Extended results of Tornado: A Run-Fail-Grow approach for Dynamic Application Tayloring
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Extended results of Tornado
A Run-Fail-Grow approach
for
Dynamic Application Tailoring
Abstract

Producing a small deployment version of an application is a challenge because static abstractions such as packages cannot anticipate the use of their parts. As such, an application often occupies more memory than actually needed. To solve this problem we propose Tornado, a technique to dynamically tailor applications to only embed code (classes and methods) they use. Tornado uses a run-fail-grow approach to prepare an application for deployment. It launches minimal version of an application and installs a minimal set of statements that will start the user’s application. This application is run and these statements are executed. When the application fails because there are classes or methods missing, the necessary code is installed. The application is executed until it reaches a stable point, allowing possibly human interaction for applications with UIs. Thus, Tornado creates minimal memory footprint versions of applications by tailoring the whole application’s code, including run-time and third party libraries.

In this report, we present the results we obtained from using Tornado to tailor two different applications. We succeeded to tailor a hello world application to occupy 1% of its original size. We also experimented with a Seaside web application tailoring in one case only the application’s and framework’s code and the whole application’s code in the other case. In this latter example, we reached memory savings of about 97%. In this report we present an overview on Tornado, and we give details of the results we obtained.
## Contents

1. Used Methodology 3
2. Hello World Application 3
3. Seaside Web Application 3
   A. Appendix: Method List of a Nurtured Hello World Application 6
   B. Appendix: Entry Points to Tailor the Seaside Web Application 8
   C. Appendix: Method List of Seaside Counter Application with Full Pharo Seed 9
   D. Appendix: Method List of Seaside Counter Application with Empty Seed 15
1 Used Methodology

We tested our Tornado implementation by tailoring two different Pharo applications: a hello world application and a simple but yet interactive web application based on the Seaside framework [1]. Our methodology consisted in: setting up a seed for the application, preparing the application entry points and executing the application. In the case of the interactive web application, we interacted with it through a web browser. Once we finished the process, we extracted the resulting application by making a snapshot of it in a Pharo image file. We tested the generated snapshots to verify they work properly (under the assumption that only the previously used features of the application should work).

Finally, to present our results we measured the size of the generated snapshots files and compared them with the snapshots of the full applications under Pharo’s production option\(^1\). The results prove the soundness of our solution.

2 Hello World Application

We used Tornado to tailor a **hello world** application writing 10 times the ‘hello world’ string to the standard output (stdout). In this case study we used an empty seed to grow both base libraries and the application’s code. Figure 1 shows the installed entry point to tailor this application. Table 1 shows our results for this case. We succeed to reduce the application’s size to 1% of its original counterpart.

\(^1\)FileStream startUp: true.

```plaintext
1 to: 10 do: [ \[ :i | FileStream stdout nextPutAll: 'hello'; crlf \].
```

Figure 1: Entry point of the Hello World application with an empty seed.

<table>
<thead>
<tr>
<th></th>
<th>Size(KB)</th>
<th>Occupied(%)</th>
<th>Saved(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference</td>
<td>12872</td>
<td>100%</td>
<td>0%</td>
</tr>
<tr>
<td>Tailored</td>
<td>131</td>
<td>1%</td>
<td>99%</td>
</tr>
</tbody>
</table>

Table 1: Results of the tailored Hello World application.

3 Seaside Web Application

We also used Tornado to tailor a simple web application consisting in a webpage with a counter containing two buttons. These two buttons perform requests to the web server to increase and decrease the counter. The Seaside application framework was configured with its default values, without making any customizations.

\(^1\)Pharo allows to prepare a snapshot for production. This option cleans some caches and removes some well known objects from the system, thus, freeing space.
In this case, we used two different seeds for tailoring: a seed containing all Pharo base libraries and an empty seed. Appendix B presents the entry points for these both seeds. The tailoring was done by starting the application and exercising it by generating requests through a web browser, clicking on its decrease and increase buttons.

