Type inference for PHP
Using annotations to provide more precise results

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Contents

Abstract

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Preface

In this section I will thank everyone who has helped me. Maybe also introduce some anecdote on how this research came to be.

Chapter 1

Introduction

1.1 PHP

PHP[1]is a server-side scripting language created by Rasmus Lerdorf in 1995. The original name Personal Home Page changed to PHP: Hypertext Preprocessor in 1998. PHP source files are executed using the PHP Interpreter. The language is dynamically typed, which means that the behaviour of the source code will be examined during run-time. Statically typed languages would apply these modification during compile type. PHP supports duck-typing, which means that the type of an expression can be transformed to another type at a certain point.

The programming language PHP evolved after its creation in 1995. In the year 2000 Object-Oriented (OO) language structures were added to the langue with the release of PHP 4.0. The 5th version of PHP was release in 2004 including improved the OO support. To be able to resolve conflicts between library and create better readable class names, namespaces were added to the release of PHP 5.3 in 2009. Namespaces are comparable to packages in JAVA. The most recent stable version is 5.5 in which the OPcache extension is added. OPcache speeds up the performance of including files on run-time by storing precompiled script bytecode in shared memory.

According to the Tiobe Index[2]of july 2014, PHP is the 7th most popular programming language. The language has been in the top 10 since its introduction in the Tiobe index in 2001. More than 80 procent of the websites have a php backend[3]. The majority of these websites use PHP version 5, rather than version 4 or version 3. It is therefor useful to focus on PHP version from 5 and disgard the older unsupported versions.

Although the popularity for more than a decade, there is still a lack of good PHP code analysis tools. These tools can help to reveal security vulnerabilities or bugs in source code. The tools can also provide code completions to developers or make automatic transformations on the code possible, for example to execute refactoring patterns. Other dynamic languages suffer the same difficulties

1.2 Position

As far as we know, there is no constraint based type inference research like this one performed for PHP. That makes this research unique. There have been similar analysis for other dynamic languages, like smalltalk, ruby and javascript.

[1]http://php.net
[2]http://www.tiobe.com/index.php/content/paperinfo/tpci/index.html, July 2014
[3]http://w3techs.com/technologies/details/pl-php/all/all, July 2014

1.3 Contribution

TODO Review this part when the result of the analysis are performed. Some idea's are that this analysis can help IDE tools to perform transformations on the source code. But the performance may not be sufficient.
Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. If you read this text, you will get no information. Really? Is there no information? Is there a difference between this text and some nonsense like "Huardest gefburn"? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. This text should contain all letters of the alphabet and it should be written in of the original language. There is no need for special content, but the length of words should match the language.

1.4 Plan

The rest of the thesis is as follows: chapter 2 contains background and context information about related work. Here we will explain the php language and explain similar research. In the next chapter 3 the research method is explained, which will explain the steps taken in this the research.

Chapter 2

Background and context

2.1 PHP Language Constructs

In this section important language constructs are presented. Explanations of these constructs should help to understand the performed analysis. Including some concepts like scope, includes, dynamic variables, dynamic class instantiation, dynamic function call, dynamic dispatch, runtime environment variables and constants, late static binding (static keyword), magic methods.

2.1.1 Scoping

PHP has a few scopes. "Define what scope is". Global, namespace, class, method, function. The global scope is contained in every file which is not inside a function or class. The global scope can contain namespaces. Namespaces are comparable to packages in Java. When namespaces are used, classes and functions will be scoped to the namespace. You can access them by providing the namespace name.
Todo: say something about the global statement

2.1.2 Includes

Note to myself: how will I deal with this concept in my analysis (totally ignore it??? when maybe not add it to this background information). The problem of including files can be reduced using namespaces and autoloading. When a class which is not loaded in memory is instantiated, the autoloading will try to include a file and load the class. For this analysis we will include all files
* Refer to the analysis of mark hills, that most files can be resolved, but not all. We consider the use of including scripts for logic as bad practice. Every file should contain a class, and in this case, it is for our analysis not very interesting to resolve the includes.

