Integrating an object-oriented metrics tool into SNiFF+

Claus Lewerentz, Frank Simon
Software and Systems Engineering Group
BTU Cottbus

In the project *Crocodile* tools for supporting software quality measurement are developed. In particular, object oriented metrics are used to define product quality models for object oriented programs and frameworks. Our current tool implementation is based on and integrated into the SNiFF+ programming environment.

Crocodile's approach is to use the parsed data from SNiFF's symbol table for extracting a basic set of structural program properties. This symbol table always contains the up-to-date data like classes, inheritances and references of the currently open software project. Because SNiFF+ does the mapping from the programming language into the symbol table, our tool itself is language independent. The whole measuring process is done within a SNiFF+ session: It's started by a new SNiFF+ -command, it's configured through it and the feedback of the measured values is given back to SNiFF's user interface. *Crocodile* offers its own query-language for defining specific measures and quality models. A special mechanism to filter the amount of calculated measurement values to the critical ones helps the engineer to effectively do and understand the measuring. This data reduction is achieved by defining subsets of classes to be measured - considering usage and inheritance context - and by defining critical ranges for the self-defined object oriented measures.
Thus, *Crocodile* provides an easy way to create a specialized measurement process considering the user's specific goals in engineering or re-engineering. Furthermore, measurement activities are well integrated into the particular software development model and tool support through the usage of SNiFF+.

Content:

1 Objectives and Principles for an Integrated Metrics Tool

As in other engineering disciplines, it is a major objective in software development to control the product and process quality. Software product quality is expressed both by internal structural product properties as ease of maintenance or portability as well as external quality of a software product consisting of attributes like usability and correctness ([SiPa94], p 49). Because many of these attributes cannot be measured directly they are often subdivided into refined factors and criteria which in turn are related to one or more simple product metrics (cf. [Fent95], p. 42). This hierarchical approach has been implemented as a standard way to define and to measure software quality ([ISO9126]). Figure 1 shows a sub-tree of such a quality model.

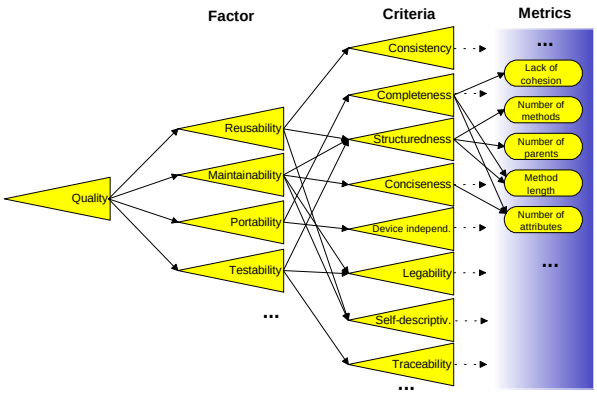


figure 1: Software-quality model

Erni enriched such quality models by including additional layers. They relate quality criteria and metrics sets by design principles and construction rules (cf. [Erni96]). These additional layers in the quality hierarchy allow for better explanation of the measured values and, particularly, to describe potential corrective actions to be taken by the software designer. An example would be the principle of good decoupling of classes, which can be measured by a combination of several simple metrics, and in turn is a rule how to achieve well-structured programs.

We advocate the use of design and code metrics as a feedback instrument for software engineers during development and evolution of software systems. The measurement process should support product review and inspection steps by providing a quick and objective analysis of structural properties and relating them to explicitly defined quality goals. This requires both, that product quality metrics are available for all types of design and code documents being produced during the construction process, and that appropriate measurement tools are accessible as an integral part of the software development environment.

Object-oriented construction techniques have the advantage of providing a uniform conceptual framework throughout design and coding and, thus, allow to combine design and code metrics in uniform quality models. Almost all of those metrics are independent from the actual object-oriented implementation language, but rely on general principles and rules for structuring programs with classes and how such class structures should look like.
Thus, in an object-oriented approach product metrics can be used as early as the first design exists and can be monitored throughout the evolution process of the program.