<table>
<thead>
<tr>
<th>Size (KB)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ref. Pharo Base Libraries (P)</td>
<td>12872</td>
</tr>
<tr>
<td>Ref. Seaside Framework (S)</td>
<td>4326</td>
</tr>
<tr>
<td>Ref. Counter Application (R)</td>
<td>52</td>
</tr>
<tr>
<td>Total Ref. Application (P+S+C)</td>
<td>17250</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Size (KB)</th>
<th>Occupied (%)</th>
<th>Saved (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P'+S'+C' / P+S+C</td>
<td>573</td>
<td>3%</td>
<td>97%</td>
</tr>
<tr>
<td>P''+S''+C'' / P+S+C</td>
<td>13090</td>
<td>76%</td>
<td>24%</td>
</tr>
<tr>
<td>S''+C'' / S+C</td>
<td>218</td>
<td>5%</td>
<td>95%</td>
</tr>
</tbody>
</table>

Table 2: Results of second case study. Results of tailoring a web application with two different seeds. On the left, the total sizes of the original application deployment components (base libraries, application framework and counter application). On the right, our results when applying after tailoring. The first two results rows are compared against the total of the reference application. The third row presents the comparison without including base libraries, already inside the seed.

Table 2 shows the results obtained when tailoring this application with each of these two seeds. Figure 2 presents a tailoring map illustrating how Tornado selects the code units from a reference application given a seeds. This figure also presents the notation we use in Table 2: P is the Pharo base libraries, S is the Seaside Framework and C is the Counter application code units present in the reference application. P', S' and C' are their counterparts selected by Tornado when using an empty seed. P'', S'' and C'' are their counterparts, as selected by Tornado when using a seed with all base libraries. In the latter, we can note that P=P''.

Figure 2: Tailoring Map. Tailoring map describing the Seaside application generated with the empty seed (left) and the full Pharo seed (right).

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(CPER) 2007-2013’, the Cutter ANR project, ANR-10-BLAN-0219.

References

A Appendix: Method List of a Nurtured Hello World Application

List of methods extracted from the nurtured Hello World application. This list includes all methods installed from the Pharo base libraries and the simple Hello World application.

Array class»new:
ArrayedCollection»size
Association class»key:value:
Association»value:
Association»value
BlockClosure»on:do:
BlockClosure»repeat
BlockClosure»valueNoContextSwitch
ByteString class»compare:with:collated:
ByteString class»findFirstInString:inSet:startingAt:
ByteString class»stringHash:initialHash:
ByteString»at:put:
ByteString»at:
ByteString»isByteString
ByteString»replaceFrom:to:with:startingAt:
ByteString»at:
ByteString»isByteString
ByteString»replaceFrom:to:with:startingAt:
ByteString»at:
ByteString»isByteString
ByteString»replaceFrom:to:with:startingAt:
ByteString»at:
ByteString»isByteString
ByteString»replaceFrom:to:with:startingAt:
ByteString»at:
ByteString»isByteString
ByteString»replaceFrom:to:with:startingAt:
Character class»cr
Character class»lf
Character class»value:
Character»=:
Character»asInteger
Character»asciiValue
Character»charCode
Collection»detect:ifNone:
Dictionary»at:ifAbsent:
Dictionary»at:ifPresent:
Dictionary»at:put:
Dictionary»noCheckAdd:
Dictionary»scanFor:
FileStream class»newForStdio
FileStream class»new
FileStream class»standardOutputStreamNamed:forWrite
FileStream class»startUp:
FileStream class»stdioHandles
FileStream class»stdoutCharacter
FileStream class»voidStdioFiles
FileStream»collectionSpeciesStandard
FileStream»enableReadBufferingSmalltalkImage
FileStream»isBinaryStandard
FileStream»next:putAll:startingAt:Standard
FileStream»nextPut:Standard
FileStream class»openOnHandle:name:forWrite:Standard
FileStream»primWrite:from:startingAt:count:Standard
GreekEnvironment class»supportedLanguages
HashTableSizes class»atLeast:
HashTableSizes class»sizes
HashedCollection class»newProto
HashedCollection»atNewIndex:put:
HashedCollection»findElementOrNil:
HashedCollection»fullCheck
HashedCollection»grow
HashCollection»initialize:
HashTableSizes class»atLeast:
HashTableSizes class»sizes
LanguageEnvironment class»currentPlatform
Locale class»currentPlatform
Locale class»determineCurrentLocale
Locale class»localeID:
Locale class»localeID:
Locale class»localeID:
Locale class»localeID:
Locale class»localeID:
Locale class»localeID:
B  Appendix: Entry Points to Tailor the Seaside Web Application