2.1.3 Conditional functions and classes

Explain the code below.

```
1 if (!class_exists("Foo"))
2   class Foo { /* ... */ }
3
4 if (!function_exists("bar"))
5   function bar() { /* ... */ }
```

Listing 2.1: Conditional class and function definitions

Explain the code below.

```
1 function f() {
2   function g() {
3     class C {}
4   }
5 }
```

```
6
7  g(); f(); // will fail because ‘g();‘ is not declared yet
8  f(); g(); // will work because ‘g();‘ is declared when calling ‘f();‘
9  f(); new C(); // will fail because ‘g();‘ needs to be called first
10 f(); g(); new C(); // will work because ‘g();‘ is called and has declared ‘f();‘
```

Listing 2.2: Conditional function declaration

2.1.4 Dynamic features

These include dynamic variables, dynamic class instantiations, dynamic function calls.

2.1.5 Late static binding

Late static binding[1]is implemented in PHP since version 5.3 by adding the keyword ‘static’ to the language. It has the same function as ‘parent’ and ‘self’, because they both point to a class. The main difference is that ‘parent’ and ‘self’ can be resolved statically. ‘static’ can only be resolved on runtime and represents the exact class that is instantiated.

2.1.6 Magic methods

In PHP it is allowed to call methods or use properties that do not exists. Normally this would result in a fatal error, but not with the use of magic methods. One of the magic methods is het constructor method ‘__ construct’.

2.1.7 Dynamic class properties

Although it is a good practice to define your class properties, it is not required. On runtime it is possible to add properties to classes, even without the implementation of magic methods.

```
1 class C {}
2 $p = (new C())->nonExistingProperty;
3 var_dump($p); // NULL
4 $c = new C();
5 $p = $c->nonExistingProperty = "property now exists";
6 var_dump($p); // string(19) "property now exists"
```

Listing 2.3: Dynamic class property

2.1.8 Other concepts

- ... nothing yet

2.2 Rascal

Rascal

2.3 M3

The M3-model is a generic model which can be used to analyse software programs. Our goals is to provide the results in an M3 model. Future research can use this to compare different programming languages.

[1] http://php.net/manual/en/language.oop5.late-static-bindings.php, July 2014

2.4 Type inference

Describe different methods of type inferences and why I chose for this one.

Chapter 3

Research Method

<< Introduction of this chapter >>

3.1 Types

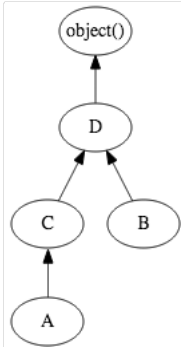
Explain here what I mean with a type...

3.1.1 PHP types

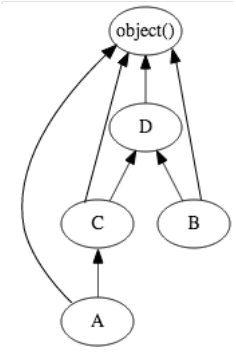
PHP has a similar class inheritance structure and interface implementation as Java. The difference is that in PHP all class are *public*, and no inner classes are allowed.
The basis types in PHP are integers, floats (similar to doubles and reals), booleans, strings, arrays, resources and null. When variables are initialised without a values, they are null. The recourse type is a special one which is not important for this research.

3.1.2 Subtypes

The subtype relation of class inheritance is a Transitive closure relation. A class extension of class A on class C will define class A as a subtype of class C, as you can see in 3.1. If a class does not extend another class, it will implicitly extend the object class. You can see that this happens with class D in the example. The predefined class *stdClass* represents the *object*() type defined in the rascal types.



