A Tool-based Methodology for Software Portfolio Monitoring

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Abstract. We present a tool-based methodology for monitoring the development and maintenance performed on the software portfolio of a large company. The toolkit on which the methodology is based includes an extendable framework for software analysis and visualization that meets strong demands with respect to scalability and usability. The methodology consists of 3 nested iterations and is carried out by software engineers with very strong consultancy skills. The shortest iteration consists in applying the toolkit to the software portfolio to obtain and register basic facts such as metrics and dependencies. In the middle iteration, the engineers interpret and evaluate the newly registered facts. The findings are reported to IT management together with recommendations about how to react to the findings. In particular, one kind of recommendation is to carry out a Software Risk Assessment on a selected system or project. Finally, the longest iteration is the publication of an annual software report, which summarizes the monitoring results of the previous year.

1 INTRODUCTION

The value of most businesses today is in large part determined by their software systems. These systems tend to be large, complex, and highly heterogeneous. Over time they have been extended, and adapted to changing requirements. Often they have been written in a mix of old and new languages of various levels of abstraction. Though critical from a business perspective, these systems are often experienced as black-boxes by managers and technical staff alike.

Typical portfolio status As an example, consider the case of a modern bank. Typically, it has come into existence through mergers and acquisitions of various smaller banks that each started to automate their processes somewhere in the 1960s. During the years, not only transaction processing and account administration where automated, but also international payments, savings, mortgages, loans, and more. Each 'financial product' was automated independently in the preferred technology of the time. In the early days, this would be Cobol with sequential files for storage and JCL for batch job coordination, all running on a mainframe computer. Over time, hierarchical databases and, somewhat later, relational databases gained popularity over the sequential files. Likewise the growing need for interactive systems stimulated the use of 4th generation Cobol generators to

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build screens, and transaction managers to communicate asynchronously between programs. The introduction of new hardware platforms boosted the use of alternatives to the Cobol language, such as C, Delphi, Clipper, and PL/SQL. More recently, web-related technologies were added, such as Java, Visual Basic and various scripting languages.

With the introduction of new technology, the old technology was not abandoned. Rather, many inventive techniques were (and are) introduced to glue them together: compiler extensions, assembly routines, database and communication utilities, code generators, etc. Many of these gluing techniques were home grown and tailored to the company's specific constellation of technologies. To the present day, brand new systems are still being developed in out-dated technology, simply because it is deemed reliable and ample expertise with it is available within the company.

This banking example is no exception. We have been privileged to perform analyses on the software of a dozen financial services companies in the Netherlands, varying from very large (more than 100,000 employees) to medium size (600 employees). For all these companies, their software was organized as described above. Before everything else, the sheer volume of their software systems is oppressive: even the smallest meaningful system is over 1 million lines of code. In all, over the last three years we have seen about 50 gigabytes worth of source code, all of it variations on the same theme: financial products.

Furthermore, we have been able to establish that the quality of the various systems developed and maintained over the years varies. The first system built with a new technology is generally low in quality. Systems that have gone through many small adaptations tend to have degraded in quality. Periods of weak management, or pressure from the business divisions may have led to over-ambitious projects that failed, but left their traces in the form of overly complex interfaces, over-dimensioned communication infrastructures and the like. The connections established between systems throughout the years have weaved them together in intractable ways.

Apparently, over time, a typical financial service company has come to be the proud owner of a huge number of intractably interweaved software systems, that are low in quality, and constructed from a wide spectrum of technologies.

Insight is indispensable Obviously this is not an ideal situation from a software engineering perspective. Maintenance of the software portfolio is more costly than necessary, and the systems are resistant to change. Such changes are needed to keep up with customer expectations, so this is also a problem from a commercial perspective.

To prevent further deterioration, and to move toward improvement of the IT situation, it is of the utmost importance that the management of the organization acquires clear insight into the difficulties, the dependencies, and the maintenance costs of its various software systems. Such information is indispensable to make strategic IT decisions on rational grounds.

We propose Software Portfolio Monitoring (SPM), a tool-based methodology that allows for the structured and efficient extraction of quality, volume and interrelations data from system source code. Since the data is gathered for multimillion lines of code systems, and since it needs to be reported to the CIO, the methodology includes steps to insure data is highly aggregated. Only relevant data is shown in a way that allows non-technical managers to make informed decisions on their company's systems.