Entry points as used to tailor the Seaside web application with a full Pharo seed and an empty seed. The first one (Figure 3) only consists in starting the web server as the base libraries are initialized and available in the seed. The latter one (Figure 4) includes the initialization of the minimal runtime needed to do networking.

```smalltalk
ZnZincServerAdaptor startOn: 8888.
```

Figure 3: Entry point of the Seaside application with a full Pharo seed.

```smalltalk
"We initialize some classes of the system"
SmalltalkImage initializeForTornado.
Symbol initializeForTornado.
Object initialize.
ExternalSemaphoreTable initialize.
Socket initialize.
Delay initialize.
Delay startUp: true.
Delay shutDown: true.
OSPlatform initialize.
DiskStore initialize.
FileStream initialize.
NetNameResolver initialize.
DateAndTime initialize.
ProcessorScheduler initialize.
WeakFinalizationList initialize.
UUIDGenerator initialize.
WeakArray initialize.
GRPharoRandomProvider initialize.
WASlime initialize.
 UIManager basicDefault: DummyUIManager new.
 ZnServer initialize.
 WAServerManager initialize.
Smalltalk instVarNamed: 'session' put: Smalltalk newSessionObject.
Smalltalk startupImage: true snapshotWorked: true.

"Finally we start the web server"
ZnZincServerAdaptor startOn: 8888.
```

Figure 4: Entry point of the Seaside application with an empty seed.
Appendix: Method List of Seaside Counter Application with Full Pharo Seed

List of methods extracted from the nurtured Web application when using a seed containing all base libraries from Pharo. This list includes all methods installed from Seaside framework and the counter application. The list of methods part of the base library are excluded as it is the same list of the methods found in Pharo base library.

WAAccessIntervalReapingStrategy#defaultConfiguration
WAAccessIntervalReapingStrategy#initialize
WAAccessIntervalReapingStrategy#interval
WAAccessIntervalReapingStrategy#reap
WAAccessIntervalReapingStrategy#stored:key:
WAActionCallback#block:
WAActionCallback#evaluateWithArgument:
WAActionCallback#isEnabledFor:
WAActionCallback#signalRenderNotification
WAActionPhaseContinuation#continue
WAActionPhaseContinuation#handleRequest
WAActionPhaseContinuation#renderContext:
WAActionPhaseContinuation#runCallbacks
WAActionPhaseContinuation#shouldRedirect
WAAdmin class#defaultServerManager
WAAdmin class#serverAdaptors
WAAdmin class#defaultServerManager
WAAnchorTag#callback:
WAAnchorTag#tag
WAAnchorTag#url
WAAnchorTag#with:
WAApplication#contentType
WAApplication#doesHandlerSupportCookies:
WAApplication#handleDefault:
WAApplication#handleFiltered:
WAApplication#isApplication
WAApplication#isImplemented:
WAApplication#keyField
WAApplication#libraries
WAApplication#mainClass
WAApplication#mimeType
WAApplication#newSession
WAApplication#resourceBaseUrl
WAApplication#sessionClass
WAApplicationConfiguration#parents
WAAttributeSearchContext#class#key#target:
WAAttributeSearchContext#at#ifPresent:
WAAttributeSearchContext#at#ifPresent:
WAAttributeSearchContext#at#put:
WAAttributeSearchContext#attribute
WAAttributeSearchContext#cachedValues
WAAttributeSearchContext#findAttributeAndSelectAncestorsOf:
WAAttributeSearchContext#initializeWithKey:
WAAttributeSearchContext#isAttributeInheritedOn:
WAAttributeSearchContext#isAttributeLocalOn:
WABrush#initialize
WABrush#parent
WABrush#setParent:canvas:
WABrush#with:
WABufferedResponse#class#on:
WABufferedResponse#contents
WABufferedResponse#destroy
WABufferedResponse#initializeOn:
WABufferedResponse#stream
WACache#at#ifAbsent:
WACache#at#ifAbsent:
WACache#expiryPolicy
WACache#initializeCollections
WACache#initializeMutex
WACache#keyAtValue#ifAbsent:
WACache#keyAtValue:
WACache#keySize
WACache#missStrategy
WACache#notifyRemoved:key:
WACache#notifyRetrieved:key:
WACache#notifyStored:key:
WACache#pluginsDo:
WACache#reapingStrategy
WACache#reap
WACache#setExpirePolicy:
WACache#setMissStrategy:
WACache#setMissStrategy:
WACache#setReapingStrategy:
WACache#setRemovalAction:
WACache#store:
WACacheCapacityConfiguration#describeOn:
WACacheMissStrategy#missed:
WACachePlugin#configuration
WACachePlugin#defaultConfiguration
WACachePlugin#initialize
WACachePlugin#removed:key:
WACachePlugin#retrieved:key:
D Appendix: Method List of Seaside Counter Application with Empty Seed

