

Report on Starfish v. 1.37
A Perl-based System for Text-Embedded
Programming and Preprocessing

(Starfish Version 1.37, Document Revision 393)

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Abstract

This report is meant to be the most up-to-date documentation on Starfish. However, it has not been completed yet. A large part of it is a direct POD Documentation generated from in-code documentation.

Starfish is an open-source, Perl-based system for text-embedded programming and preprocessing. It demonstrates a relatively simple methodology based on regular expression matching and rewriting, which is implemented in Perl in a transparent way.

The main idea is similar to the text-embedding style of PHP and other systems, many of which were also implemented as Perl modules, but there are several essential novel features of Starfish.

Contents

1	Introduction	3
1.1	Preprocessing and Text-Embedded Programming (PTEP)	3
1.2	Goals of Starfish Development	4
1.3	Java Preprocessor Example	5
1.3.1	Fully-Embedded Preprocessor	7
1.3.2	Preprocessing Multiple Files	10
1.3.3	Replace Mode	11
1.4	The Name of the Game	12
1.5	Overview	12
2	Background and Related Work	13
2.1	Text-Embedded Programming	14
2.2	Perl-based Embedded Programming	15
2.2.1	PTEP in the Update Mode	19
3	Starfish Usage and Design	20
3.1	Modifying Starfish to Different Text Styles	20
3.1.1	Default Style Example: Makefiles	22
3.1.2	HTML Style Example	23
3.2	Text Styles	26
3.2.1	HTML-Sfish Style (<code>html.sfish</code>)	26
3.3	Hooks	27
3.4	Iterative Processing	28
3.5	Starfish Processing Model	28
3.5.1	Method <code>digest</code>	28
3.5.2	Method <code>_scan</code>	29
4	Conclusion	30
A	POD Documentation	34
A.1	NAME	34
A.2	SYNOPSIS	34
A.3	DESCRIPTION	34
A.4	EXAMPLES	35

A.5	PREDEFINED VARIABLES AND FIELDS	41
A.6	METHODS	42
A.7	PREDEFINED FUNCTIONS	46
A.8	STYLES	50
A.9	STYLE SPECIFIC PREDEFINED FUNCTIONS	51
A.10	LIMITATIONS AND BUGS	52
A.11	THANKS	52
A.12	AUTHORS	52
A.13	SEE ALSO	52

Chapter 1

Introduction

This report describes the system Starfish—a system for Perl-based text preprocessing and text-embedded programming. In this introduction, we will try to make a case for a need for such system, and its design, implementational, and maybe even philosophical goals.

1.1 Preprocessing and Text-Embedded Programming (PTEP)

There is a wide need in computer science for *text preprocessing* and *text-embedded programming*, or shorter *Preprocessing and Text-Embedded Programming (PTEP)*.

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 the 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 [5], 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 preprocessing. 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 text typesetting and printing in form of papers, books and similar documents; but \TeX language also includes a “macro” language for text transformation in-place before the final preparation of the output pages. This macro part of 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 [19]. 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 dynamic PHP-generated code. A similar approach was used in ASP (Active Server Pages) [29] engine or JSP (JavaServer Pages) [28], both of which use `<%` and `%>` delimiters for code snippets.

The third example of text-embedded programming is the project Jupyter, formed in 2015, which supports inclusion of Python, Julia, or R programming language snippets in a file called Jupyter Notebook [10]. 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.

1.2 Goals of Starfish Development

Starfish development and use with that name started in 2001. These lines of documentation are written some 19 years later, so a natural question is whether there is still the same level of novelty in it, and whether there exist systems with needed functionality. The main goal of Starfish development is a universal preprocessing and text-embedded programming (PTEP), and I am not aware of another similar effort. I find the Perl particularly suitable to be an embedded language, and even more surely there is no such universal system with Perl as an embedded language. I understand that this particular Perl orientation may be seen as a subjective personal preference, but still it may represent a significant advantage to a portion of readership.

The main feature of Starfish is universal Preprocessing and Text-Embedded Programming, which is a goal that that the system can be used in many different textual contexts, such as programming languages, web languages (e.g., HTML, CSS), data formats (e.g., JSON), typesetting languages (e.g., TeX, LaTeX), and others (e.g., make, procmail).

Some of the main Starfish features that were the reason and goal of its development are:

- **Universal Preprocessing and Text-Embedded Programming (PTEP):** 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: *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 *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 pieces of 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 (active code) is evaluated.
- **Configurable PTEP:** Starfish allows user-defined configuration per directory, and it uses directory hierarchy for a more wide configuration definition.
- **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, 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 very successful and it was difficult to use since it was not meant for that kind of context. Using a general-purpose language that is used for other purposes has a clear advantage, and Perl succinctness and expressiveness in working with strings in particular, makes it an excellent candidate.

1.3 Java Preprocessor Example

Let us start in the introduction with one example to illustrate Starfish operation. As we mentioned, 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, 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 [32, 3] for preprocessing `Makefiles` [7, 25]. Java does not have a preprocessor and it would be useful in some situations.

Sometime around 2001, I was working on a Java software system where I needed two versions of 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, I needed 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 bloated and running-time efficiency of the release code would not be easy to achieve.

As an example, we will consider the following simple Java code:

```
/**
 * A simple Java file.
 */

public class simple {

    public static in 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. It is more convenient to write a text processor in Perl from scratch than to rely on the C preprocessor. That leads to the second solution: write an independent preprocessor from scratch in text-friendly high-level language like Perl. This is how we can get an idea of a general-purpose preprocessing system. The system `m4` [6, 26] 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.

1.3.1 Fully-Embedded Preprocessor

There are many ways we could approach our preprocessing task, which basically need to include or exclude annotated parts of code. Similarly to the C preprocessor, we could read

our source Java file and produce another Java file, which will then be ready for compilation. To distinguish these two files, we could come up with a different name extension for the first Java file, which we could call a *meta-source code* file. One issue with this approach is that we now must manage two files for the same Java source file, and the second issues is solving the question of how exactly our preprocessor should look like. 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 these issues are addressed with a *fully-embedded preprocessor*, which combines preprocessing instructions and preprocessing result in the same file, and allows for a quite general Perl preprocessing code. Starfish provides this functionality.

Our example Java file could be written in the following way using the Starfish convention:

```
/**
 * 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.

The result of preprocessing is not a new file, but the source file is actually updated. We call this the *update mode* of Starfish and it is the default mode. This is why we call Starfish a *fully-embedded preprocessor*. If the name of the Java file is `simple.java` then we would run the following command:

```
$ starfish simple.java
```

and 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 is not confused with 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 couple of subsections.