The hierarchical quality model itself depends much on the target environment of the software product and the design and coding standards to be followed by the developers. The definition of adequate quality criteria, called „quality aim determination" ([Balz98], p. 269 ff.), is an important part of the process definition and should be done during requirements analysis phase. Particularly, the development and evolution of long living and reusable software products like object-oriented frameworks and component libraries require strong quality criteria (cf. [Erni96], p. 65 f).
Fenton advocates the use of such flexible and adaptable quality models and calls this the „*define your own quality model*" approach ([Fent95], p. 225).

To take into account the iterative character of development processes, which is particularly true for object oriented frameworks, the quantitative analysis results from successive program versions can be used to determine quality trends ([Erni96], p. 68 f). Such feedback on the development activities can help the software engineer to work against the loss of structure often experienced due to functional extensions and adaptations of software to new requirements.

These observations guided us to develop an adequate metrics tool for supporting measurement-based product quality management as an integral part of the software engineering process. The central requirements are:

- The process of data collection for the measurement process has to be as simple as possible and not to put additional overhead to the CASE environment and the software engineer.
- The metrics tool should be smoothly integrated into a CASE environment.
- The underlying quality model as well as the metrics definitions have to be highly flexible and adaptable.
- The metrics tool should give an immediate, understandable feedback to the software engineer even for more complex measures. It should easily allow for the tracking of problem spots in the program design or code according to a given quality model.

2 Measuring with *Crocodile*

According to the goal to use measurement-based analysis as early as possible in the development process, we concentrate on structural data available on architecture level. The object-oriented system model at least consists of

- classes and the inheritance and association relations between them,
- methods and attributes with their visibility and their usage
  (which attributes are accessed and which methods are called from other methods).

The necessary data for measuring object-oriented designs can be represented as an entity relationship diagram as shown in figure 2.

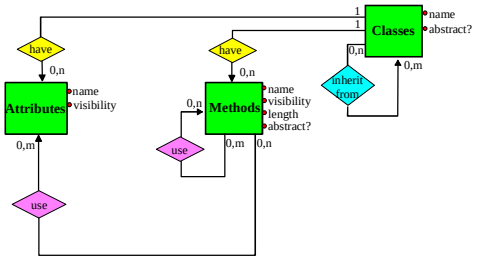


figure 2: Necessary data for measuring OO-designs

In *Crocodile* every measure is derived from these data. Metrics are defined by the means of a simple expression language with SQL-like queries over the described ER-schema. Since there are no pre-defined or built-in measures, even basic-ones have to be defined this way to establish the foundation of specific quality models. The next subsections explain this in some more detail.

2.1 Defining measures

Crocodile provides three kinds of basic measures: class related, (e.g. number of methods), method related (e.g. length of method), and attribute related measures (e.g. number of references to an attribute).
The definition of a new measure generally comprises

- an iterator over a set of entities of a particular type (class, method, attribute),
- the name of the new measure, and
- an expression using SQL-like queries and calculations.

The following simple example shows the definition of a new class measure named `number_of_all_methods`.

```
for_all_classes C
      (number_of_methods:= count methods
       where methods.class_id = C.class_id)
```

For each class C `number_of_methods` is calculated by counting all methods belonging to this class. In such cases the `class_id` of the method, expressing the association between classes and methods in the ER-schema, is equal to the `class_id` of C.

Our query definition language supports

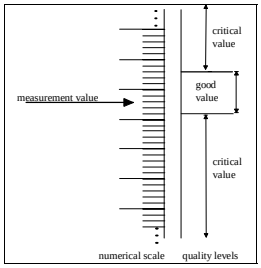
- any joins including aliases,
- regular expression matching,
- column to column comparisons in WHERE clauses,
- complex conditions, and
- nested SELECT-statements.