List of methods extracted from the nurtured Web application when using an empty seed. This list includes all methods installed from Seaside framework, the Counter application and the base library of Pharo.

Array class»new:
Array•isSelfEvaluating
Array•printOn:
Array•replaceFrom:to:with:startingAt:
Array•shouldBePrintedAsLiteral
ArrayedCollection class»new:withAll:
ArrayedCollection class»new
ArrayedCollection class•with:with:with:
ArrayedCollection class•with:with:
ArrayedCollection class•with:
ArrayedCollection class•mergeSortFrom:to:by:
ArrayedCollection•size
ArrayedCollection•sort:
Association class•key:value:
Association class•key:value:
Association•expireWeakKey
Association•expiredWeakKey
Association•key:WeakKey
Association•key:value:WeakKey
Association•keyWeakKey
Association•value:WeakKey
Association•value:
Association•valueWeakKey
Association•value
BlockClosure•argumentCount
BlockClosure•asContextWithSender:
BlockClosure•asContext
BlockClosure•assert
BlockClosure•cull:
BlockClosure•ensure:
BlockClosure•fixCallbackTemps
BlockClosure•forkAt:named:
BlockClosure•forkAt:
BlockClosure•ifCurtailed:
BlockClosure•ifError:
BlockClosure•isClosure
BlockClosure•newProcess
BlockClosure•numArgs
BlockClosure•numCopiedValues
BlockClosure•on:kernel:
BlockClosure•on:fork:
BlockClosure•outerContext

System extension on Pharo:
ByteArray class
CNGTextConverter class
CP1250TextConverter class
CP1253TextConverter class
ChangesLog class
Character class

