Towards Maintainer Script Modernization in FOSS Distributions[*]

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ABSTRACT

Free and Open Source Software (FOSS) distributions are complex software systems, made of thousands *packages* that evolve rapidly, independently, and without centralized coordination. During packages *upgrades*, corner case failures can be encountered and are hard to deal with, especially when they are due to misbehaving *maintainer scripts*: executable code snippets used to finalize package configuration.

In this paper we report a software modernization experience, the process of representing existing legacy systems in terms of models, applied to FOSS distributions. We present a process to define meta-models that enable dealing with upgrade failures and help rolling back from them, taking into account maintainer scripts. The process has been applied to widely used FOSS distributions and we report about such experiences.

Categories and Subject Descriptors

D.2.10 [**Software Engineering**]: Design; I.6.5 [**Model Development**]: Modeling Methodologies; D.2.13 [**Software Engineering**]: Reusable Software—*Domain engineering*

General Terms

Languages, management, reliability

Keywords

FOSS, model-driven engineering software modernization

1. INTRODUCTION

Free and Open Source Software (FOSS) distributions, as well as other complex systems, provide their software components in "packaged" form. Packages, available from remote repositories, are installed and removed on local machines by means of *package manager* applications, such as APT [20] or Apache Maven [1]. Package managers are responsible of both finding suitable upgrade strategies by solving dependencies and conflicts among packages, and of actually deploying the involved packages on the filesystem, possibly aborting the operation if problems are encountered.

During the installation and removal of a package, additional actions are required in order to finalize the component within the overall system configuration. Such actions are usually delegated to executable *maintainer scripts*, contained in the packages. Maintainer scripts are written in fully general POSIX shell script that makes very hard, impossible in the general case, to predict a priori their side-effects which can affect the entire system. As a consequence, a satisfactory solution able to deal with automatic recovery of faults caused by misbehaving maintainer scripts is still missing [8].

Model Driven Engineering (MDE) [3] can be crucial to improve the management of system configurations since models can make explicit dependencies and effects that are naturally implicit. Representing a FOSS installation with models paves the way to two different kinds of support to upgrade management:

1. *dry run* simulation of upgrades, looking for inconsistent configurations induced by misbehaving maintainer scripts or otherwise buggy packages;
2. fine-grained *logging* of actions executed on the real installation during package deployment; the obtained log can then be used to better drive downstream rollback mechanisms.

A model is obviously an abstraction of the reality. In modeling it is of crucial importance the level of abstraction taken into account. On one side we have to abstract away many details in order to have tractable models, on the other side the models must be able to effectively present relevant maintainer scripts. This paper faces with the precise problem of *modernize* maintainer scripts focusing on *software modernization* of FOSS installations and in particular of maintainer scripts. The idea of renewing legacy systems by means of model driven approaches has been pursued by the Object Management Group (OMG) since 2003. In particular, OMG defined the Architecture-Driven Modernization (ADM) task force [21] to support software modernization of existing assets which are imported into MDE enabled development environments.

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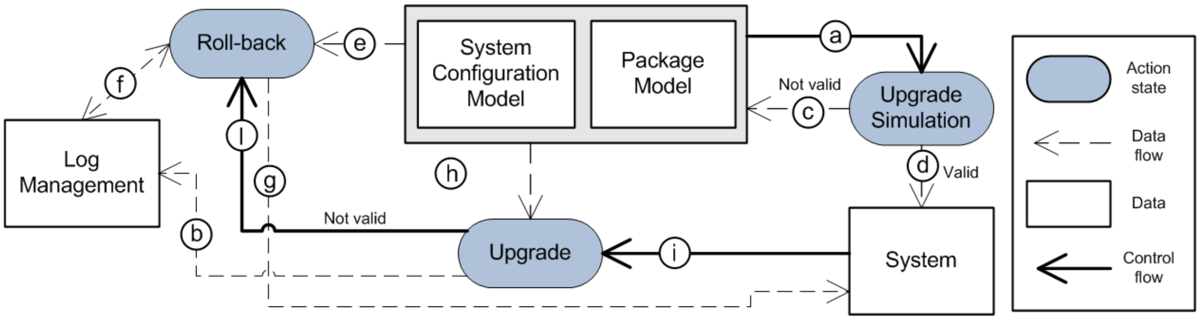


Figure 1: Model-driven approach to manage system configuration proposed

In this paper, we analyze the domain of package-based FOSS distributions and formalize as meta-models installations, for the purpose of upgrade simulation and logging. In particular we highlight the analysis of maintainer scripts that has been conducted for the Debian GNU/Linux and for some RPM-based distributions. The resulting metamodels underpin the extraction process (also called *injection*) of models from existing FOSS distributions enabling the application of model-driven techniques and tools.

Paper structure.

We begin by providing necessary details about FOSS distributions in Section 2. Section 3 outlines the model-driven approach to deal with upgrade simulation and logging. Section 4 describes the analysis of maintainer scripts on real-life distributions, while Section 5 describes the specification of sample real maintainer scripts by using the defined modeling constructs. Section 6 presents related works and Section 7 concludes the paper by describing perspective work.