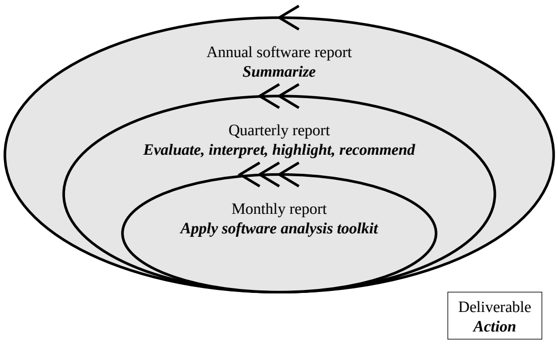


Fig. 1. The SPM methodology consists of three nested iteration.

2 THE METHODOLOGY

In this section we provide an outline of our methodology for Software Portfolio Monitoring (SPM). We will describe the activities and deliverables of each iteration. Also, we will discuss the relationship of SPM to the various company management levels and to related services such as Software Risk Assessments and Documentation Generation.

2.1 Iterations

The methodology consists of three nested iterations, as illustrated in Figure 1. Short iterations are indicated with a small ellipse; longer iterations by a larger, enclosing, ellipse. For each iteration, both the deliverable is indicated, and the actions that are executed to obtain the deliverable. Each larger iteration takes the deliverables of the iterations it encloses as input (new data) as well as the deliverables of previous iterations of the same size (previously registered data). In this paper, we assume a shortest iteration duration of a month. In practice, the particular situation is taken into account to decide the most appropriate duration.

Monthly iteration. The inner iteration is performed on a monthly basis. In this iteration, the Software Analysis Toolkit is applied to the software portfolio, resulting in a large number of basic facts about the code. These facts include metrics, dependency information, and detected violations of programming conventions or standards. All these facts are collected into a data repository. From this repository, a report is generated that presents the facts in a human digestible fashion. This means that the data is appropriately grouped and filtered, and visualized in graphs and charts that meet the information needs of individual project managers. In Section 3, the architecture of the Software Analysis Toolkit will be discussed in more detail.

In an ideal situation, the monthly application of the software analysis toolkit would be automated completely. In practice, the realities of legacy software make some degree of human supervision and intervention indispensable. These realities include the size and heterogeneity of the software portfolio, the ever-continuing maintenance activities on the portfolio, the low CMM level of many client organizations, the abundance of competing standards within a single organization, local conventions and idioms that are not rigorously enforced, remnants of failed or obsolete projects, and more.

Thus, the capabilities required from the software engineers that perform the monthly iterations is not merely to operate the toolkit, but also to adapt and extend it within a very short time frame. In fact, we advocate adoption of an extreme programming attitude toward legacy system analysis tools [**?**]. In particular, we recommend unit testing as an efficient and pragmatic means of guarding the performance and behavior of the various toolkit components when they undergo adaptation and extension. Also, to meet the strong demand of robustness, generality, scalability, and speed of development required from the components of the toolkit, the software engineers must master advanced implementation techniques (see also Section 3).

Quarterly iteration. Every three months, the technical data gathered in the inner iterations is interpreted and evaluated by software engineering experts. Also, the data is related to business goals as formulated by IT management. The findings are presented to IT management together with recommendations about how to react to the findings.

By interpretation, we mean that various selections of the data are combined and contrasted to discover for instance trends, correlations, and outliers. For example, based on the fact that certain modules have exceeded a certain complexity threshold, an engineer might hypothesize that these modules implement several related functions in a tangled fashion. He might discover that the database dependency information for these modules corroborates his hypothesis. Finally, he may take a small sample from these modules, read their code and verify that his hypothesis is indeed true.

By evaluation, we mean that the engineer makes value judgments about the software portfolio. The judgments will not be a reflection of his personal taste. Rather, he will base them on best practices reported in the literature, on published quality standards, comparisons with industry best and average, and so on. In other words, he will need to access general knowledge about software engineering practice, as formulated in the past by others.

During the course of the quarterly iteration, the monitoring experts conduct interviews with the CIO and other individual members of the IT Management. The purpose of these interviews is to formulate the tactic and strategic business goals and their IT-related consequences. Additionally, a workshop with several members of the IT management can be organized to supplement the interviews.

The evaluation and interpretation of the technical data, as well as recovery of IT-related business goals are instrumental in the most important element of the quarterly iteration: the drafting of recommendations. These recommendations can be of various kinds. They can be highly detailed, short-term recommendation, such as redesigning a particular interface, migrating particular persistent data from hierarchical to relational storage, or upgrading a particular third-party component. On the other hand, some recommendations may have a more general, long term character, such as integrating two functionally similar, but technically distinct systems, or reducing the procedural character of the object-oriented portions of the portfolio.