15
Character class = space
Character class = value:
Character =
Character asCharacter
Character asInteger
Character asSymbol
Character asUppercase
Character asciiValue
Character charCode
Character characterSet
Character codePoint
Character digitValue
Character greaseInteger
Character isAlphaNumeric
Character isCharacter
Character isDigit
Character isLetter
Character isOctetCharacter
Character isSeparator
Character isVowel
Character leadingChar
Character to:
Collection class = withAll:
Collection = addAll:
Collection allSatisfy:
Collection anySatisfy:
Collection asArray
Collection detect: ifNone:
Collection emptyCheck
Collection inject: into:
Collection isCollection
Collection isEmptyOrNil
Collection isNotEmpty
Collection noneSatisfy:
Collection notEmpty
Collection printElementsOn:
Collection printNameOn:
Collection printOn:
Collection removeAll:
Collection removeAllFoundIn:
Collection sorted:
Collection sorted
CommandLineUIManager class = replacing:
CommandLineUIManager = initialize
CommandLineUIManager = replacing:
CompiledMethod = frameSize
CompiledMethod = objectAt:
CompiledMethod = primitive
CompiledMethod = replacing:
CompiledMethod = step
CompiledMethod = stepToCallee
CompiledMethod = terminate
CompiledMethod = terminateTo:
CompiledMethod = initialPC
CompiledMethod = isPrimitive
CompiledMethod = numLiterals
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<th>Float</th>
<th>GRSmallDictionary class BlasioAll</th>
</tr>
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<tbody>
<tr>
<td>Fraction numerator: denominator:</td>
<td>HashTableSizes class BlasioAtLeast:</td>
</tr>
<tr>
<td>Fraction &gt;=</td>
<td>HashTableSizes class BlasioSizes</td>
</tr>
<tr>
<td>Fraction reduced</td>
<td>HashedCollection class BlasioNew:</td>
</tr>
<tr>
<td>Fraction numerator: denominator:</td>
<td>HashedCollection class BlasioNewFor:</td>
</tr>
<tr>
<td>Fraction truncated</td>
<td>HashedCollection BlasioArray</td>
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<tr>
<td>GRCodecStream class on:</td>
<td>HashedCollection BlasioAtEnd:</td>
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<td>GRCodecStream atEnd</td>
<td>HashedCollection BlasioFindElementOrNil:</td>
</tr>
<tr>
<td>GRNullCodec class codecName</td>
<td>HashedCollection BlasioFullCheck</td>
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<td>GRNullCodec class supportsEncoding:</td>
<td>HashedCollection BlasioGrow:</td>
</tr>
<tr>
<td>GRNullCodec encoderFor:</td>
<td>HashedCollection BlasioInitialize:</td>
</tr>
<tr>
<td>GRNullCodec url</td>
<td>HashedCollection BlasioSize</td>
</tr>
<tr>
<td>GRNullCodecStream nextPutAll:</td>
<td>Heap class BlasioWithAll:sortBlock:</td>
</tr>
<tr>
<td>GRObject class new</td>
<td>Heap BlasioAdd:</td>
</tr>
<tr>
<td>GRObject initialize</td>
<td>Heap BlasioDo:</td>
</tr>
<tr>
<td>GROrderedMultiMap allAt:</td>
<td>Heap BlasioDownHeapSingle:</td>
</tr>
<tr>
<td>GROrderedMultiMap at: add:</td>
<td>Heap BlasioGrowHeap:reSort</td>
</tr>
<tr>
<td>GRPharoConverterCodecStream class on: converterHeap BlasioGrowSize</td>
<td></td>
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<tr>
<td>GRPharoConverterCodecStream contents</td>
<td>Heap BlasioGrowTo:</td>
</tr>
<tr>
<td>GRPharoConverterCodecStream initializeOn: converterHeap BlasioIsEmpty</td>
<td></td>
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<tr>
<td>GRPharoConverterCodecStream size</td>
<td>Heap BlasioPrivateRemoveAt:</td>
</tr>
<tr>
<td>GRPharoGenericCodec class supportedEncodingNa</td>
<td>Heap BlasioRemove:ifAbsent:</td>
</tr>
<tr>
<td>GRPharoGenericCodec class supportsEncoding</td>
<td>Heap BlasioRemoveFirst</td>
</tr>