1.3.2 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: To have one `$Version` parameter controlling many files, we could simply have 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 an option `-e` for 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. 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. A similar process is used sometimes in the system of Makefile in a project with multiple directories [8], and in the Imake system for Makefile generation.[3, 32]

1.3.3 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 lose 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 would like to finish this introductory Starfish example.

1.4 The Name of the Game

The parts of Starfish system were developed from 1998, and then in 2001 I searched for other systems that would have features that I needed and have been working on. I did not find a good match, but there were a number of systems with with some similarity. The closest one was ePerl [4] system created by Ralf S. Engelshall in 1998, implemented in C but using an installed Perl system. There was also a Perl implementation of the same ePerl system by David Ljung Madison [15]. The system was meant to be used for at least two different text styles: plain text and HTML, and its vision and philosophy were generally very close to my goals. However, it was not a close enough match, so I started a new project, and for a lack of better name, I called it SLePerl, which was short for “Something Like ePerl”. At some point during 2001, a friend of mine at the graduate school asked “What is SLePerl!?” and we started pondering about the better name. Since the system runs on Perl code snippets in text, a metaphor could be a shellfish with embedded pearls. We agreed that Oyster sounded like a great name, but there was actually (yet another) Perl module for embedded Perl called `Text::Oyster` [16]. Starfish seemed to be a good name, since it feeds on shellfish, with an exception that the system Starfish feeds on Perl snippets within text. The module `Text::Starfish` was created in 2002 and uploaded to the CPAN soon after. It was described in an article in the Perl Journal in 2005. [12]

1.5 Overview

After this introductory chapter, in Chapter 2 we discuss background and related work; Chapter 3 presents user documentation, Chapter 4 describes the system design, and Chapter 5 gives more starfish details for reference, and Chapter 6 is a conclusion. Appendix A contains the POD documentation. This documentation is written as a part of code and is included in the man page as well. As such, it is meant to be a reference that may be frequently needed during coding and actual use of Starfish.

Chapter 2

Background and Related Work

We will describe in this chapter 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 different applied area of Computer Science, such as in 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 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 [5, 31].

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. However, we will see very soon some typical usage for such snippets. Before that, let us define some notions in this model.

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*, or *live code*. The text outside the segments is called *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 sometimes called an *escape* character. A similar generalized approach is adopted in Starfish, in which the active code is recognized by *hooks*.

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 (`,``\`), 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., model for code execution, but it is difficult to learn for coding 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 [9].

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. After execution of the snippets, they are replaced with the generated text output, and the resulting page is used for viewing and browsing. This model is used in the very popular PHP language [19], and also in ASP (Active Server Pages) [29] and JSP (JavaServer Pages) [28].

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. For example, the string delimiters are “<?” and “?>” or “<?php” and “?>” in PHP, “<%” and “%>” in ASP, and “<?” and

“!>” in ePerl. During processing, the text outside the code snippets is left intact, while the code snippets are evaluated and the evaluation results are used to replace the snippets. 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

We will describe here some previous work on Perl-based embedded programming. Our vision for universal PTEP is not that it is a major characteristic of a programming language, but it should be an orthogonal framework that allows several programming languages as options.

The Perl programming language is particularly suitable for implementation of text-embedded capability due to its string-processing functionalities, and its ability for run-time code interpretation and execution (the ‘eval’ function).

In 1998, when the work on Starfish started, there was a system that that partially implemented needed functionality — it was called **ePerl (Embedded Perl Language)** by Ralf S. Engelshall.[4] The language ePerl was developed in the period from 1996 to 1998. It is an embedded Perl language in the sense that we described, but ultimately there were several reasons why it did not fit needed requirements: (1) it seemed to be too heavy-weight, (2) it did not support the *update* mode, that will be described in the next chapters, and (3) it does not the universal PTEP approach with multiple text styles. Other authors [15] also noted that ePerl is heavy-weight: The language ePerl was a binary package created by modifying the Perl source code and requiring compilation during installation. We prefer a more light-weight solution that relies on the standard Perl, and our solution is installed as a Perl module.

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.

Perl Templating

Textual templates are a very natural concept and a core idea in Perl. From the start, Perl had textual “FORMATS” in addition to formatting function such as `sprintf` and variable interpolation in strings. It is always tempting to extend this into more elaborate templates, which are then easily extended to have added embedded Perl code, and then we can talk also about text-embedded programming. A review of a book about one of the most popular such Perl extensions, the Template Tool toolkit [1], it is stated:

Among the many different approaches to “templating” with Perl—such as Emperl, Mason, HTML::Template, and hundreds of other lesser known systems—the Template Toolkit is widely recognized as one of the most versatile.

I wonder if “hundreds” is really true, but it could easily be. Out of those hundreds, we will try to at least mention as many as I could come across in this section.

Text::Template [2] 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** [21], 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 [24] 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 exists.

Mojolicious [17] is a Perl web framework with its template language [18] for embedded Perl. It uses `<%` and `%>` as the code delimiters, with some interesting features, such as syntactic shortcuts, such as using `<%=` and `%>` to produce output, or capturing mode for collecting segments into a variable.

Template Toolkit (1996–2014) [22, 23] is a template processing system, which is a collection of Perl modules. It is designed in the “input-agnostic” way, as stated in the documentation, which in our terminology means that it works with different text styles, with the following ones listed: HTML, XML, CSS, JavaScript, Perl code, plain text, and so on. However, it is mostly used to generate static and dynamic web content. It uses the replace mode of operations, as most other template systems. The starting and ending code delimiters are `%[` and `%]`, although they can be changed. It allows embedded Perl, but it seems to mostly use its own templating language. It is very popular, with a book published about it [1]. Compared to Starfish, while it does aim at the different text styles, it supports only replace mode, it relies on its own templating language, and although it allows changing starting and ending code delimiters, it does not seem to allow multiple hook styles. The Template Toolkit provides an extensive language with focus on templates, and it could be used, but it is not meant for preprocessing and text-embedded programming.

Embperl (1997–2012) [20] is an embedded Perl framework for building web sites under the umbrella of the `mod_perl`, the Apache web server Perl module. It completely written

in C and optimized for delivering online content. Embperl has the following snippet delimiters:

[`-` and `-`] are the main delimiters for executing code,

[`+` and `+`] are delimiters for code with an output value,

[`!` and `!`] are delimiters for code to be executed only once,

[`$` and `$`] are delimiters for templating meta-commands, which are used in the inverted escaping mode; i.e., combining outer text with code.

perlpp — **Perl preprocessor** (2013–2018) <https://metacpan.org/pod/distribution/Text-PerlPP/bin/perlpp> has goal to process Perl code within any text file. It uses delimiters `<?` and `?>`, with some additional flavours and specific PerlPP commands. It uses the replace mode.

Text::EP3 — **The Extensible Perl PreProcessor** (1998–2006) <https://metacpan.org/pod/Text::EP3> uses replace mode with delimiters starting with `@` at the beginning of line, such as `@perl_begin` and `@perl_end`.