2. FOSS DISTRIBUTIONS

Overall, the architectures of all FOSS distributions are quite similar. Each user machine, i.e., a distribution *installation*, has a local *package status* recording which packages are locally installed and which are available from remote distribution repositories. In an *upgrade scenario* the system administrator requests a change of the package status (e.g., install, remove, upgrade to a newer version) by the mean of a package manager, which is in charge of finding a suitable *upgrade plan*. More precisely, the package manager solves dependencies and conflicts, retrieves packages from remote repositories as needed, and deploys individual packages on the filesystem, possibly aborting the operation if problems are encountered along the way.

A *package* is usually a bundle of three main parts:

Files the set of files and directories shipped within the package for installation: executable binaries, data, documentation, etc. *Configuration files* is the subset of files affecting the runtime behavior of the package and meant to be locally customized by the system administrator. Proper internalization of configuration file details is relevant for our purposes, as specific configurations can (implicitly) entail dependencies not otherwise declared by the involved packages (see Section 5 for an example).

Meta-information contains package-related information such as: a unique identifier, software version, maintainer and package description, and most notably *inter-package relationships*. The kinds of relationships vary with the distribution, but a common core subset includes: dependencies (the need of other packages to work properly), conflicts (the inability of being co-installed with other packages), feature provisions (the ability to declare named features as provided by a given package, so that other packages can depend on them), and restricted boolean combinations of them [12].

Maintainer scripts are a set of programs, usually written in shell script, that are used to enable maintainers to attach actions to hooks that are fired by the installer. Which hooks are available depends on the installer; `dpkg` offers one of the most comprehensive set of hooks: pre/post-unpacking, pre/post-removal, and upgrade/downgrade to specific versions [15]. Maintainer scripts are challenging objects to model, both for its semantics (shell script is a full-fledged, Turing-complete programming language) and for its syntax which enjoys a plethora of meta-syntactic facilities (here-doc syntax, interpolation, etc.).

During package deployment, various kinds of failures can be induced by maintainer scripts. The “simplest” example is a runtime failure of a script (usually detected by a non-zero exit code), against which system administrator are left helpless beside their shell script debugging abilities. A more subtle, though possibly easier to deal with, kind of failure are inconsistent configurations left over by upgrade scenario not predicted by maintainers. For instance: a maintainer script can “forget” to un-register a plugin from its main application while removing the package shipping the plugin, hence living around an inconsistent configuration (which might, or might not, cause execution failures in the main application).

Our aim is to develop meta-models able to grasp the details of FOSS installations for the purpose of preemptive discovery of both kind of upgrade failures. Also, in those cases where simulation is not enough to detect failures, we want our meta-models to be able to equip runtime execution of scripts with detailed execution logs. Those execution logs can then be offered to state of the art roll-back mechanisms (see Section 6 and [8]).

3. MODEL-BASED UPGRADE

The problem of maintaining FOSS installations is far from trivial and has not yet been addressed properly [8]. One of the main reason is that package managers are aware only of package meta-information (and in particular on inter-package relationships), which are not expressive enough. As a consequence, package managers are not enough to detect and manage several upgrade failure scenarios.

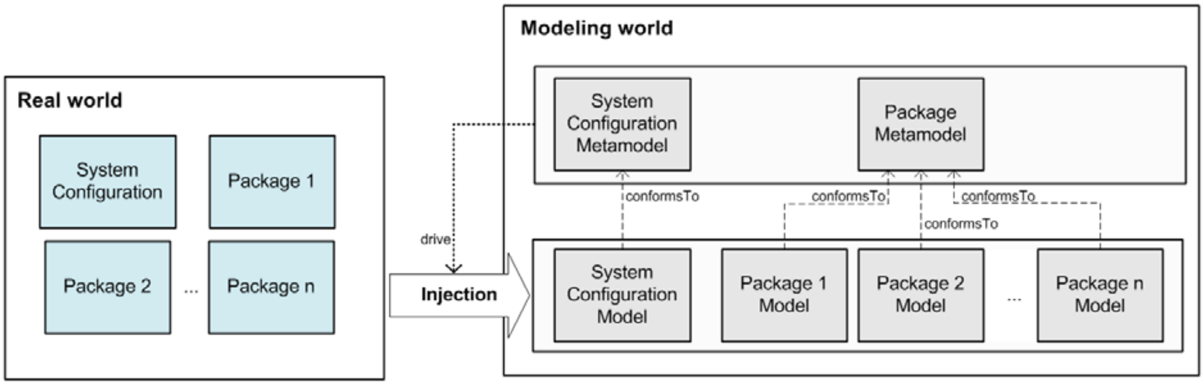


Figure 2: Model injection

Recently, in the context of the Mancoosi[1] project, a model-driven approach has been proposed [5] to improve upon that, by equipping package managers with model of the hosting FOSS installation. Equipped with that, package managers can both simulate upgrades (trying to detect configuration inconsistencies) and, during deployment on the real system, create a more detailed log of script executions that can be used later on to pinpoint upgrade roll-back mechanism to the precise point where the failure occurred during deployment.

The proposed approach is then firstly based on *upgrade run simulation*; the simulation takes into account two models (see Figure 1): the *System Configuration Model* and the *Package Model* (see the arrow ⓐ). The former describes the state of a given system in terms of installed packages, running services, configuration files, etc. The latter provides information about the packages involved in the upgrade in terms of inter-package relationships. Since a trustworthy simulation has to consider the behavior of the maintainer scripts which are executed during the package upgrades, the package model also specifies an abstraction of them and of their behavior.