<tr>
<td>GRPharoLatin1Codec class supportedEncodingNames</td>
<td>Heap BlasioSetCollection:tally:</td>
</tr>
<tr>
<td>GRPharoLatin1Codec class supportsEncoding</td>
<td>Heap BlasioSize</td>
</tr>
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<td>GRPharoPlatform addToShutDownList:</td>
<td>Heap BlasioSortBlock:</td>
</tr>
<tr>
<td>GRPharoPlatform addToStartUpList:</td>
<td>Heap BlasioSorts:before:</td>
</tr>
<tr>
<td>GRPharoPlatform includesUnsafeUrlCharacter:</td>
<td>Heap BlasioUpHeap:</td>
</tr>
<tr>
<td>GRPharoPlatform includesUnsafeXmlCharacter:</td>
<td>Heap BlasioUpdateObjectIndex:</td>
</tr>
<tr>
<td>GRPharoPlatform semaphoreClass</td>
<td>ISO885915TextConverter class encodingNames</td>
</tr>
<tr>
<td>GRPharoRandomProvider class initialize</td>
<td>ISO88592TextConverter class encodingNames</td>
</tr>
<tr>
<td>GRPharoRandomProvider class nextInt:</td>
<td>InstructionStream:interpretExtension:in:for:</td>
</tr>
<tr>
<td>GRPharoRandomProvider class randomClass</td>
<td>InstructionStream:interpretNextInstructionFor:</td>
</tr>
<tr>
<td>GRPharoUtf8Codec class basicForEncoding:</td>
<td>Integer class BlasioReadFrom:base:</td>
</tr>
<tr>
<td>GRPharoUtf8Codec class supportsEncoding</td>
<td>Integer class BlasioReadFrom:</td>
</tr>
<tr>
<td>GRPharoUtf8Codec decode:</td>
<td>Integer *=</td>
</tr>
<tr>
<td>GRPharoUtf8Codec decoderFor:</td>
<td>Integer +=</td>
</tr>
<tr>
<td>GRPharoUtf8Codec encoderFor:</td>
<td>Integer -=</td>
</tr>
<tr>
<td>GRPharoUtf8Codec name</td>
<td>Integer ==</td>
</tr>
<tr>
<td>GRPharoUtf8Codec url</td>
<td>Integer ==</td>
</tr>
<tr>
<td>GRPharoUtf8CodecStream encodeFast:</td>
<td>Integer BlasioAsCharacter</td>
</tr>
<tr>
<td>GRPharoUtf8CodecStream next:</td>
<td>Integer BlasioAsInteger</td>
</tr>
<tr>
<td>GRPharoUtf8CodecStream nextPut:</td>
<td>Integer BlasioCopyto:</td>
</tr>
<tr>
<td>GRPharoUtf8CodecStream nextPutAll:</td>
<td>Integer BlasioDenominator</td>
</tr>
<tr>
<td>GRPlatform class current</td>
<td>Integer BlasioDigitCompare:</td>
</tr>
<tr>
<td>GRPlatform reducedConflictDictionary</td>
<td>Integer BlasioDigitDiv:neg:</td>
</tr>
<tr>
<td>GRSmallDictionary class new:</td>
<td>Integer BlasioDigitMultiply:neg:</td>
</tr>
<tr>
<td>GRSmallDictionary class new</td>
<td>Integer BlasioDigitSubtract:</td>
</tr>
</tbody>
</table>
WAResponse»status
WAResponseGenerator class: on: ShiftJIS
WAResponseGenerator class: initializeOn:
WAResponseGenerator: notFound
WAResponseGenerator»requestContext
WAResponseGenerator: request
WAResponseGenerator»respond
WAResponseGenerator»requestContext
WAResponseGenerator»response
WARoot class: context:
WARoot»setContext:
WAScriptGenerator: initialize
WAScriptGenerator: loadScripts
WAScriptGenerator: writeLoadScriptsOn:
WAScriptGenerator: writeScriptTagOn:
WAServerAdaptor class: defaultSmall
WAServerAdaptor class: manager:
WAServerAdaptor class: new
WAServerAdaptor class: port:
WAServerAdaptor class: startOn:
WAServerAdaptor: codec
WAServerAdaptor: contextFor:
WAServerAdaptor: defaultPort
WAServerAdaptor: defaultRequestHandler
WAServerAdaptor: handle:
WAServerAdaptor: handlePadding:
WAServerAdaptor: handleRequest:
WAServerAdaptor: initializeWithManager:
WAServerAdaptor: initialize
WAServerAdaptor: manager
WAServerAdaptor: port:
WAServerAdaptor: port
WAServerAdaptor: process:
WAServerAdaptor: requestFor:
WAServerAdaptor»request: requestHandler
WAServerManager class: default
WAServerManager class: initialize
WAServerManager class: shutDown
WAServerManager class: startUp
WAServerManager: register:
WASession»actionField
WASession»canStart:
WASession»initialize:
WASession»application
WASession: clearJumpTo
WASession»createCache