Basset::Template — **my templating system** (2004–7) <https://metacpan.org/pod/Basset::Template> is a template system in replace mode, which uses delimiters `<%` and `%>`, and also `%%` and new line.

ExtUtils::PerlPP — **A Perl Preprocessor** (1995–2001) <https://metacpan.org/pod/ExtUtils::PerlPP> a preprocessor using patterns such as `~~version~~` with intention to be used with MakeMaker. It uses the replace mode.

PML — **(PML Markup Language)** (1999–2000) <https://metacpan.org/pod/PML> a template processor in the replace mode aimed for HTML, with syntax such as `{ $\$$ title}` and special commands such as `@if`.

Preproc::Tiny — **Minimal stand-alone preprocessor for code generation using Perl** (2016) <https://metacpan.org/pod/Preproc::Tiny> a preprocessor in replace mode which originated from the need to generate C++ code. It uses delimiters such as `@@` and new-line, and [`@` and `@`]. It uses `$OUT` variable for the output.

iperl — **bring any text documents alive with bits of embedded Perl** (2000) <https://metacpan.org/pod/iperl> and <https://metacpan.org/pod/Text::iPerl> is an embedded Perl processor with various styles (using function `set_style`). It is invoked using command `include`, `include_filehandle`, or `include_string`. The code delimiters may be changed, but one example uses starting with `!` to the end of line, or `!{` and `}!` and some variations.

In Summary

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 has a large coverage goal of covering more 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 some systems. Under *full embedding* we refer to capability that all functionality and customizability, such as adaptation of patters, can be achieved with code inside the snippets embedded in the text file.

2.2.1 PTEP in the Update Mode

We can have generally different ways in which embedded code executed and how its output is used. For example, even the concept of Literate Programming [27] introduced by Knuth in 1984 [14] can be considered text-embedded programming, although the code is only executed after it is automatically gathered into the source files, and then compiled.

All the systems that we discussed until now in this section, support a more of execution that we will call the *replace mode*. 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*, from its initial public release in 2001 [11]. This mode was briefly discussed in the 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 do not need to set up translation process from source file to target files, which makes the process simpler; (2) it provides an easy inspection of the embedded code and the output it produces, which is very convenient in prototyping process, 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 how the update mode works, but it should be mentioned in the related work since a well-known system Jupyter [10, 30], released in 2015, operates in the update mode. The Jupyter system is used to produce so-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.

Chapter 3

Starfish Usage and Design

This chapter describes some implementational topics regarding Starfish.

3.1 Modifying Starfish to Different Text Styles

As we mentioned earlier, we call *text styles* different types of plain text that we want to process with Starfish. The default style is a generic plain text, where we assume that the character ‘#’ denotes a start of a line comment, since it is used in many contexts. Some other text styles are `java` for Java source code, `html` for an HTML file, etc. The term *file type* is usually used to distinguish the styles that we just mentioned, but since we assume that different styles may mix in the same file, we will use the term *text style*.

The main parameters that need to be adapted for each new style are the patterns used to detect active code, the output delimiters, the line comment that may be used to comment out active code, and possibly other parameters, such as optionally snippet code preprocessing, snippet evaluation, or output modification. For example, Figure 3.1 shows active elements of the Java code used previously with emphasized character 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*.¹ In Figure 3.1, the begin-end hook consists of the string pair (‘`//<?`’, ‘`!>`’). In addition to this hook, there is another hook (‘`<?`’, ‘`!>`’), which is not used in this example. Even though the first hook may seem redundant, it makes a difference in 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 regular 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

¹The term *hook* is inspired by a similar use of hook in Emacs.

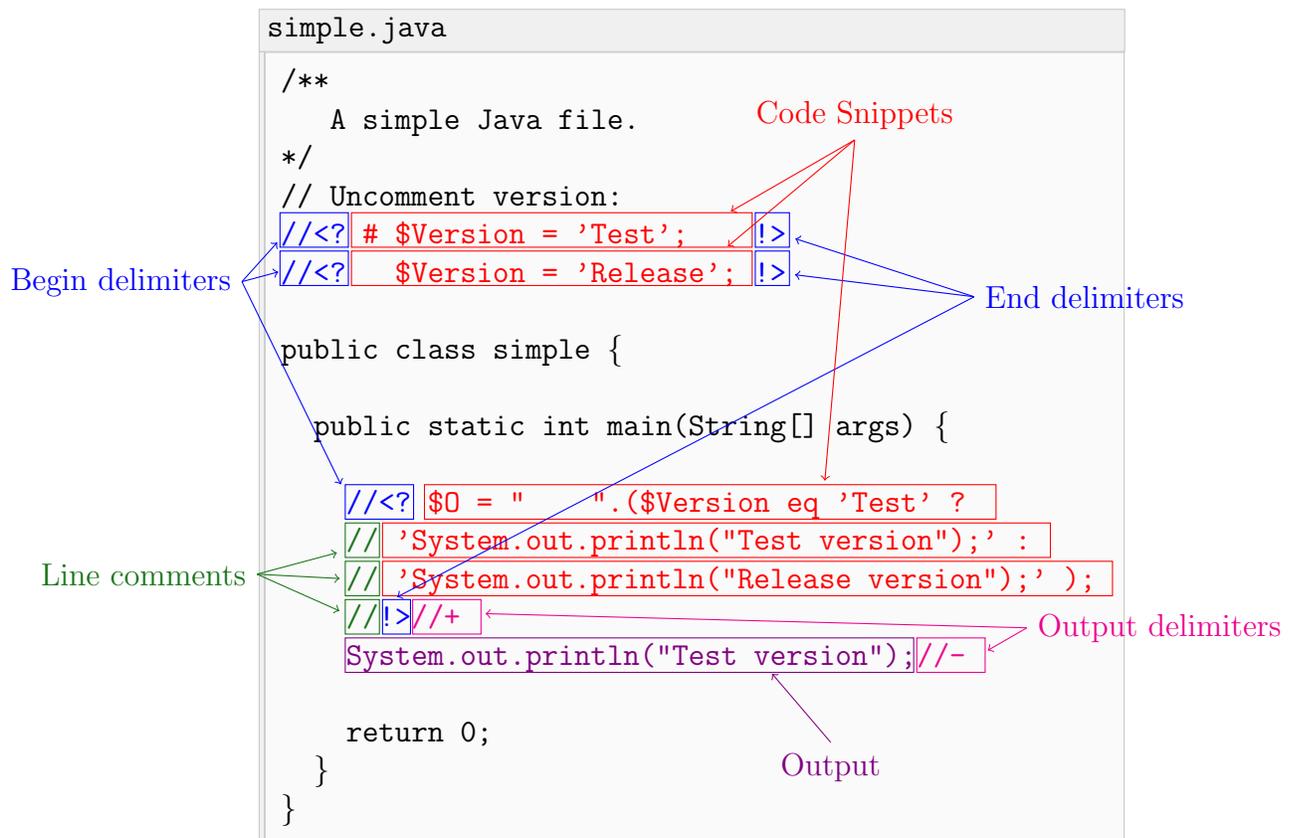


Figure 3.1: Illustration of Starfish parameters in Java code with active Starfish code

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 two 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 indicator (parameter *LineComment*). Line comment indicators are removed during the code preparation, the code is evaluated, and the contents of the variable *\$0* is used to determine the generated output. To be more precise, it is the variable *\$_:0*, since it is defined in the *main* name space of Perl.

