks, and other parameters. The Starfish parser always looks for the leftmost shortest match in the list of hooks in order to locate the next code snippet. Once the code snippet is identified, the parser will also check for the optional immediately following snippet output (only in the update mode), and remove it.

The output is detected using the *Output delimiters*. Since the output delimiters may include a generated number in order to avoid conflict with the output, the output delimiters parameter (*OutDelimiters*) is actually an array of four strings: ("//", "+\n", "//", "-\n"), where the `\n` denotes the new-line character, and where concatenation of the first two strings is the default starting output delimiter, and the concatenation of the second two strings is the ending output delimiter. If there is a conflict with the snippet output, a number is inserted between the starting and ending strings to form non-conflicting delimiters. The code snippet should be commented out from the surrounding text, this is one reason why we need information about the line comment (parameter *LineComment*). Line comments are removed during the code preparation, the code is evaluated, and the contents of the variable `$0` is used to determine the generated output.

All these parameters, hooks, output delimiters, line comment, as well as the functions for code preparation and evaluation can be modified to accommodate different text styles. We can adjust these parameters *ad hoc* in any snippet or configuration file to adapt to a new text style. A number of text styles (e.g., java, html, perl, python, and makefile) are already provided in Starfish and we can set them by calling the `setStyle` function. Otherwise, Starfish will automatically choose the appropriate style based on the file extension. If the file extension is unknown, Starfish will set up the *default* style.

Many text styles, such as Perl, Makefile, shell scripts, procmail scripts, Python, and configuration files, use the hash symbol (#) as the line comment, so this line comment is chosen for the default Starfish style. Due to a specific syntax in Makefiles and Python, where the generated output indentation is important, the output indentation is adjusted according to the indentation of the lines in the code snippet.

4.1 Default Style Example: Makefiles

If a file name extension cannot be recognized, the Starfish will process text in the default style, which relies on # as the line comment string, with the standard hooks and output delimiters. Makefiles are recognized as a separate style, but it is very close to the default style so we will look a Makefile as an example. The Makefiles are per-directory recipe files for the system make [21, 6], which is used to run appropriate commands to build files, including code compilation and linking, testing, and other common tasks done using the command-line interface. It can be used to efficiently compile C source files that need to be compiled, L^AT_EX files to be processed into PDF, figures produces etc. Writing rules and dependencies for Makefiles can be tedious, and this is why make provides some help with its own advanced rules. These advanced rules can be complex because they are a language of its own, they are not always portable, and they do not provide flexibility of a general programming language. One attempt to address this problem was the Imake system [28], which runs C preprocessor on a Makefile before passing it to make. Some languages provide their own Makefile generators for certain situations, such MakeMaker for Perl, but in a more general sense we would like to have a Makefile preprocessor that would be adaptable for handling many different projects, such as web site deployment, or LaTeX typesetting.

As an example, let us say that we want to have a Makefile that would adapt to any directory with a set of Java files, so that after running make all files that need to be compiled are compiled. We could write a Makefile consisting only of the following Starfish snippet:

```
#<? @javafiles = <*.java>;
#   echo "all: @javafiles\n";
#   echo map { s/\.java$//; "$_.class: $_.java; javac $_.java\n" } @javafiles;
#!>
```

The code above finds all .java files in the current directory and includes them into compilation. After running:

```
$ starfish Makefile
```

assuming that our directory contains files A.java, B.java and C.java, the Makefile is updated as follows:

```
#<? @javafiles = <*.java>;
#   echo "all: @javafiles\n";
#   echo map { s/\.java$//; "$_.class: $_.java; javac $_.java\n" } @javafiles;
#!>#+
all: A.java B.java C.java
A.class: A.java; javac A.java
B.class: B.java; javac B.java
C.class: C.java; javac C.java
#-
```

4.2 HTML Style Example

In our second example, we will show the HTML Starfish style. The HTML style in Starfish (html) is set up by setting the begin and end hook delimiters to be '<!--<?' and '!>-->', the output delimiters to be '<!-- + -->' and '<!-- - -->', or more precisely as the four-tuple ("<!-- +", " -->", "<!-- -", " -->"), and by not having line comments. In this way, the Starfish code is properly commented out and not visible in the browser in the update mode of the HTML file. The code would still work in the replace mode, in which case the target HTML file would be generated by replacing the code snippets with their output, in the same style as PHP, JSP, and ASP. Starfish can be run in the dynamic way using the Apache web server, for example, where the output files would be produced “on-the-fly”, again in the same fashion as PHP.