Besides simple selection and joining of basic data, arithmetic operators are used to scale and to combine simple measures into more *complex measures* (corresponding to indirect measure in [Fent95]). For example after defining the queries for `number_of_methods` and `number_of_attributes` it is possible to define a new measure `weighted_class_complexity` with the following definition:

```
for_all_classes
     (weighted_class_complexity:=  (3*number_of_methods)+
                                   (2*number_of_attributes))
```

2.2 Interpretation of measurement values

An essential part of any quantitative quality model is the definition of ranges for metrics values, which allow for the interpretation of measurement results as either good or critical with respect to a particular quality (sub-) goal (cf. figure 3). The definition of such value partitions or, more generally, quality levels (cf. [ISO9126]), provide a means to filter the huge amount of measurement values to those indicating critical situations. The software engineer should review such situations carefully.
In *Crocodile* we support the following ways to define critical values within the measurement context:



- values are critical if they are inside an absolute interval,
  e.g. `number_of_all_methods [0,5]`
- values are critical if they are outside an absolute interval (as shown in fig. 3),
  e.g. `number_of_public_attributes ]0,0[`
- values are critical if they belong to the group with the x highest respectively lowest values,
  e.g. `length_of_method [max,x]`
- values are critical if they belong to the group with the y percent highest respectively lowest values,
  e.g. `weighted_class_complexity [min,y%]`

figure 3: quality levels

The metrics together with such critical value ranges form the leaf level of the above described hierarchical quality model as for instance shown in fig. 1.

2.3 Defining the detailed quality model

For interpreting the calculated measurement results they have to be connected to some quality criteria which are expressed in terms of those measurements. A critical value indicates that the corresponding criterion is not fulfilled. To be as flexible as possible *Crocodile* does not come with fixed, built-in quality models. So the full model has to be defined. Starting from the root which could be a general quality goal like reusability descriptions of directed paths from this goal down to the concrete measures. It is possible to connect one measure to different criteria using different threshold values. For instance, it's possible to connect the class measure

`number_of_public_methods` to the criterion `completeness` with a higher threshold value than in a connection to the criterion `descriptiveness`. Therefore, the definition of a sub-tree for the described criteria could look like

```
quality → portability → completeness → number_of_public_methods ]15,50[
quality → reusability → descriptiveness → number_of_public_methods ]3,30[
```

This quality model is used by *Crocodile* to provide an interpreting of the measurement results. The in [ErLe96] described additional layers between criteria and metrics that consist of design rules (cf. chapter 1) can be realised by adding corresponding nodes, e.g. `descriptiveness → keep_public_interfaces_narrow → number_of_public_methods ]3,30[.`

2.4 Class context for basic measures

When measuring object oriented software three problems can occur:

- In most cases object-oriented software builds on top of basic libraries, providing the access to the operating system, GUI support, or data structures and algorithms. When measuring such composed programs the software engineer might only be interest in analysing the self-written parts, because only these are under his control.
- The functionality of a class - containing methods and attributes - might be distributed over all classes it inherits from. Therefore, the result values for some structural measures might not reflect the situation within this class appropriately.
- Another kind of distributing functionality over several classes can be reached by association including aggregation. When measuring one class without considering its usage of other classes, e.g. graphical library, the result values for some structural measures could lead to wrong conclusions..

To handle such situations and to allow the user for an explicit definition of what to include into the measurement *Crocodile* offers three mechanisms (cf. [Erni96]):

- *Crocodile* provides an easy way of selecting a **class-focus**, which contains all classes to be measured. To measure particular parts of a composed program only those classes are included in the focus.
- *Crocodile* offers a solution to the distributed functionality of a class over an inheritance tree by providing the possibility to select an **inheritance-context**. The functionality of classes - containing methods and attributes - from the inheriting context is copied into subclasses of the focus. Thus, the class is changed to its flat representation and the measures are considering the full set of properties of this class.
- Corresponding to the inheritance-context, *Crocodile* provides the possibility of selecting a **use-context**. When measuring a focus there are only considered references of used attributes and methods from classes within the focus. By selecting a use-context there exists the possibility to measure the focus containing connections to outside of the focus.

3 Architecture and Implementation of *Crocodile*

The *Crocodile* metrics tool is designed to be fully integrated into existing software development environments (SDE) that supply object-oriented design and coding tools (structure editors, parsers, source code browsers) and version management. The main

components of the *Crocodile* tool are abstract interfaces to the SDE services and to an SQL-database system, the quality model description, a query language interpreter, and additional user interface components to select the measurement context and to present the analysis results.