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 *set_style* function. Starfish automatically chooses an appropriate style at the beginning 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 in those built-in styles.

3.1.1 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* [25, 7], 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 to be produced into images, 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 [32], 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 solely 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
#-
```

This is a ready Makefile that would cause the command `make` to run necessary compilations.

3.1.2 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
```

3.2 Text Styles

Starfish has a number of predefined styles which are automatically set based on the input file extension, or can be manually set using the function `set_style`. The set of predefined styles are: HTML (style `html`, extensions `.html` and `.htm`, case insensitive), HTML templating style (style `html.sfish`, extensions `.html.sfish` or `.sf`, case insensitive), \TeX and \LaTeX (style `tex`, extensions `.tex` and `.latex`, case insensitive), Java (`java`), Makefile (`makefile`), PostScript (`ps`), Python (`python`), and Perl (`perl`).

3.2.1 HTML-Sfish Style (`html.sfish`)

The HTML style is created with the update mode in mind, which means that we need to carefully protect any embedded code from being directly viewable by a Web browser. This is achieved by keeping it always within HTML comment delimiters. This is important in order not to unintentionally break the HTML page layout, but, of course, a curious reader can always see it by viewing the HTML source. We often want to use the HTML style in the replace mode, either in generating static or dynamic web sites, and since we do not have to care in the replace mode about commenting out the snippet code, we can introduce some additional simple hooks, such as using delimiters `<? and !>`, and commenting lines with `#` at the very beginning of a line. For this purpose, we introduce the `html.sfish` style, which is automatically detected by the file name extension `.html.sfish`.

Using `#` as a line comment in the `html.sfish` style makes it easy to comment out some HTML pieces from being produced, or for example, we can use the following `emacs` editor command in the source:

```
#-*-mode: HTML; compile-command: "make all"; -*-
<!--<? read_starfish_conf();
      $creationyear=2020; $title='Vlado Keselj: Mail Address';
      echo &myheader1();
      !>-->
```

And so on...

3.3 Hooks

Starfish uses the concept of a “hook” (or triggers) and evaluators to initiate processing on a text. The name “hook” is inspired by a similar term used in Emacs. For example, the delimiters ‘<?’ and ‘!>’ represent a hook, which is associated with an evaluator that will evaluate the code between the delimiters and produce the result that will replace the hook. In the update mode, the code will be replaced with something like:

```
<? code !>#+
...output
#-
```

while in the replace mode, the code is replaced with “...output,”.

Each text style includes one or more hooks for that style, but we can also modify Starfish hooks at any time. The main method for adding hooks is `add_hook` and if it used as a function it will add hook to the current `Star` object. There are hooks of several types, and the hook type is specified as the first argument (a string) of the `add_hook` method. The following are examples of some hook types:

- **string** — string replacement,
- **be** — begin and end snippet delimiters,
- **regex** — regular expression recognized active code
- **ht:re2** — a special regular expression based hook for Python and Makefile styles, which need information about the current indentation

Hook type ‘string’: The hook type **string** is a simple hook type, which specifies that a string should be replaced with another string. For example, after the following embedded code:

```
<?starfish
add_hook('string', '<code>App::Utils</code>',
  '<a href="https://metacpan.org/pod/App-Utils" target="_blank">'
  '<code>App::Utils</code></a>'); ?>
```

any occurrence of `<code>App::Utils</code>` is replaced with:

```
<a href="https://metacpan.org/pod/App-Utills" target="_blank">
<code>App::Utills</code></a>
```

Implementation note: The regex (regular expression) hooks pass captured substrings as arguments to the replacement function. If the whole captured string (`$&`) is needed, it can be obtained from the `$self->{currenttoken}` field.

3.4 Iterative Processing

In the default mode of processing, Starfish reads input file, processes it, and writes it back to the output file if the output is different. The processing of the text could be repeated. The number of iterations is set by default to 1, but it could be larger. If the number of iterations is very large, the number of actual iterations could be smaller if a fixed point is reached earlier. A typical code of setting the number of iterations to 2 is the following:

```
$Star->{Loops} = 2;
```

We can read the number of the current loop with `$Star->{CurrentLoop}`.

In case of replace mode, the iterations are repeated on the original input file and only in the last iteration the replaced output is produced.

3.5 Starfish Processing Model

The typical use of the system is by calling the `starfish` command, which runs the `starfish_cmd` function with arguments being passed from the command line.

The `starfish_cmd` function creates a Starfish object `$sf`, translates the options from the command line into the appropriate settings of the object, and runs the method `$sf->process_files(@tmp)`, where `@tmp` contains the names of the files given in the command line. The function `starfish_cmd` returns the object `$sf` at the end.

The method `$sf->process_files` expects a list of files. Each file is processed and written out. The main part of processing start with setting `$sf->{data}` to the file contents, calling the method `$sf->digest()`, and writing the processed output, which is found in `$sf->{Out}`.

3.5.1 Method digest

The method `$sf->digest()` mainly consists of a loop which scans the `$sf->{data}` and prepares output in `$self->{Out}`. A custom function defined as reference `$sf->{Final}` can be used for final processing of the output.

3.5.2 Method `_scan`

The method `_scan` is called by the method `digest` to scan text and find the next token. It uses the list of hooks to find the first active code. If there is outer text before the active code, it will return it as a token first and in the next call it will return the active code.

Chapter 4

Conclusion

This report give documentation on the system Starfish, an implementation of the concept of universal *Preprocessing and Text-Embedded Programming (PTEP)*. The report now fairly well reflects the most important features of Starfish. There are still some undocumented features, some that should be included, but also some that are experimental. In the continuation of this report, Appendix A contains the POD (Perl's Plain Old Documentation format) documentation provided with the module `Text::Starfish`. The appendix is generated with a POD-to-L^AT_EX tool. Compared to the main text of this report, the POD documentation is written with an attempt to be a good reference document to be used in typical man-page Unix-style environment.