There are two possible simulation outcomes: *not valid* and *valid* (see the arrows ⓒ and ⓓ, respectively). In the former case it is expected that the upgrade on the real system will fail. Thus, before proceeding with it the problem spotted by the simulation should be fixed. In the latter case—*valid*—the upgrade on the real system can be operated (see the arrow ⓘ). However, since the models are an abstraction of the reality, upgrade failures might occur due to reasons like I/O errors or by maintainer scripts features unaccounted for in the modeling. During package upgrades *Log Models* are produced to store all the transitions between configurations (see arrow ⓑ). The information contained in the system, package, and log models (arrows ⓔ and ⓕ) can then be used in case of failures (arrow ⓛ) when the performed changes have to be undone to bring the system back to the previous valid configuration (arrow ⓖ).

In order to apply on real scenario the approach depicted in Figure 1, existing systems have to be represented in terms of models. In this respect, the availability of *injectors* is crucial since they are tools that transform software artifacts into corresponding models in an automatic way. In particular, as shown in Figure 2, given a real software system and a set of packages a corresponding representation in the modeling world has to be obtained. Since it is not possible to specify in detail every single part of systems and packages, trade-offs between model completeness and usefulness have been evaluated. In this respect, models are specified by using modeling constructs which are formalized in specific metamodels (see Section 3.1) that have been conceived during a domain analysis phase (see Section 4).

Over the last years, several approaches for extracting models from software artifacts have been proposed even though the optimal solution which can be used for any situation does not exist yet [16]. The complexity of the problem relies on the limitation of current lexical tools which do not provide the proper abstractions and constructs to query code and generate models with respect to given metamodels. Some approaches like [25, 13] focus on generating metamodels from grammars but they have some drawbacks that may restrict its usefulness, such as the poor quality of the automatically generated metamodel [16]. Approaches like [17] enable the automatic generation of injectors starting from annotated metamodels with syntactic properties. However, they do not permit reuse of existing grammars written for well-known parser generators. Techniques like [16] propose specific languages to query software artifacts and generate models according to specified source-to-model transformation rules.

Several projects are under development to provide tools and methodologies for model-driven modernization and model injection. For instance, MoDisco [11] defines an infrastructure for supporting model-driven reverse engineering by relying on the concept of *discoverer* which is a piece of software in charge of analyzing part of an existing system and extracting a model using the MoDisco's infrastructure.

3.1 FOSS distributions metamodels

The metamodels which underpin the model based approach depicted in Figure 1 have been defined according to an iterative process consisting of two main steps: *a)* elicitation of new concepts from the domain to the metamodel; and *b)* validation of the formalization of the concepts by describing part of real systems. The metamodels which have been defined are as follows:

- the *System Configuration metamodel*, which contains all the modeling constructs necessary to make the FOSS system able to perform its intended functions. In par-

[1] `http://www.mancoosi.org`

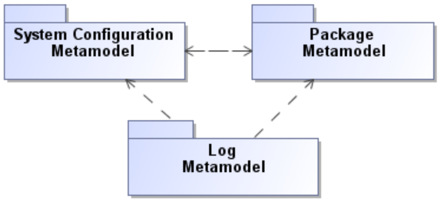


Figure 3: Dependencies among metamodels

ticular it specifies installed packages, configuration files, services, filesystem state, loaded modules, shared libraries, running processes, etc. The system configuration metamodel takes into account the possible dependency between the configuration of an installed package and other package configurations. The ability to express such fine-grained and installation-specific dependencies is a significant advantage offered by the proposed metamodels which embody domain concepts which are not taken into account by current package manager tools;

- the *Package metamodel*, which describes the relevant elements making up a software package. The metamodel also gives the possibility to specify the maintainer script behaviors which are currently ignored—beside mere execution—by existing package managers;
- the *Log metamodel*, which is based on the concept of transactions that represent a set of statements that change the system configurations. Transitions can be considered as model transformations [3] which let a configuration C_1 evolve into a configuration C_2.

Log models play a key role for both *preference roll-back* and *"live" failures.* The former takes place when a user wants to recover a previous configuration, for whatever (even non-functional) reason. Note that the log models provide information useful to roll-back to any previous valid configuration, not necessary a contiguous one. The latter happens when undetected failures are encountered while deploying upgrades on the real system. In such a case, the information stored in the log model are exploited to retrieve the fallacious statements and provide hints on how to roll-back to the configuration from which the broken transaction has started.
As shown in Figure 3, *System Configuration* and *Package* metamodels have mutual dependencies, whereas the *Log* metamodel has only direct relations with both *System Configuration* and *Package* metamodels. For a detailed description of the metamodels, please refer to [5, 9].

The first step that needs to be performed when defining a metamodel is to accurately study the domain in order to understand the elements and the artifacts that need to be modeled as presented in the next section.