In some cases, the monitoring data are not sufficient to warrant concrete recommendations. They reveal a problem, but do not suggest a solution yet. In these cases,

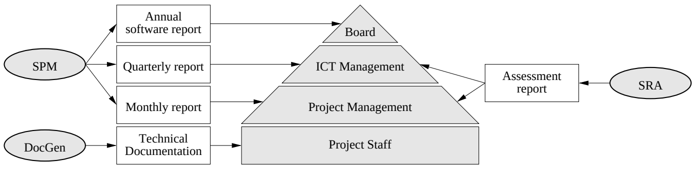


Fig. 2. Software Portfolio Monitoring (SPM) and its relationships to deliverables, management levels, and other tool-based services, viz. Software Risk Assessments (SRA) and Documentation Generation (DocGen).

the recommendation formulated by the monitoring experts will be to perform a Software Risk Assessment (see below) on the system or project in which the problem has been signaled. Such an assessment consists of an in-depth analysis, involving interviews and workshops with technical staff and application of specialized tooling, and leads to a concise report with concrete and detailed recommendations for the system or project under consideration.

The deliverable of the quarterly iteration is a written report to IT management, which is presented in person by the monitoring experts in an IT management meeting.

Annual iteration. Every year, the deliverables of the monthly and quarterly iterations are summarized in an Annual Software Report. The intended audience of this report is the general management of the company, which is not necessarily IT-savvy. For this reason, the software engineering experts that compile the report need to be able to explain IT issues in layman's terms. In addition to the summaries of the monthly and quarterly iterations, the Annual Software Report may include IT-related financial information, if available in sufficient detail. In this case, the monitoring experts need to have some level of knowledge of business economics and finance.

2.2 Organizational context of tool-based services

The various reports produced during the various iterations of Software Portfolio Monitoring are delivered to different management levels within the client organization. This is shown in Figure 2. The monthly reports are delivered to project managers. The quarterly reports are presented at the IT management level, i.e. to the Chief Information Officer and his immediate subordinates. The Annual Software Report is intended for consumption by the general management.

Also shown in Figure 2 are the relationships of SPM to other services based on static software analysis, i.e. Software Risk Assessments and Documentation Generation.

Software Risk Assessments. Software Risk Assessments [**?**] are performed on request by the IT management, possibly following a recommendation from a quarterly monitoring report. Like SPM itself, a Software Risk Assessment is a tool-based service. But whereas SPM is a continuous effort conducted on a full software portfolio, an SRA is a one-time inspection of a limited body of software (generally a single system). Also, SPM serves to identify general trends, while SRA focuses on specific software risks. The audience of SRA reports are general IT management and IT project management.

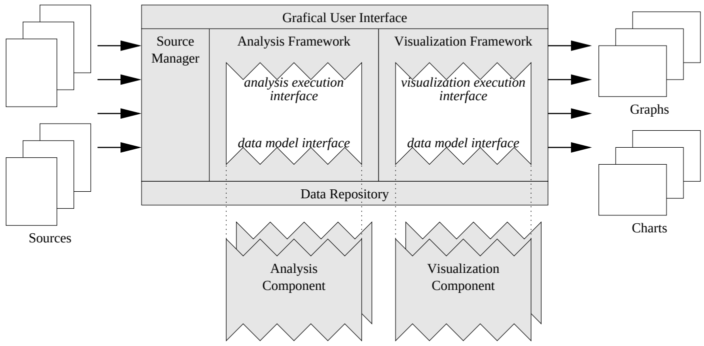


Fig. 3. Architecture of the Software Analysis Toolkit. It consists of a framework into which specific analysis and visualization components can be plugged.

Documentation Generation. Documentation Generation [**?**] is the fully automatic generation of technical documentation from program source code. In contrast to well known documentation generators, such as javadoc, the purpose is to document not only the APIs of the software, based on comments inserted by programmers for that purpose, but to document the internal structure of the programs as well without a specific documentation effort by the programmers. The primary audience of generated technical documentation is not IT management, but the technical staff, including programmers, testers, reviewers, and operators.

3 TOOL BASIS

In this section we provide an outline of the Software Analysis Toolkit (SAT) on which SPM is based. Figure 3 shows the architecture of the SAT, consisting of a framework and components. We describe both the generic framework for analysis and visualization and its instantiation with specific analysis and visualization components. The SAT was developed by the Software Improvement Group.