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Appendix A

POD Documentation

A.1 NAME

Text::Starfish.pm and starfish - Perl-based System for Preprocessing and Text-Embedded Programming

A.2 SYNOPSIS

starfish [**-o**=*outputfile*] [**-e**=*initialcode*] [**-replace**] [**-mode**=*mode*] *files*...

where *files* usually contain some Perl code, delimited by `<?` and `!>`. Use function `echo` to produce output to be inserted into the file.

A.3 DESCRIPTION

Starfish is a system for Perl-based preprocessing and text-embedded programming, based on a universal approach applicable to many different text styles. You can read the documentation contained in the file `report.pdf` for an introduction. For an initial understanding about how Starfish works, you can think of Perl code being inserted in arbitrary text between `<?` and `!>` delimiters, which can be executed in a similar way as PHP code in an HTML file. Some similar projects exist and some of them are listed in §A.13. Starfish has been unique in several ways. One important difference between `starfish` and similar programs (e.g., PHP) is that the output does not necessarily replace the code, but it is appended to the code by default.

The package contains two main files: a module file (`Starfish.pm`) and a small script (`starfish`) that provides a command-line interface to the module. The options for the script are described in subsection "starfish_cmd list of file names and options".

A.4 EXAMPLES

A simple example

Let us have a plain file named `example.txt` with the following content:

```
<? echo "Hello world!" !>
```

In the command line, run the command:

```
starfish example.txt
```

If we open the file `example.txt`, the content will be:

```
<? echo "Hello world!" !>#+  
Hello world!#-
```

The same effect would be obtained with the code `$0 = "Hello world!"`. This way of updating the file is called the "update" mode of Starfish and it is the default mode. The "replace" mode can be used, but then we should have a different output file, as in the following command:

```
starfish -replace -o=example-out.txt example.txt
```

and the content of the file `example-out.txt` would now be:

```
Hello world!
```

The module parameters can be changed, and their default values vary according to the text style. These parameters are described in the description of the `set_style` method.

HTML Examples

Example 1

If we have an HTML file, e.g., `7.html` with the following content:

```
<HEAD>  
<BODY>  
<!--<? $0="This code should be replaced by this." !>-->  
</BODY>
```

then after running the command

```
starfish -replace -o=7out.html 7.html
```

the file `7out.html` will contain:

```
<HEAD>
<BODY>
This code should be replaced by this.
</BODY>
```

The same effect would be obtained with the following line:

```
<!--<? echo "This code should be replaced by this." !>-->
```

Output file permissions

The permissions of the output file will not be changed. But if it does not exist, then:

```
starfish -replace -o=7out.html -mode=0644 7.html
```

makes sure it has all-readable permission.

Example 2

Input file 21.html:

```
<!--<? use CGI qw/:standard/;
      echo comment('AUTOMATICALLY GENERATED - DO NOT EDIT');
!>-->
<HTML><HEAD>
<TITLE>Some title</TITLE>
</HEAD>
<BODY>
<!--<? echo "Put this." !>-->
</BODY>
</HTML>
```

Output:

```
<!-- AUTOMATICALLY GENERATED - DO NOT EDIT -->
<HTML><HEAD>
<TITLE>Some title</TITLE>
</HEAD>
<BODY>
Put this.
</BODY>
</HTML>
```

Example from a Makefile

```
LIST=first second third\  
fourth fifth  
  
<? echo join "\n", getmakefilelist $Star->{INFILE}, 'LIST', "\n" !>#+  
first  
second  
third  
fourth  
fifth  
#-
```

Beside \$O, \$Star is another predefined variable: It refers to the Starfish object currently processing the text.

TeX and LaTeX Examples

Simple TeX or LaTeX Example

Generating text with a variable replacement:

```
%<?echo "  
% When we split the probability reserved for unseen characters equally  
% among the remaining $UnseenNum characters, we obtain the final estimated  
% probabilities:  
%!"!>
```

Example from a TeX file

```
% <? $Star->Style('TeX') !>  
  
% For version 1 of a document  
% <? #$$Star->addHook("\n%Begin1", "\n%End1", 's/\n%+/\n/g');  
%   #$$Star->addHook("\n%Begin2", "\n%End2", 's/\n%*/\n%/g');  
%   #For version 2  
%   $Star->addHook("\n%Begin1", "\n%End1", 's/\n%*/\n%/g');  
%   $Star->addHook("\n%Begin2", "\n%End2", 's/\n%+/\n/g');  
% !>  
  
%Begin1  
%Document 1  
%End1  
  
%Begin2  
Document 2  
%End2
```

LaTeX Example with Final Routine used for Slides

```
% -*- compile-command: "make 01s 01"; -*-
%<? ##read_starfish_conf();
% $TexTarget = 'slides';
% sfish_add_tag('sl,1', 'echo');
% sfish_add_tag('slide', 'echo');
% sfish_ignore_outer;
% $Star->add_final( sub {
%   my $r = shift;
%   $r =~ s/^% -\*- compile-command.*\n//;
%   $r.= "\\end{document}\n";
%   return $r;
% } );
% !>
```

```
\section{Course Introduction}
```

Not in slide.

```
%slide:In slide.
```

```
%<sl,1>
In slides and lectures.
%</sl,1>
```

Example with Test/Release versions (Java)

Suppose you have a standalone java file p.java, and you want to have two versions:

```
p_t.java -- for complete code with all kinds of testing code, and
p.java -- clean release version.
```

Solution:

Copy p.java to p_t.java and modify p_t.java to be like:

```
/** Some Java file. */

//<? $0 = defined($Release) ?
// "public class p {\n" :
// "public class p_t {\n";
//!>//+
public class p_t {
//-
```

```

public static int main(String[] args) {
    //<? $0 = "    ".(defined $Release ?
    //qq[System.out.println("Test version");] :
    //qq[System.out.println("Release version");]);
    //!>///  

    System.out.println("Release version");//-
    return 0;
}
}

```

In Makefile, add lines for updating p.t.java, and generating p.java (readonly, so that you do not modify it accidentally):

```

p.java: p_t.java
    starfish -o=$@ -e='$$Release=1' -mode=0400 $<
tmp.ind: p_t.java
    starfish $<
    touch tmp.ind

```

Command-line Examples

The following are the reference examples. For further information, please lookup the explanations of the command-line options and arguments.

```
starfish -mode=0400 -replace -o=paper.tex -mode=0400 paper.tex.sfish
```

In the above line, Starfish is used on top of a TeX/LaTeX file. The Starfish is separated from the .tex file to keep the source clean. However, a user in this situation may by mistake start editing the paper.tex file, so we set the output file mode to 0400 to prevent this accidental editing.

Macros

Note: This is a quite old part of Starfish and needs a revision. Macros are a form of code folding (related terms: holophrasting, ellusion(?)), expressed in the Starfish framework.