4. MAINTAINER SCRIPTS ANALYSIS

The metamodels outlined in Section 3.1 have been obtained though a suitable domain analysis study. The most difficult part of this analysis process is the study of the maintainer scripts. The adopted scripting languages are mainly POSIX shell but they are written also in Perl [24], Bash [23], etc. Scripting languages have rarely been formally investigated and with no exciting results [26, 18], thus posing additional difficulties in understanding their side-effects which can spread throughout the whole (file)system. Our aim is to describe the most common macro-actions of maintainer scripts in terms of models which abstract from the real system, but are expressive enough to grasp several of their effects on package upgrades. The analysis phase is then extremely important in order to find the right trade-off between expressiveness and abstraction.

Due to the large amount of scripts to consider (e.g., about 25·000 on Debian Lenny, see Section 4.1), we tried to collect them in clusters to be able to concentrate the analysis on representatives of the equivalence classes identified. The adopted procedure for clustering has been as follows:

1. *Collect all maintainer scripts* of a given distribution. By not choosing a random subset we are sure to have collected the most representative set of scripts;
2. *Identify scripts generated from helper tools.* A large number of scripts or part of them is generated by means of "helper" tools that provide a collection of small, simple and easily understood tools that are used to automate various common aspects of building a package. Since (part of) maintainer scripts are automatically generated using these helpers and their boiler plates, we can concentrate the analysis on the helpers themselves, rather than on the result of their usage;
3. *Ignore inert script parts.* As all scripting languages, shell scripts contain parts which do not affect their computational state such as blank lines or comments. Intertwined with the removal of generated parts (to be analyzed later on) we have systematically ignored inert script parts, possibly leading upon removal to empty scripts that have been therefore ignored as a whole;
4. *Study of scripts written "by hand".* The remaining scripts need to be more carefully studied, as they have been written from scratch by package maintainers to address a specific need, most likely not covered by any helper tool. Actually we worked on identifying further recurrent templates that maintainers use when writing the scripts.

In the remainder of this section we present the result of the analysis performed on two representative FOSS distributions: Debian GNU/Linux and an RPM-based distribution. Note that due to space restrictions we cannot report all the details, but the interested reader can refer to [9].

4.1 Debian GNU/Linux

The analysis has been performed considering a "snapshot" of Debian *Lenny*, the just released "stable" brand of Debian. The snapshot has been taken on December 4th, 2008, considering only the `amd64` architecture (soon to become the most widespread architecture on end-user machines), and all the packages shipped by the Debian archive and targeted at the end user (i.e., sections `main`, `contrib`, and `non-free`). Each (binary) package[2] in Debian can come with 5 different kinds of maintainer scripts:

[2] From now on, unless otherwise stated, we will use the term "package" to refer to binary packages.

Group	Occurrences	Representative script name
G1	93	libk/libkpathsea4_2007.dfsg.2-4_amd64.deb.preinst
G2	54	d/dict-freedict-swe-eng_1.3-4_all.deb.postinst
G3	54	d/dict-freedict-fra-deu_1.3-4_all.deb.postrm
G4	35	j/jabber-jud_0.5-3+b1_amd64.deb.preinst
G5	35	g/gauche-c-wrapper_0.5.4-2_amd64.deb.postinst
G6	33	w/wogerman_2-25_all.deb.config
G7	31	m/mii-diag_2.11-2_amd64.deb.prerm
G8	30	libs/libsocket6-perl_0.20-1_amd64.deb.postrm
. . .	. . .	. . .

Table 1: Excerpt of the obtained groups

1. `preinst` (mnemonic for "pre-installation") scripts that are run before the files shipped by a package being installed have been unpacked on the filesystem of the target machine;

2. `postinst` (mnemonic for "post-installation") scripts that are run after the files shipped by a package have been unpacked on the target filesystem;

3. `prerm` (mnemonic for "pre-removal script") scripts that are executed just before removing from the target filesystem those files which belong to the package which is being removed;

4. `postrm` (mnemonic for "post-removal") scripts that are executed just after removing the files belonging to the package being removed from the filesystem;

5. `config` (mnemonic for "configuration") scripts that are used to configure a software which requires specific user input to be configured.

Considering 5 maintainer scripts per package we obtain a potential universe of scripts to be considered of 114˙115 scripts (i.e., 22˙823 × 5). Luckily, 88˙675 (77.7%) of those are actually missing from the corresponding packages. This means that the remaining actual script universe which need to be analyzed consists of "just" 25˙440 scripts (22.3% of 114˙115).

4.1.1 Scripts generated from helpers

Package maintainers use complex toolchains to facilitate their maintenance work which is otherwise prone to repetition of self-similar tasks. In Debian, the legacy helpers used to generate maintainer script snippets is the `debhelper` collection [7]. For the most part, it consists of tools which are invoked at package build time to automate package-construction tasks such as installing specific file categories (e.g., manual pages, documentation, etc.) in the location prescribed by the Debian policy [15]. Instead of requiring each maintainer to write exactly the same shell script snippets by hand, `debhelper` also offers a template mechanism called "autoscripts" which writes down the needed snippets when needed. To our ends, this means that we can restrict our analysis to the templates themselves, because they are either verbatim copied in the resulting scripts or, in the worst case scenario, filled using simple textual "holes" such as the current package names.

We extracted from `debhelper` autoscripts templates, which amount to 52 templates in total [9]. Each of those templates contains statements that are executed as a whole. For instance, in Listing 1 a sample template is reported. It consists of statements which are executed after the removal of the GNOME configuration tool [3].