3.1 Framework

The framework of the Software Analysis Toolkit consists of a graphical user interface that provides access to three pieces of functionality: gathering source code, performing static analysis on the code, and visualizing their analysis results. The components that implement analysis and visualization are themselves frameworks into which various subcomponents can be inserted that implement individual analysis and visualization algorithms. A repository that persistently stores all information extracted from the sources is shared by the components for gathering, analysis, and visualization.

We will discuss various components of the framework in more detail.

Source Manager. The Source Manager is responsible for gather source code. It allows the user to define a *system* and associate to this system a name, source code locations, and a brief description. These attributes of the system will be stored in the data repository for future reference.

The source locations are recursively searched by the Source Manager to gather the source files associated to the defined system. With each file found a file type will be associated, based on its extension and sometimes parts of its content. Examples of file types are *Cobol program*, *Cobol copybook*, *C header file*, *Ant build file*, and *unknown*.

The operator of the toolkit can request the source locations to be searched again at regular intervals, or only on manual request. If between searches files have been changed, added, or deleted, this is detected and registered in the data repository.

Analysis Framework. The Analysis Framework offers the user for each defined system a selection of analyses that can be executed on it. Only those analyses are available that are applicable, given the various file types occurring in the system. The user can select all or some of the applicable analyses, start their execution, and watch their progress.

Which analyses are available for which file types depends on the available instantiations of the framework. These instantiations are required to implement an *analysis execution interface* so that they can be started, watched, and stopped, and they are allowed to use a *data model interface* to store their results in the data repository. Examples of instantiations will be given below.

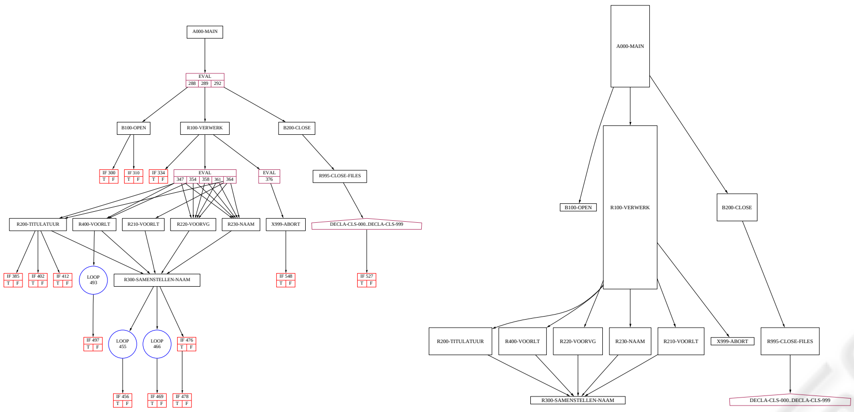
Visualization Framework. The Visualization Framework allows the user to visualize the results of the analyses, once they have been completed. Basically, two categories of visualizations are available: charts and graphs. Both are highly parameterizable. Which visualizations are available exactly depends on the available instantiations of the framework. These instantiations are required to implement a *visualization execution framework* to allow them to be parameterized and rendered. They use a *data model interface* to retrieve from the data repository the analysis results that need to be visualized.

3.2 Analysis components

Analysis components vary in their degree of sophistication and generality. Some components are applicable only to certain types of files. For instance, a component of control-flow reconstruction may implement an algorithm that works only for ANSI-Cobol-85. Other components are applicable more generally. For instance, a component for counting lines of code and comment could work for any language that employs one of the common comment conventions.

We will briefly give a description of some available analysis components. Also, we will discuss general requirements to be imposed on these components.

Lines of code and comment. To be able to count code and comment lines, the analysis component must be able to distinguish comments from code. Since different (programming) languages employ different comment conventions, the component implements recognizers for common conventions. Full tokenization of the input files is usually not necessary; the recognizers can be implemented using standard regular expression libraries. Based on the file type, the proper recognizer is chosen. When a format or language is encountered with a comment convention for which no recognizer is available, the SAT operator needs to extend the component with an additional recognizer.



(a) CCG where nodes are reconstructed procedures, conditionals, loops, and switches.

(b) CCG after filtering out conditions, and using fanout metric to determine node size.

Fig. 4. Conditional call graph (CCG) reconstructed from a Cobol program.

Function Point Analysis by backfiring. Function Point Analysis is a methodology for attributing a *functional* size to a given software system. The backfiring method [**?**] allows to make an estimate of the number of function points based on the number of logical statement in which the system is encoded. Depending on the implementation language, a specific multiplication factor is applied to the number of logical statements to arrive at the function point estimate.