Starfish includes a set of macro features in an experimental phase. There are two modes, hidden macros and not hidden, which are indicated using variable \$Star->{HideMacros}, e.g.:

```

starfish -e='$Star->{HideMacros}=1' *.sfish
starfish *.sfish

```

Macros are activated with:

```
<? $Star->defineMacros() !>
```

In Java mode, a macro can be defined in this way:

```
//m!define macro name  
...  
//m!end
```

After `//m!end`, a newline is mandatory. After running Starfish, the definition will disappear in this place and it will be appended as an `auxdefine` at the end of file.

In the following way, it can be defined and expanded in the same place:

```
//m!defe macro name  
...  
//m!end
```

A macro is expanded by:

```
//m!expand macro name
```

When macro is expanded it looks like this:

```
//m!expanded macro name  
...  
//m!end
```

Macro is expanded even in hidden mode by:

```
//m!fexpand macro name
```

and then it is expanded into:

```
//m!fexpanded macro name  
...  
//m!end
```

Hidden macros are put at the end of file in this way:

```
//auxdefine macro name  
...  
//endauxdefine
```

Old macro definition can be overridden by:

```
//m!newdefe macro name  
...  
//m!end
```

A.5 PREDEFINED VARIABLES AND FIELDS

\$O

After executing a snippet, the contents of this variable represent the snippet output.

\$Star

More precisely, it is `$::Star`. `$Star` is the Starfish object executing the current code snippet (this). There can be a more such objects active at a time, due to executing Starfish from a starfish snippet. The name is introduced into the main namespace, which might be a questionable decision.

\$Star->{Final}

If defined, it should be an array of CODE references, which are applied as functions on the final output before writing it out. These are used as final routines, typically to add or remove some of the first lines or finals lines. Each function takes input as a parameter and returns it after processing. The variable should accessed using the method `add_final`.

\$Star->{INFILE}

Name of the current input file.

\$Star->{Loops}

Controls the number of iterations. The default value is 1, but we may want to repeat starfishing the text several times, or even until a fix-point is reached. For example, by setting the number of Loops to be at least 2, as in:

```
$Star->{Loops} = 2 if $Star->{Loops}<2;
```

we require Starfish to proces the input in at least two iterations.

\$Star->{Out}

Output content of the current processing unit. For example, to use #-style line comments in the replace Starfish mode, one can make a final substitution in an HTML file:

```
<!--<? $Star->{Out} =~ s/^#.*\n//mg; !>-->
```

It is important to have in mind that the contents of this variable is the output processed so far, so any final output processing should be done in a snippet where no new output is produced.

`$Star->{OUTFILE}`

If option `-o=*` is used, then this variable contains the name of the specified output file.

A.6 METHODS

`Text::Starfish->new(options)`

The method for creation of a new Starfish object. If we are already processing within a Starfish object, we may use a shorter variant `$Star->new()`.

The options, given as arguments, are a list of strings, which may include the following:

`-infile=*` Specifies the name of the input file (field `INFILE`). The file will not be read.

`-copyhooks` Copies hooks from the Star object (`$::Star`). This option is also available in `loadinclude`, `getinclude`, and `include`, from which it is passed to `new`. It causes the new object to have similar properties as the current Star object. It could be generalized to include any specified object, or to use the prototype object that is given to the constructor, but there does not seem to be need for this generalization. More precisely, `-copyhooks` copies the fields: `Style`, `CodePreparation`, `LineComment`, `IgnoreOuter`, and per-component copies the array hook.

`$o->add_final($func_ref)`

Adds the function referred to by `$func_ref` to the list of functions to be executed on the output at the end of processing. See also the parameter `$Star->{Final}`.

`$o->add_tag($tag, $action)`

Normally used by `sfish_add_tag` by translating the call to `$Star->add_tag($tag, $action)`. Examples:

```
$Star->add_tag('slide', 'ignore');
$Star->add_tag('slide', 'echo');
```

See `sfish_add_tag` for a few more details.

`$o->add_hook($ht,...) -- (and function add_hook)`

Adds a new hook. The first argument is the hook type, which is a string. If it is used as a function, it will run on the `$::Star` object. The following is the list of hook types with descriptions:

string, somestring, replacementstring

A simple hook to replace a string with another string. In the update mode, we must take care that the string to be replaced is commented out if needed. For example, after the following embedded code:

```
<?starfish
add_hook('string', '<code>App::Utils</code>',
  '<a href="https://metacpan.org/pod/App-Utils" target="_blank">'.
  '<code>App::Utils</code></a>'); ?>
```

any occurrence of `App::Utils` is replaced with:

```
<a href="https://metacpan.org/pod/App-Utils" target="_blank">
<code>App::Utils</code></a>
```

be, *prefix*, *suffix*

Adding a hook with new prefix (begin delimiter) and suffix (end delimiter). The following example replaces the default hook `<?...!>` with a new one `<?new ...!>`:

```
rm_hook('be', '<?', '!'.>'); # remove default hook (notice that we avoid
# literal ending delimiter '!>' in order
# not to be confused with default suffix
add_hook('be', '<?new ', '!'.>'); # adding a new hook
```

regex, *regex*, *replace*

The hook type `regex` is followed by a regular expression and a replace argument. Whenever a regular expression is matched in text, it is “starfished” according to the argument `replace`. If the argument `replace` is the string “comment”, it is treated as the comment. If the argument `replace` is code, it is used as the evaluation code. For example, the following source in an HTML file:

```
<!--<? $Star->add_hook('regex', qr/^\.section:(\w+)\s+(.*)/,
sub { $_=<a name\"$_[2]\"><h3>$_[3]</h3</a>\" } ) !>-->

line before
.section:overview Document Overview
line after
```

will produce the following output, in the `replace` mode:

```
line before
<a name"overview"><h3>Document Overview</h3</a>
line after
```

ht:re2, *regex*, *replace*

The hook type `ht:re2` is a special type used for Python and Makefile styles in order to capture indentation, which needs to be maintained in the output. It is regular expression based.

\$o->addHook -- deprecated, should use add_hook

This method is deprecated. It will be gradually replaced with `add_hook`, which is better defined since it includes hook type.

Adds a new hook. The method can take two or three parameters:

```
($prefix, $suffix, $evaluator)
```

or

```
($regex, $replacement)
```

In the case of three parameters (`$prefix`, `$suffix`, `$evaluator`), the parameter `$prefix` is the starting delimiter, `$suffix` is the ending delimiter, and `$evaluator` is the evaluator. The parameters `$prefix` and `$suffix` can either be strings, which are matched exactly, or regular expressions. An empty ending delimiter will match the end of input. The evaluator can be provided in the following ways:

special string 'default'

in which case the default Starfish evaluator is used,

special strings 'ignore' and 'echo'

'ignore' ignores the hook and produces no echo, 'echo' simply echos the contests between the delimiters.

other strings

are interpreted as code which is embedded in an evaluator by providing a local `$_`, `$self` which is the current Starfish object, `$p` - the prefix, and `$s` the suffix. After executing the code `$p.$_.$s` is returned, unless in the replacement mode, in which `$_` is returned.

code reference (sub {...})

is interpreted as code which is embedded in an evaluator. The local `$_` provides the captured string. Three arguments are also provided to the code: `$p` - the prefix, `$_`, and `$s` - the suffix. The result is the value of `$_`.