Listing 1: Sample tamplate

```
if [ "$1" = purge ]; then
    OLD_DIR=/etc/gconf/schemas
    SCHEMA_FILES="#SCHEMAS#"
    if [ -d $OLD_DIR ]; then
        for SCHEMA in $SCHEMA_FILES; do
            rm -f $OLD_DIR/$SCHEMA
        done
        rmdir -p --ignore-fail-on-non-empty
            ↪$OLD_DIR
    fi
fi
```

All the recurrent templates like the one in Listing 1 are formalized in the metamodel [9]. In this way maintainers, which are used to write scripts by means of `debhelper` and the previously identified templates, will find familiar and meaningful statements in the metamodel.

When the maintainer needs to add specific code to maintainer scripts, code which is not provided by autoscript templates, `debhelper` enables mixing generated lines with lines written by hand. All generated lines are tagged with specially-crafted comments, so that they are recognizable mechanically.

Starting from the non-empty maintainer scripts extracted from Lenny (summing up to 25˙440 scripts), we analyzed how many of them are *entirely* composed by lines generated using the autoscript mechanism. Also, we produced a "filtered" version of all the remaining maintainer scripts (i.e., those that contain at least *some* line written by hand by the package maintainer) which has been analyzed later on in more details. The summary of generated (part of) maintainer scripts is as follows:

	n. of scripts	*lines of code (LOCs)*
non-blank	25˙440 (100%)	386˙688 (100%)
generated	16˙348 (64.3%)	162˙074 (41.9%)
by hand	9˙061 (35.6%)	224˙614 (58.1%)

About 2/3 of all the maintainer scripts are composed only of lines generated using the autoscript mechanism.

[3] GNOME: The Free Software Desktop Project - `http://http:www.gnome.org`

4.1.2 Analysis of scripts “by hand”

The scripts that survived to the previous phases are 9˙061. These scripts have been analyzed “by hand”. The idea of that final analysis is to find additional templates or additional statements that should be considered when defining the metamodel. The analysis “by hand” has been performed as follows:

Template	Occurrences	Origin Group
Template1	97	G1
Template2	69	G14
...	...	...

Table 2: Excerpt of the occurrences of the Templates

1. All the scripts that survived to the previous pruning phases are clustered in groups, where a group collects scripts that contain exactly the same statements. For each group we then selected one representative. Table 1 shows an excerpt of the groups that we identified, ordered by occurrence. The second column shows the occurrences while the third column contains the name of the script representative of the group. By referring to Table 1, group G1 consists of 92 scripts which are identical to the `libk/libkpathsea4_2007.dfsg.2-4_amd64.deb.preinst` script and then this script identifies a potential template;

2. The next step consists in identifying the occurrence of the identified templates in the collection of 9˙061 scripts. For instance the occurrence of *Template1* is 97 and refers to group *G1* of Table 1. Table 2 shows an excerpt of the template occurrences. More precisely, the first column contains the elicited templates and the second one their occurrences. Last column refers to the groups which originated the considered templates;

3. Once templates have been identified (we identified 116 templates) together with their occurrences, the next step consists of identifying similarities among templates in order to collect them in classes. In fact, we recall that the occurrences are calculated with exact matching and that a white space can also compromise the matching. We found 10 classes that collect 1˙340 scripts;

4. The next step consists in analyzing each class in order to understand how to deal with this kind of scripts. In other words, we have to understand whether the already identified statements are sufficient or whether new statements are required;

5. The last step has been the analysis of scripts “by hand” with occurrence 1 in order to understand whether they are already covered or whether they contain statements that we are not able to deal with. In this last step we analyzed other 43 scripts.

Summarizing the entire process, the total amount of considered packages is 22˙823. Considering 5 maintainer scripts per package we obtain a (potential) universe of 114˙115 scripts (i.e., 22˙823 × 5). Luckily, 88˙675 (77.7%) of those are actually missing from the corresponding packages. The universe of the remaining scripts consists of 25˙440 scripts (22.3%). The analysis covered approximatively the 66% of the existing 25˙440 scripts and the 93% of the universe of 114˙115 potential scripts.

4.2 RPM-based distributions

RPM (RPM Package Manager) is one of the most common software package manager used within FOSS distributions. Although RPM was originally designed to work with Red Hat Linux, it is nowadays used in several other distributions, such as Mandriva, Fedora, and Suse.

The `spec` [2] file plays the main role in the RPM package build process. In fact, such file contains all the information required to (i) compile the program and build source and binary packages, and (ii) install and uninstall the program on the target machine. The `spec` file is divided in several sections and each section is denoted by a corresponding keyword like `%pre`.

Since we are interested in installation and removal aspects, we focus only on the RPM sections that are involved: *Install* and *Uninstall* scripts section. Similarly to Debian, in the RPM format there are four kind of scripts (`%pre`, `%post`, `%preun`, and `%postun`) each of them meant to be executed at different stages of the package upgrade process.

It is not very common having RPM packages that require actions to be performed prior to installation. In fact none of the 350 packages that comprise Red Hat Linux 4.0 makes use of `%pre` scripts. A typical example of `%post` script (which is executed after installation) consists of the `ldconfig` command which updates the list of available shared libraries after a new one has been installed. If a package uses a `%post` script to perform some function, quite often it will include a `%postun` script that performs the inverse of the `%post` script, after the package has been removed.