These components and the overall tool architecture are shown in figure 4 and are briefly described in the following:

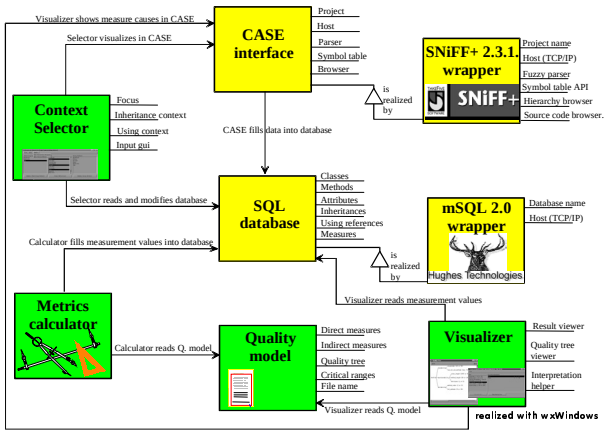


figure 4: Architecture of Crocodile

- The *CASE interface* allows to activate language parsers and to access the symbol table information built-up through the parsing process. Other required services are the usage of source code and structure browsers to feed back analysis results into the program representation maintained by the CASE tools. The abstract CASE interface is implemented by specific wrapper classes to existing CASEs. Our current platform is SNiFF+ 2.3.1 from TakeFive. The integration is explained in more detail below.

- The *SQL database* stores the basic structural data according to the schema described in section 2. This data is extracted from the CASE's symbol table. Additional data for complex measures is created and stored during the analysis process. The interface provides full SQL query access to all of this data. As above this abstract interface is implemented via specific wrapper classes on top of commercially available DBMS. Our current implementation uses mSQL 2.0 from Hughes Technologies (cf. [Robi98]).

- The *Context Selector* allows interactive definition of the measurement context in terms of focus, inheritance context and use context selection as discussed in section 2.4. Based on

the actual measurement context the basic structural data is adapted accordingly. The user interface parts of this component are implemented with wxWindows (cf. [ReJo95]).

- The *Quality Model* contains all descriptions of the basic and complex measures, the definition of critical value ranges and the goal/sub-goal hierarchy definition. This information is used by the Visualizer component to explain the critical spots in the measurement results. The project specific quality model is stored along with the project data.

- The *Metrics Calculator* interprets the measurement definitions to evaluate and adds new measurement values to the SQL database.

- The *Visualizer* identifies and displays the condensed measurement results as critical spots in the analysed program. Therefore, it provides the connection to the display and browsing functionalities of the CASE interface as well as some additional display functions. It also offers functions to generate measurement reports written in HTML.

To explain the integration of *Crocodile* as an add-on for SNiFF+ we briefly take a look at the SNiFF+ architecture, as displayed in figure 5.

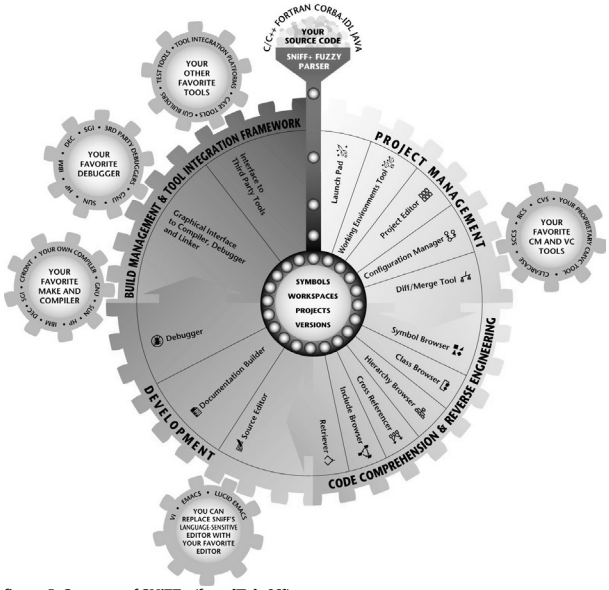


figure 5: Structure of SNiFF+ (from [Take96])

The functionality of SNiFF+ is grouped into the function-clusters „Project Management“, „Code Comprehension & Reverse Engineering“, „Development“, and „Build Management & Tool Integration Framework“.