For the format with two parameters, (`$regex`, `$replacement`), currently in this mode `addHook` understands replacement 'comment' and code reference (e.g., `sub { ... }`). The replacement 'comment' will repeat the token in the non-replace mode, and remove it in the replace mode; e.i., equivalent to no echo. The regular expression is matched in the multi-line mode, so `^` and `$` can be used to match beginning and ending of a line. (Caveat: Due to the way how scanner works, beginning of a line starts after the end of previously matched token.)

Example:

```
$Star->addHook(qr/^#.*\n/, 'comment');
```

`$o->ignore_outer()`

Sets the mode for ignoring the outer text in the replace mode. The function `sfish_ignore_outer` does the same on the default object `Star`. If an argument is given, it is used to set the mode, so as a consequence the mode can be turned off by giving the argument `''`.

`$o->last_update()`

Or just `last_update()`, returns the date of the last update of the output.

`$o->process_files(@args)`

Similar to the function `starfish_cmd`, but it expects already built Starfish object with properly set options. Actually, `starfish_cmd` calls this method after creating the object and returns the object.

`$o->rmHook($p,$s) -- deprecated, should use rm_hook`

Removes a hook specified by the starting delimiter `$p`, and the ending delimiter `$s`.

`$o->rm_hook($ht,...) -- and function rm_hook`

Removes a hook. Example:

```
rm_hook('be', '<?', '!'>'); # removes all hooks with give begin and end
```

`$o->rmAllHooks()`

Removes all hooks. If no hooks are added, then after exiting the current snippet it will not be possible to detect another snippet later. A typical usage could be as follows:

```
$Star->rmAllHooks();  
$Star->addHook('<?starfish ',,'?>', 'default');
```

`$o->setStyle($s) -- deprecated, should use set_style`

Deprecated method. The method or function `set_style` should be used.

`set_style method or function`

Sets a particular style of the source file. If used as function, the object `Star` is used as the "self" object. Currently implemented options are: `html`, `java`, `makefile`, `perl`, `ps`, `python`, and `tex` (same as `latex`, `TeX`). If the parameter `$s` is not given, the style given in

`$o->{STYLE}>` will be used if defined, otherwise it will be guessed from the file name in `$o->{INFILE}>`. If it cannot be correctly guessed, it will be the Perl style.

Setting a style can have various side effects, but it typically involves setting the following variables:

```
$o->{Style}          # style string id
$o->{CodePreparation} # function to clean the code before running
$o->{LineComment}    # string starting a line comment
$o->{OutDelimiters}  # array ref with four elements: $b1, $b2 for
                    # starting output delimiter, and $e1, $e2 for
                    # the ending output delimiter; $b1 and $e1
                    # must not end with a digit, and $b2 and $e2
                    # must not start with a digit
$o->{IgnoreOuter}    # boolean variable to ignore outer text, false
                    # by default
$o->{hook}           # array ref, list of hooks
```

A.7 PREDEFINED FUNCTIONS

`include(filename and options)` -- starfish a file and echo

Reads, starfishes the file specified by file name, and echos the contents. Similar to PHP `include`. Uses `getinclude` function.

`getinclude(filename and options)` -- starfish a file and return

Reads, starfishes the file specified by file name, and returns the contents (see also `include` to echo the content implicitly). By default, the program will not break if the file does not exist. The option `-noreplace` will starfish file in a non-replace mode. The default mode is replace and that is usually the mode that is needed in includes (non-replace may lead to a suprising behaviour). The option `-require` will cause program to croak if the file does not exist. It is similar to the PHP function `require`. A special function named `require` is not used since `require` is a Perl reserved word. Another interesting option is `-copyhooks`, for using hooks and some other relevant properties from the Star object (`$::Star`). This option is eventually passed to `new`, so you can see the constructor `new` for more details.

The code for get include is the following:

```
sub getinclude($@) {
    my $sf = loadinclude(@_);
    $sf->_digest();
    return $sf->{Out};
}
```

and it can be used as a useful template for using `loadinclude` directly. The function `loadinclude` creates a Starfish object, and reads the file, however it is not digested yet, so one can modify the object before this.

loadinclude(*filename and options*) -- load file and get ready to digest

The first argument is a filename. Loadinclude will interpret the options `-replace`, `-noreplace`, and `-require`. A Starfish object is created by passing the file name as an `-infile` argument, and by passing other options as arguments. The file is read and the object is returned. By default, the program will not break if the file does not exist or is not readable, but it will return undef value instead of an object. See also documentation about `include`, `getinclude`, and `new`.

`-noreplace` option will set up the Starfish object in the no-replace mode. The default mode is replace and that is usually the mode that is needed in includes. The option `-require` will cause program to croak if the file does not exist. An interesting option is `-copyhooks`, which is documented in the `new` method.

read_starfish_conf

This function is usually called at the beginning of a starfish file, in order to read local configuration. it tests whether there exists a file named `starfish.conf` in the current directory. If it does exist, it checks for the same file in the parent directory, then grandparent directory, etc. Once the process stops, it starts executing the configuration files in the order from first ancestor down. For each file, it changes directory to the corresponding directory, and requires (in Perl style) the file in the package main.

sfish_add_tag (*tag, action*)

Used to introduce simple tags such as line tag `%s1,1:` and `%<s1,1>...</s1,1>` in TeX/LaTeX for inclusion and exclusion of text. Example:

```
sfish_add_tag('s1,1', 'echo');
sfish_add_tag('slide', 'ignore');
```

and, for example, the following text is included:

```
%s1,1:some text to the end of line
%<s1,1>
more lines of text
%</s1,1>
```

and the following text is excluded:

```
%slide:this line is excluded
%<slide>
more lines of text excluded
%</slide>
```

sfish_ignore_outer()

Sets the default object `$Star` in the mode for ignoring outer text if in the replace mode. If an argument is given, it is used to set the mode, so as a consequence the mode can be turned off with `sfish_ignore_outer('')`.

starfish_cmd *list of file names and options*

The function `starfish_cmd` is called by the script `starfish` with the `@ARGV` list as the list of arguments. The function can also be used from Perl code to "starfish" a file, e.g.,

```
starfish_cmd('somefile.txt', '-o=outputfile', '-replace');
```

The arguments of the functions are provided in a similar fashion as argument to the command line. As a reminder, the command usage of the script `starfish` is:

```
starfish [ -o=outputfile ] [ -e=initialcode ] [ -replace ] [ -mode=mode ] file...
```

The options are described below:

-o=outputfile

specifies an output file. By default, the input file is used as the output file. If the specified output file is '-', then the output is produced to the standard output.