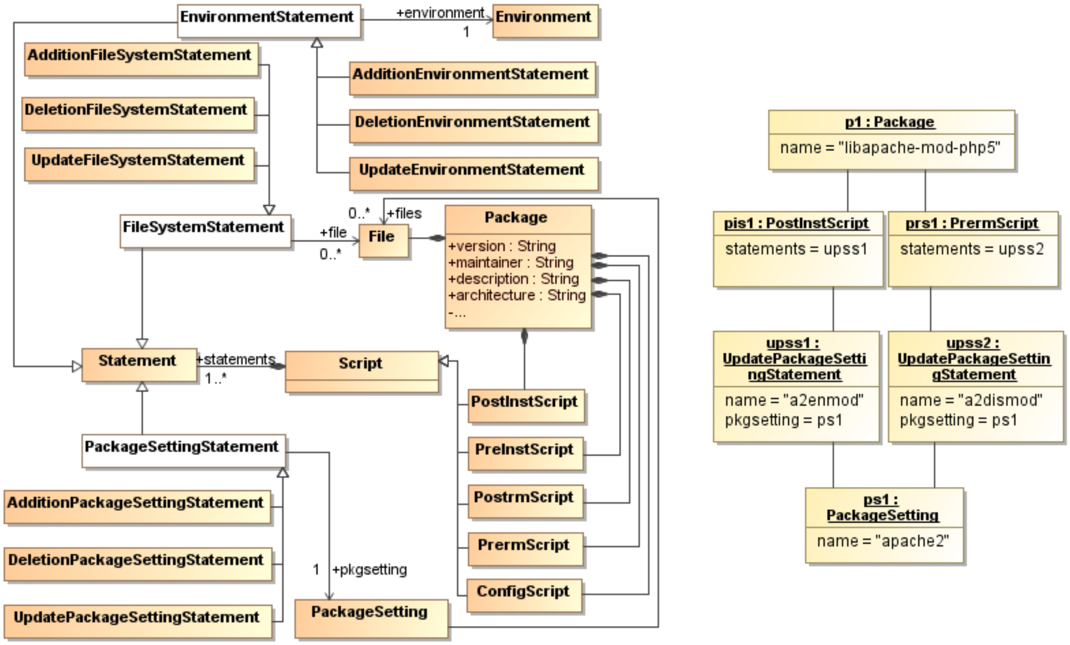
The scripts which are executed before removing packages (`%preun`) are used to prepare the system immediately prior the package deletion. Specularly, `%postun` is executed after package deletions. Quite often, `%postun` scripts are used to run `ldconfig` to remove newly erased shared libraries from `ld.so.cache`. As highlighted before, these scripts typically do the inverse of `%post` ones (which might happen to be the same action, as with `ldconfig`, when it simply consists in updating some sort of cache/registry).

Similarly to Debian, Fedora,[4] an RPM-based Linux distribution, also makes use of templates for the maintainer scripts[5]. Such templates, called autoscripts, are reported in [9]. The `spec` files of the Fedora distribution we have considered can be downloaded at `http://svn.rpmforge.net/svn/trunk/rpms/`. The available `spec` files are 4˙704, and considering that each of them can contain four kinds of scripts, the potential universe that has to be analyzed consists of 4˙704*4=18˙816 scripts. Actually, the scripts that are present in this set are 2˙038, that is approximately 10.8% of 18˙816. These scripts are divided as follows: 81 %`pre`, 911 %`post`, 234 %`preun`, and 812 %`postun`. We extracted the four kinds of scripts from each spec file and, in order to make the analysis, we created four new files containing the scripts.

Unfortunately, in this case we are not able to identify scripts that are generated from helpers, since there is no marking that helps in identifying the generated parts. For

[4] Fedora Project Web site: `http://fedoraproject.org`

[5] Fedora scriptlet snippets: `http://fedoraproject.org/wiki/Packaging/ScriptletSnippets`



a) Fragment of the Package metamodel

b) Sample Package model

Figure 4: Package specification

this reason, we performed analysis "by hand", similarly to what is described for Debian. Then, all the scripts are clustered in groups, where a group collects scripts that contain exactly the same statements. For each group we then selected one representative.

From this first analysis we can say that more than 50% of the scripts can be generated by templates. Once the scripts previously identified have been deleted, we continued the analysis, the next step being to use the identified templates in order to check their matches as part of the code of a script. Since the matches are always exact, we performed another step of analysis. We then manually inspected the scripts and manually identified the match. Thus, we defined other templates that complement the already defined templates.

To summarize, this analysis demonstrates that, by means of templates, 1˙962 scripts among the 2˙038 that constitute our universe of scripts can be automatically generated for sure (∼93,6%). Please also remember that the "potential" amount of scripts, as described at the beginning of this section, is the number of spec files multiplied by 4 (that is the number of different kinds of scripts). Then the total amount of potential scripts is 18˙816, and the remaining scripts, which are 76, represent the 0,4% of the total potential. Furthermore, a large part of the remaining 76 scripts is simply a combination of some customized templates or parts of templates that could be modeled by means of more simple statements.