(a) Inheritance relation



(b) Subtype relation

```
1 class A extends C {}
2 class B extends D {}
3 class C extends D {}
4 class D {}
```

Listing 3.1: Inheritance in PHP

Figure 3.1: Relation of subtypes among classes

3.2 Constraint extraction

Introduction is needed here... for now I will just list the types that I have found. Maybe this needs to be moved to a different chapter.
This is a list of items which are not supported yet:

- Assign statements:
  - Ref assign :: $\$a = \&\$b$
  - List assign :: $list(\$a, \$b) = array(\text{"}one\text{"}, \text{"}two\text{"})$;
- References (in PHP they are symbol table aliases)

  - on expression assignments :: $\$a = \&\$b$
  - on functions :: function $\&f() \{\dots\}$
  - on parameters :: function $f(\$a) \{\dots\}$
- Variable structures:
  - Variable variables :: $\$\$a$;
  - ~~Variable class instantiation~~ :: $new\ \$a$;
  - ~~Variable method or function calls~~ :: $\$a()$;
- Method or function parameters (including type hints)
- Casts of expressions

Note to myself ::
type has field
type has name
type has method
type has magic method

$$\frac{E_1 = E_2}{[E_2] <: [E_1]}$$

```
1 $a = $b; // normal assign
2 $a = &$b // todo: ref assign and list assign
```

Listing 3.2: Assignment

```
1 $a &= $b;   /* $a = int() */
2 $a |= $b;   /* $a = int() */
3 $a ^= $b;   /* $a = int() */
4 $a <<= $b; /* $a = int() */
5 $a >>= $b; /* $a = int() */
6 $a %= $b;   /* $a = int() */
```

Listing 3.3: Assignments with operators resulting in ints

$$\frac{(E_1 \ \&= E_2) \vee (E_1 \ |= E_2) \vee E_1 \ \hat{}= E_2) \vee (E_1 <<= E_2) \vee (E_1 >>= E_2) \vee (E_1 \ \%= E_2)}{[E_1] = int()}$$

```
1 $a .= $b;   /* $a = string() */
2 // * Error when $b is of type object() and __toString is not defined or does not
      return a string */
```

Listing 3.4: Assignments with string concat operator

$$\frac{E_1 \ .= E_2}{[E_1] = string()}$$

```php
$a /= $b;  /* $a = int() */
// * Error when $b is of type array() */
$a -= $b;  /* $a = int() */
// * Error when $b is of type array() */
```

Listing 3.5: Assignments with operators

$$\frac{(E_1 \ /= E_2) \vee (E_1 -= E_2)}{[E_1] = int()}$$

```php
$a *= $b; /* when $b == (bool()|int()|null()) */ /* $a = int() */
$a *= $b; /* when $b != (bool()|int()|null()) */ /* $a = float() */
$a += $b; /* when $b == (bool()|int()|null()) */ /* $a = int() */
$a += $b; /* when $b != (bool()|int()|null()) */ /* $a = float() */
```

Listing 3.6: Assignments with operators

$$\frac{(E_1 \ *= E_2) \vee (E_1 \ += E_2)}{[E_1] <: int()}$$

```php
$a == $b   /* bool() */
$a === $b  /* bool() */
$a != $b   /* bool() */
$a <> $b   /* bool() */
$a !== $b  /* bool() */
$a < $b    /* bool() */
$a > $b    /* bool() */
$a <= $b   /* bool() */
$a >= $b   /* bool() */
```

Listing 3.7: Comparison operators

$$\frac{(E_1 == E_2) \vee (E_1 === E_2) \vee (E_1 \ != E_2) \vee (E_1 <> E_2) \vee (E_1 \ !== E_2) \subseteq E}{[E] = bool()}$$

$$\frac{(E_1 < E_2) \vee (E_1 > E_2) \vee (E_1 <= E_2) \vee (E_1 >= E_2) \subseteq E}{[E] = bool()}$$

```php
new C;
```

Listing 3.8: Class instantiation

$$\frac{new\ C \subseteq \Gamma \qquad class\ C()^* \ldots \subseteq \Gamma}{[new\ C] = C, C.name == [new\ C].name}$$