As an HTML example, let us consider the following short HTML file with embedded Starfish code, which can be used to write a short blog:

```
<!--<? read_starfish_conf;
      $date_created = 'July 4, 2020';
      $title = 'My sample blog';
```

```

        echo blog_header(); !>-->

<p>This is an example blog post. Below, you can find some source
code:
<!--<?
$_= <<'EOT';
/**
    A simple Java file with Test & Release
*/
// Uncomment version:
//<? $Version = 'Test';    !>
//<? # $Version = 'Release'; !>

public class simple {

    public static int main(String[] args) {

        //<? $0 = "    " .($Version eq 'Test' ?
        // 'System.out.println("Test version");' :
        // 'System.out.println("Release version");' );
        //!>
        //etc...
        EOT
        echo "<PRE>" .htmlquote($_) . "</PRE>";
        !>-->

```

We have a short code snippet at the beginning to generate start of the HTML file using the function `blog_header`, which is defined in the file `starfish.conf` so that we can use the same function for all blog posts. The function definition is as follows:

```

sub blog_header {
    return "<html><title>$title</title><body>\n".
        "Blog created: $date_created<br>\n".
        "Last update: ".file_modification_date()."\n".
        "<h1>$title</h1>\n";
}

```

The `blog_header` function uses the Starfish-provided function `file_modification_date`, which supplies the last modification date of the file. It is interesting to note that Starfish itself modifies the file; however, if there are no new update changes since the last time we ran Starfish, new runs of Starfish will not incorrectly update time to the time of the newest run.

We want to include Java source code in HTML. This can be done using the `<PRE>` tag, however HTML still treats characters `<` and `&` in a special way, so we are using Starfish-provided function `htmlquote` to escape those characters.

If we run Starfish on this file with:

```
$ starfish blogexample.html
```

the file will be updated as follows:

```

<!--<? read_starfish_conf;
$date_created = 'July 4, 2020';
$title = 'My sample blog';
echo blog_header(); !>--><!-- + --><html><title>My sample blog</title><body>
Blog created: July 4, 2020<br>
Last update: July 4, 2020
<h1>My sample blog</h1>
<!-- - -->

<p>This is an example blog post. Below, you can find some source

```

```

code:
<!--<?
$_= <<'EOT';
/**
    A simple Java file with Test & Release
*/
// Uncomment version:
//<?  $Version = 'Test';    !>
//<? # $Version = 'Release'; !>

public class simple {

    public static int main(String[] args) {

        //<? $0 = "      " .($Version eq 'Test' ?
        // 'System.out.println("Test version");' :
        // 'System.out.println("Release version");' );
        //!>
    //etc...
    EOT
    echo "<PRE>".htmlquote($_)."</PRE>";
    !>--><!-- + --><PRE>/**
        A simple Java file with Test & Release
    */
    // Uncomment version:
    //&lt;?  $Version = 'Test';    !>
    //&lt;? # $Version = 'Release'; !>

    public class simple {

        public static int main(String[] args) {

            //&lt;? $0 = &quot;      &quot; .($Version eq 'Test' ?
            // 'System.out.println(&quot;Test version&quot;);' :
            // 'System.out.println(&quot;Release version&quot;);' );
            //!>
        //etc...
    </PRE><!-- - -->

```

This is the output in the default Update mode. The Replace mode would produce a more clean HTML source without Starfish source, which could be done for a production web site with the following command as an example:

```
$ starfish -replace -o=~/.public_html/blog.html blogexample.html
```

5 Conclusion

In this paper, we want to present a proposal for a unified view of *Preprocessing and Text-Embedded Programming (PTEP)* in different contexts. We give a background and a review of related work showing that PTEP is widely used in different contexts. Its use is fragmented and the implementations use different and context-specific syntax in most cases. If we want to apply PTEP to a new context, we would always need to implement a preprocessor from scratch. We propose a universal approach to PTEP, with a number of novel feature, and an open-source implementation of this approach named Starfish [11, 10, 12].

We discuss a case study of a Java preprocessor functionality achieved with Starfish, which serves as an illustrative example. After an implementation description of Starfish, we show how it can be customized for different text styles, and show additional examples of the makefile style, and html style. Starfish supports additional styles, for which we do not have space here to discuss, but the concept of universal PTEP opens many new future directions, such as addressing further different text styles, use as a macro language, and easy introduction of micro-languages for different local context. In a grand view of things, universal PTEP is a step towards finding commonality in some

universal preprocessing and text-embedding task, and defining them in a unified way in different contexts of textual *computer instruction*, such as computer programming, typesetting, configuration, and others.

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