5. MODELING MAINTAINER SCRIPTS

The outcome of the analysis has been concretized in the metamodels summarized in Sect. 3.1. They have been validated with real systems and in the following we report an example which relies on the `Package` metamodel depicted in Figure 4.a. It contains metaclasses that are required to model maintainer scripts like the following:

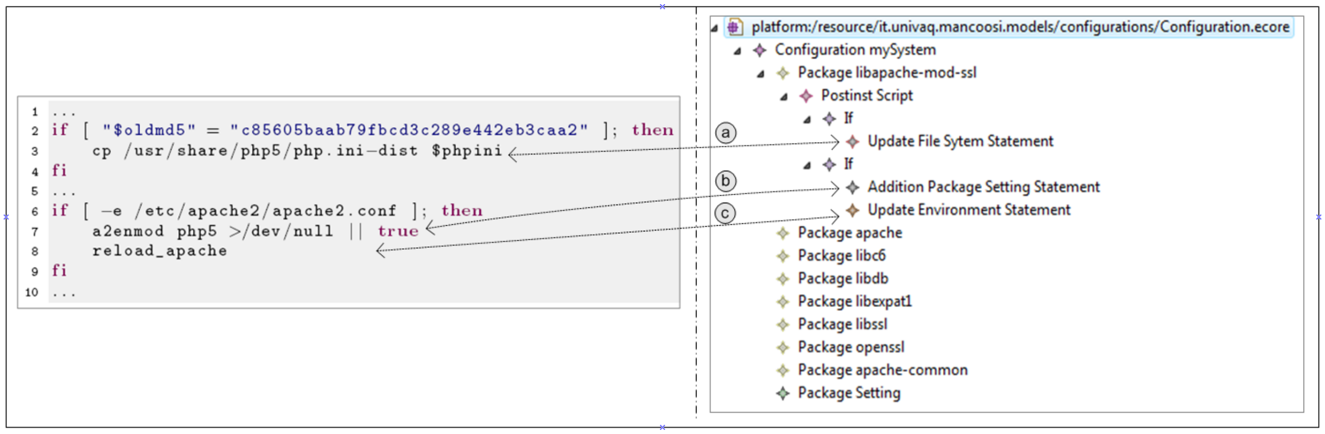
```
1 #!/bin/sh
2 if [ -e /etc/apache2/apache2.conf ] ; then
3     a2enmod php5 >/dev/null || true
4     reload_apache
5 fi
```

In particular, the installation of PHP5—a web scripting language integrated with the Apache web server—executes the *postinst* script above which will be executed once the package has been unpacked on the target system. Essentially, the installed Apache module `php5` gets enabled by the above snippet invoking the `a2enmod` command in line 3. The Apache service is then reloaded (line 4) to make the change effective. Upon PHP5 removal, the reverse will happen, as implemented by the following `prerm` script pertaining to the PHP5 package:

```
#!/bin/sh
if [ -e /etc/apache2/apache2.conf ] ; then
    a2dismod php5 || true
fi
```

The model-based specification of such scripts encompasses the metaclass `Statement` in Figure 4.a which represents an abstraction of the commands that can be executed by a given script to affect the environment, the file system or the package settings of a given configuration (`EnvironmentStatement`, `FileSystemStatement`, and `PackageSettingStatement`, respectively). For instance, the sample model in Figure 4.b reports the scripts contained in the package `libapache-mod-php5` which contains the scripts reported at the beginning of the present section. For clarity of presentation, Figure 4.b contains only the relevant elements of the `postinst` and `prerm` scripts which are represented by the elements `pis1` and `prs1`, respectively.

The most significant metaclasses of the Package metamodel which underpin the script behavior specification are



```
...
if [ "$oldmd5" = "c85605baab79fbcd3c289e442eb3caa2" ]; then
    cp /usr/share/php5/php.ini-dist $phpini
fi
...
if [ -e /etc/apache2/apache2.conf ]; then
    a2enmod php5 >/dev/null || true
    reload_apache
fi
...
```

```
platform:/resource/it.univaq.mancoosi.models/configurations/Configuration.ecore
  Configuration mySystem
    Package libapache-mod-ssl
      Postinst Script
        If
          Update File Sytem Statement
        If
          Addition Package Setting Statement
          Update Environment Statement
    Package apache
    Package libc6
    Package libdb
    Package libexpat1
    Package libssl
    Package openssl
    Package apache-common
    Package Setting
```

Figure 5: Fragment of the `libapache2-mod-php5_5.2.6-5_amd64.deb.postinst` script

`Script`, and `Statement`. In particular, according to the different configuration elements which can be affected by the execution of a given script statement, the abstract metaclass `Statement` is specialized in different metaclasses that are `FileSystemStatement`, `EnvironmentStatement`, and `PackageSettingStatement`. Moreover, each of them is in turn specialized for capturing additions, removals, and upgrades. In particular, the statements which add, delete, and modify the `FileSystem` are respectively represented as `AdditionFileSystemStatement`, `DeletionFileSystemStatement` and `UpdateFileSystemStatement` instances. The shell commands `touch`, `rm` and `cp`, are sample instances of such metaclass.

The statements which modify the `Environment` of a given configuration are given in terms of instances of `EnvironmentStatement` specializations. Shell commands like `installmenu`, `rmmod`, `ldconfig` of Linux distributions, can be respectively modeled as `AdditionEnvironmentStatement`, `DeletionEnvironmentStatement` and `UpdateEnvironmentStatement` instances.