Cobol control flow reconstruction. Cobol does not have procedures in the sense of delimited blocks of code with well-defined entry and exit points and interface. Instead, it has labeled blocks of code and various mechanisms for jumping to and from these blocks. In [**?**], a light-weight algorithm is described for reconstructing procedures from Cobol code, and their interdependencies, i.e. to analyze the intra-program control-flow of Cobol programs. An example of a conditional call graph reconstructed from a Cobol program is shown in Figure 4(a).

Clone detection using metrics. Clones are duplicate pieces of software that generally result from copy-paste techniques in programming. Clones can differ slightly, for instance in the names of variables or in the exact order of statements and declarations. A pragmatic technique for detecting clones is to compute metrics over the code, and compare the metrics [**?**]. If the metrics for two pieces are (almost) identical, they are clones.

General requirements. The analysis components described above are just examples, but they demonstrate the general requirements all analysis components should satisfy to be useful for SPM: scalability and genericity.

The amount of source code in a typical software portfolio ranges between 1 million and 100 million lines of code. Processing this code to obtain the basic monitoring data should under no circumstance take more than a few hours. The computational complexity of the implemented algorithms should be kept within bounds. In this sense, the analysis components must be scalable.

The implementation techniques used in constructing the analysis components should be of a high degree of genericity. By genericity we mean that a piece of code works for many different kinds of data. In this case, it means that the (elements of the) analysis algorithms should work for many different kinds of source models. If genericity is lacking, the algorithms will lack conciseness, robustness, and reusability. As a result, it will be extremely difficult to implement and adapt them within short time frames, and they will easily break when they are applied to slightly different source language dialects. Generic implementation techniques include generic traversal [**?**], strategic and adaptive programming [**?**], and island grammars [**?**].

3.3 Visualization components

The second kind of component that can be plugged into the framework of the software analysis toolkit are visualization components. These components can be implemented using external visualization libraries or making calls to external visualization tools. We will briefly describe some available visualization components.

Charts. To visualize software metrics, charts are a helpful medium. We have used a Java library called JFreeChart for this purpose. This library allows composing bar charts, line charts, pie charts, and more. Also, it allows combining several metrics in a single chart. The additional functionality that our metrics visualization component offers includes selection and thresholding functions.

Graphs. To visualize dependencies in software, we use a graph browser. This browser allows navigation through hierarchical graphs. It also allows selection and filtering of graphs in various ways. This is very important to reduce information overload, i.e. to turn a big ball of spaghetti into a surveyable graph in which important aspects stand out. Figure 4(b) shows a conditional call graph reconstructed from a Cobol program. To reduce the size, condition nodes have been contracted. Also, the node size is determined by the fanout metric, i.e. procedures with more outgoing calls to other procedures are shown bigger.

Animation. For Software Portfolio Monitoring, we are not only interested in presenting data about software at a particular moment. We need to visualize the *evolution* of the software throughout time. Of course charts can be used for this purpose, where one of the axes represents time. Another instrument is the use of animations. Figure 5 shows a 3-frame animation of the evolution of various size metrics of a Java system. The advantage of using an animation in this case is that both axes can be used to plot metrics, thus allowing more metrics to be visualized simultaneously.

4 CONCLUSION

We have described a iterative methodology for monitoring the development and maintenance performed on the software portfolio of a large company. The methodology is

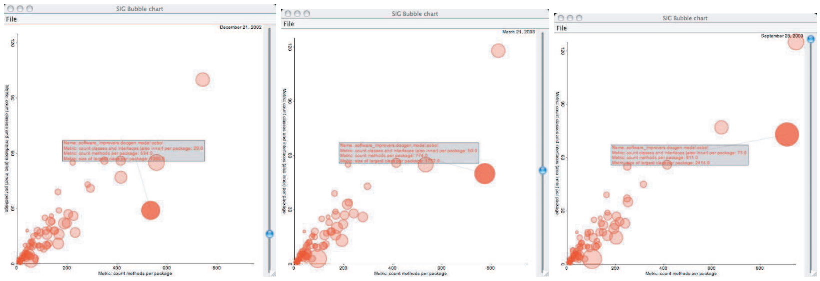


Fig. 5. A Java system in december 2002, march and september 2003. Bubbles represent packages. The x-axis shows the number of methods, the y-axis shows the number of types (classes and interfaces), and the bubble surface shows the size of the largest class in the package. Note that during this period, the selected package doubled in size, both in terms of number of methods and number of types. But in terms of methods-per-class ratio, it scores lower than any of the other packages.

tool-based, in the sense that its inner iteration involves the application of a software analysis toolkit on the entire software portfolio. The remaining iterations deal with interpretation, evaluation, and aggregation of the collected data and presenting them to IT and general management.