*no required params in constructor

```php
new C($foo);
```

Listing 3.9: Class instantiation with parameters

$$\frac{new\ C\ (E_1, E_2, \ldots, E_k) \subseteq \Gamma \qquad class\ C\ (th_1\ E_1, th_2\ E_2, \ldots, th_k\ E_k) \subseteq \Gamma}{[new\ C] = C, C.name == [new\ C].name}$$

// todo: add something about the parameter constraints (note to myself: misschien moeten deze 'los' behandeld worden.)
// th = typeHint

```
new $c;
```

Listing 3.10: Class instantiation of an expression

$$\frac{new\ E_1 \subseteq \Gamma}{[new\ E_1] = \text{object}()}$$

```
function f() {
  $a = 1;
  $a = "true";
}
// typeOf($a) is typeOf($a1, $a2, ..., $an);
```

Listing 3.11: Type of variable within their scope; this applies to global- function- and method-scope

$$\frac{E, E', E'', E''' \ldots\ etc \subseteq f}{[E] = [E] \vee [E'] \vee [E''] \vee [E'''] \ldots\ etc}$$

```
function f() {}
// no return = null()
```

Listing 3.12: No return statements in function or method

$$\frac{\text{return} \not\subseteq f}{[f] = null()}$$

```
function f() {
  if (rand(0,1))
    return $a;
  else
    return $b;
}
// returns typeOf($a) or typeOf($b)
```

Listing 3.13: Return of a function or method; every exit path ends with a return statement

$$\frac{(\text{return}\ E_1) \vee (\text{return}\ E_2) \vee \cdots \vee (\text{return}\ E_k) \subseteq f}{[f] <: [E_1] \vee [E_2] \vee \cdots \vee [E_k]}$$

```
function f() {
  if (rand(0,1))
    return $a;
  else if (rand(0,1))
    return $b;
}
// returns typeOf($a) or typeOf($b) or null()
```

Listing 3.14: Return with possible no return value

$$\frac{(\text{return } E_1) \vee (\text{return } E_2) \vee \cdots \vee (\text{return } E_k) \vee (\neg \text{ return}) \subseteq f}{[f] <: [E_1] \vee [E_2] \vee \cdots \vee [E_k] \vee null()}$$

```
1 function f() {}
2 f();
```

Listing 3.15: Functional call

$$\frac{f() \subseteq \Gamma}{[f()] <: \text{return of } [f]}$$

```
1 function f() {}
2 $f = "f";
3 $f(); // unknown what function will be called
```

Listing 3.16: Variable function call

$$\frac{E_1() \subseteq \Gamma}{[E_1()] = mixed()}$$

How to resolve expressions:

- Find all expressions which are defined above and annotate them with @type.
- Annotate the rest of the expressions with @type = any();

3.3 Annotations

Explain how the annotations are added to the constraints. This is the second paragraph. Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. If you read this text, you will get no information. Really? Is there no information? Is there a difference between this text and some nonsense like “Huardest gefburn”? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. This text should contain all letters of the alphabet and it should be written in of the original language. There is no need for special content, but the length of words should match the language.

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3.4 Constraint solving

Explain what will be done to solve the constraints.
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3.5 Case Study

Explain how the case study is performed.
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Chapter 4

Results

Summary of the results.
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4.1 Annotations

The results of the analysis when adding the annotations to the analysis. Compare the results with the results of the analysis without the annotation information.
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Chapter 5

Conclusion

Summary of the whole work, with conclusions. T.B.A.
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5.1 Future work

Explain something about combining this analysis to other analysis (like dead code elimination, constant folding/propagation resolve, alias analysis) to gain more precise results.

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Something about performance optimisations... Explain what is already done to boost the performance and what still can be done.
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Use a bigger corpus to gains better results of the analysis by doing analysis on more programs.
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Glossary

Rascal

Rascal is a meta-programming language developed by SWAT (Software analyse and transformation) team at CWI in the Netherlands.

Transitive closure

A relation R on a set X is transitive if, for all x,y,z in X, whenever x R y and y R z then x R z.