As pointed out in Section 2, an installed package might depend on settings properly stored in dedicated configuration files (i.e., the service `apache2` depends on the configurations specified in the file `httpd.conf` usually stored in the `/etc/apache2` directory). The statements which modify such settings are modeled by means of instances of the `PackageSettingStatement` extensions. Finally, maintainer scripts might contain statements which do not change the system configuration but are comments, emit messages, etc. Such cases can be specified by means of instances of the `NeutralStatement` metaclass.

A summarizing example is depicted in Figure 5 which reports a fragment of the `postinst` script of the Debian Lenny `libapache2-mod-php5_5.2.6-5_amd64.deb` package. The code is injected with respect to the `Package` metamodel summarized above by giving place to the model on the right-hand side of Figure 5. In particular, the copy operation of the file `php.ini-dist` represents a modification of the file system and is hence modeled as an `UpdateFileSystemStatement` element (see the arrow ⓐ). Once the `php5` module has been installed, the configuration of the `apache2` package has to be modified by enabling the new module. This operation is performed by executing the command `a2enmod` which is modeled as an `AdditionPackageSettingStatement` element (see the arrow ⓑ). Finally, the `UpdateEnvironmentStatement` element in the model (see the arrow ⓒ) represents the command which reloads the `Apache` Web server to update the environment with the previous modification.

6. RELATED WORKS

The main difficulties related to the management of upgrades in FOSS distributions depend on the existence of maintainer scripts which can have system-wide side-effects, and hence can not be narrowed to the involved packages only. An interesting proposal to support the upgrade of a system, called NixOS, is presented in [10]. NixOS is a purely functional distribution meaning that all static parts of a system (such as software packages, configuration files and system boot scripts) are expressed as pure functions. Among the main limitations of NixOS there is the fact that some actions related to upgrade deployment can not be made purely functional (e.g., user database management). [19] proposes an attempt to monitor the upgrade process with the aim to discover what is actually being touched by an upgrade. Unfortunately, it is not sufficient to know which files have been involved in the maintainer scripts execution but we have also to consider system configuration, running services etc., as taken into account by our metamodels.

Concerning software modernization, OMG defined the Architecture Driven Modernization (ADM) task force [21] that aims at building standard metamodels and tools for supporting software renewal. Reus et al. in [22] and [14] propose similar MDA processes for software migration. They parse the text of the original system and build a model of the abstract syntax tree. This model is then transformed into a pivot language that can be translated into UML. The context of such works is different from that considered in this paper which deals with FOSS distributions and especially with maintainer scripts.

7. CONCLUSION AND FUTURE WORK

Dealing with upgrade failures in FOSS systems is a challenging task, mainly due to the complexity of maintainer scripts which are executed during upgrade deployment on the real system. Such scripts are written in languages that have rarely been formally investigated, thus posing additional difficulties in understanding their system-wide side-effects.

In this paper we have analyzed two FOSS distributions and outlined the corresponding metamodels which have been conceived to support a model-driven approach for simulating upgrades and equipping roll-back mechanisms with detailed deployment logs, including maintainer script actions. The benefits of such an approach are manifold:

1. consistency checking possibilities are increased and trustworthy simulations of package upgrades become easier with respect to current package managers which only take into account inter-package relationships;

2. models can drive roll-back operations to recover previous configurations according to user decisions or forced by upgrade failures;

3. the evolution and the modifications the system underwent during its life cycle can consistently be recorded and used at run-time for roll-back operations.

This way installation and removal simulations can take into account both package dependencies and the behavior of maintainer scripts (which currently, on real systems, are used at deployment-time but ignored for planning) leading to more realistic simulations and enabling checking for more complex model inconsistencies. Even tough in this paper only two Linux distributions have been taken into account, the proposed approach is meant to be general. In this respect, the proposed metamodels will be refined by means of an iterative approach in order to capture unforeseen elements which are required to specify FOSS systems in general. The evolution of metamodels gives place to a number of problems related to the management of existing models which have to be adapted once the corresponding metamodels change. In order to deal with such problems, the approach in [4, 6] will be taken into account and used in the domain of FOSS systems.

As claimed in different parts of this work, the extraction of models from legacy software artifacts is a challenging task and existing lexical tools can not be directly used because of their limited capabilities to "query" textual artifacts and generate corresponding models. This represents the most important future work which has to be carried on to fully support maintainer script modernization. Existing approaches (like [11] and [17]) will be considered and applied to the metamodels which have been conceived according to the analysis presented in this work. Once the injection phase has been sufficiently automatized, we will instantiate the metamodels on a widely used FOSS distribution, and develop a supporting tool for integrating the presented model-driven approach with the existing system configuration/management tools. Moreover, we will define a model-based language, to be substituted to existing ones, for specifying the system configurations and packages at a higher level of abstraction. This new language will enable simulation and verification of maintainer scripts and will drive the roll-back of system upgrades.

On the practical side, we currently have the metamodels, and in particular the log metamodel, but we still lack the communication infrastructure with a package manager on one side and a log-equipped roll-back mechanism. We are closing this gap together with other partners of the Mancoosi project. The aim is to shortly have a prototype of a next-generation package manager which couples detailed knowledge of the installation via models with roll-back capabilities driven by upgrade deployment logs.

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