-e=initialcode

specifies the initial Perl code to be executed.

-replace

will cause the embedded code to be replaced with the output. WARNING: Normally used only with **-o**.

-mode=mode

specifies the mode for the output file. By default, the mode of the source file is used (the first one if more outputs are accumulated using **-o**). If an output file is specified, and the mode is specified, then `starfish` will set temporarily the `u+w` mode of the output file in order to write to that file, if needed.

Those were the options.

echo *list*

appends all elements of the list to the special variable `$0`.

DATA FUNCTIONS

read_records(\$string)

The function reads strings and translates it into an array of records according to DB822 (db8 for short) data format. If the string starts with 'file=' then the rest of the string is treated as a file name, which contents replaces the string in further processing. The string is translated into a list of records (hashes) and a reference to the list is returned. The records are separated by empty line, and in each line an attribute and its value are separated by the first colon (:). A line can be continued using backslash (\) at the end of line, or by starting the next line with a space or tab. Ending a line with \ will replace "\\n" with "\n" in the string, otherwise "\n[\t]" are kept as they are. Lines starting with the hash sign (#) are considered comments and they are ignored, unless they are part of a multi-line string. An example is:

```
id:1
name: J. Public
phone: 000-111

id:2
etc.
```

If an attribute is repeated, it will be renamed to an attribute of the form att-1, att-2, etc.

DATE AND TIME FUNCTIONS

current_year

returns the current year in string format.

file_modification_time

Returns modification time of this file (in format of Perl time).

file_modification_date

Returns modification date of this file (in format: Month DD, YYYY).

FILE FUNCTIONS

appendfile \$filename, @list

appends list elements to the file.

getfile \$filename

reads the contents of the file into a string or a list.

getmakefilelist(\$makefilename, \$var)

returns a list, which is a list of words assigned to the variable `$var` in the makefile named `$makefilename`; for example:

```
FILE_LIST=file1 file2 file3\  
file4  
  
<? echo join "\n", getmakefilelist $Star->{INFILE}, 'FILE_LIST' !>
```

Embedded variables are not handled.

putfile \$filename, @list

Opens the file `$filename`, writes the list elements to the file, and closes it. `'putfile filename'` will only touch the file.

A.8 STYLES

There is a set of predefined styles for different input files: HTML (`html`), HTML templating style (`html.sfish`), TeX (`tex`), Java (`java`), Makefile (`makefile`), PostScript (`ps`), Python (`python`), and Perl (`perl`).

HTML Style (`html`)

HTML Templating Style (`html.sfish`)

This style is similar to the HTML style, but it is supposed to be run in the replace mode towards a target `.html` file, so it allows for more hooks. The character `#` (hash) at the beginning of a line denotes a comment.

Makefile Style (`makefile`)

The main code hooks are `<?` and `>`.

Interestingly, the makefile style has similar special requirements as Python. For example, in the following expansion:

```
starfish: tmp  
    starfish Makefile  
    #<? if (-e "file.tex.sfish")  
    #{ echo "\tstarfish -o=tmp/file.tex -replace file.tex.sfish\n" } !>#+
```

```
starfish -o=tmp/file.tex -replace file.tex.sfish
#-
```

it is convenient to have the embedded output indented in the same way as the embedded code.

A.9 STYLE SPECIFIC PREDEFINED FUNCTIONS

`get_verbatim_file(filename)`

Specific to LaTeX mode. Reads textual file *filename* and returns a string ready for inclusion in a LaTeX document. It untabifies the file contents for proper representation of whitespace. The function code is basically:

```
return "\\begin{verbatim}\n".
    untabify(scalar(getfile($f))).
    "\\ end{verbatim}\n";
```

Note: There is no space between `\\` and `end{verbatim}`.

`htmlquote(string)`

The following definition is taken from the CIPP project.

(<http://aspn.activestate.com/ASPN/CodeDoc/CIPP/CIPP/Manual.html>, link does not seem to be active any more)

This command quotes the content of a variable, so that it can be used inside a HTML option or `<TEXTAREA>` block without the danger of syntax clashes. The following conversions are done in this order:

```
& => &amp;
< => &lt;t;
"  => &quot;
```

A.10 LIMITATIONS AND BUGS

The script swallows the whole input file at once, so it may not work on small-memory machines and with huge files.

A.11 THANKS

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A.12 AUTHORS

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2007 Charles Ikeson (overhaul of test.pl)

This script is provided "as is" without expressed or implied warranty. This is free software; you can redistribute it and/or modify it under the same terms as Perl itself.

The latest version can be found at <http://web.cs.dal.ca/~vlado/srcperl/>.

A.13 SEE ALSO

There are several projects similar to Starfish. Some of them are text-embedded programming projects such as PHP with different programming languages, and there are similar Perl-based projects. When I was thinking about a need of a framework like this one (1998), I have found ePerl project. However, it was too heavy weight for my purposes, and it did not support the "update" mode, vs. replace mode of operation. I learned about more projects over time and they are included in the list below.

[ePerl] ePerl

This script is somewhat similar to ePerl, about which you can read at

<http://www.oss.org/pkg/tool/eperl/>. It was developed by Ralf S. Engelshall in the period from 1996 to 1998.

php

<http://www.php.net>

[ePerl-h] ePerl hack by David Ljung Madison

This is a Perl script simulating the ePerl functionality, but with obviously much lower weight. It is developed by David Ljung Madison, and can be found at the URL: <http://marginalhacks.com/Hacks/ePerl/>

[Text::Template] Perl module Text::Template by Mark Jason Dominus.

<http://search.cpan.org/~mjd/Text-Template/> Text::Template is a module with similar functionality as Starfish. An interesting similarity is that the output variable in Text::Template is called \$OUT, compared to \$O in Starfish.

[HTML::Mason] Perl module HTML::Mason by Jonathan Swartz, Dave Rolsky, and Ken Williams.

<http://search.cpan.org/~drolsky/HTML-Mason-1.28/lib/HTML/Mason/Devel.pod> The module HTML::Mason can also be seen as an embedded Perl system, but it is a larger system with the design objective being a "high-performance, dynamic web site authoring system".

**[HTML::EP] Perl Module HTML::EP - a system for embedding Perl into HTML,
by Jochen Wiedmann.**

<http://search.cpan.org/~jwied/HTML-EP-MSWin32/lib/HTML/EP.pod> It seems that the module was developed in 1998-99. Provides a good CGI support, run-time support, session handling, a database server interface.