All tools are working on a central data repository, basically formed by the symbol table of the SNiFF+ parsers. It contains all data about the structure of a project like classes, their attributes, methods, use-references etc. SNiFF+ provides good customising and tool integration facilities. By only relying on the symbol table and SNiFF's tool access interface for using built-in browsers and source code editors, *Crocodile* has got the following advantages:

- it is language independent because it doesn't have to deal with parsing, but simply re-uses the available parse results. *Crocodile* hasn't to care about special macro expansions or a particular compiler.
- analysis of even incomplete code is possible due to SNiFF's „*on the fly*“ parsing technology [Take96].

- it automatically supports the project management, because it's using the installed and maybe specialized mechanisms.
- it automatically uses the favourite text editor installed in the customised SNiFF+ environment.

The integration of *Crocodile* with SNiFF+ is done through two interfaces:

- SNiFF*access* through which applications can interact with SNiFF+. By sending requests to and receive notifications from SNiFFaccess *Crocodile* is able to control the built-in tools of SNiFF+, e.g. the hierarchy-browser or the source code editor (cf. [SNIF96]).
- The *SymbolTable-API* which allows add-on applications to query the symbol table information of a project. The access functions are provided by the SNiFF+ symbol interface library. They have a C linkage and are based on the idea, that requests to the symbol table are performed as queries (cf. [SNiF96]).

To summarise the integration of *Crocodile* into SNiFF+: *Crocodile* adds a new functionality to an existing SDE while further using the specialized and preferred tools. The architecture of the connection between SNiFF+ and *Crocodile* is shown in figure 6.

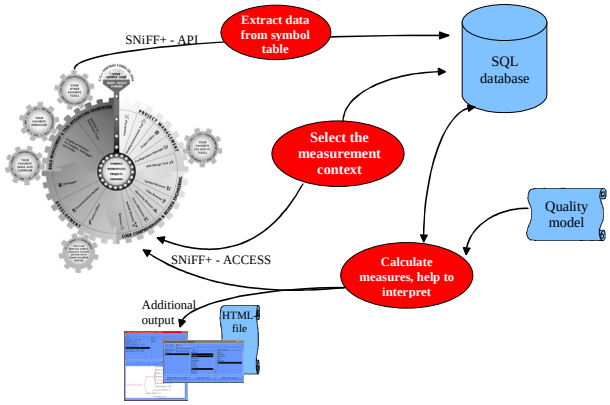


figure 6: Connection between Crocodile and SNiFF+

4 How to use *Crocodile*: A sample session

Referring to figure 6 the measurement process within SNiFF+ with the *Crocodile* measurement add-on can be divided into four phases:

1) Preparation of a quality model configuration file including
   - definitions of basic-measures and complex measures,
   - definition of a detailed quality hierarchy including the critical value ranges for the measures.
2) Extraction of the data from the SNiFF+ symbol table into the *Crocodile* database for further calculation.
3) Selection of a measurement context consisting of focus, inheritance context and use context.
4) Measurement and interpretation of the calculated and visualised values.

All steps except for the first-one are executed from within a SNiFF+-Session. In the following subsections screenshots of a sample session are used together with some brief comments to sketch the typical usage of our tool.

4.1 Preparation of a Quality Model

The configuration file is a plain ASCII-file which can be worked on with every text editor, for example the source code editor built into SNiFF+. The description contains the following sections in this order

- `basic_measures` with SQL-like queries (cf. section 2.1)
- `complex_measures` where scaled and combined measures are defined (cf. section 1.1)
- `quality_tree` where the detailed quality hierarchy is defined. Its leafs have to be consist of an above defined basic or complex measure and corresponding threshold intervals (cf. section 2.2).

The quality model should be appropriate for the development task and should reflect the interesting properties for the application situation. Figure 9 shows an example for a quality model using a graphical tree-like representation.

4.2 Extraction of Data from the Symbol Table

After modifying the `.UserMenus.sniff` file in the home directory the menu bar of the SNiFF+-source editor looks like figure 7. All measuring activities with *Crocodile* are controlled from within the current SNiFF+-session. The menu command `Fill Database` exports the current content of the symbol table to *Crocodile*'s database. The symbol table automatically contains the data of the current open project. When working with a subproject, only that data is exported. The project sources may be incomplete, syntactically inaccurate and having uncompilable code because the symbol table only stores structural design data. Besides starting this data export no further user interaction is required for this step.

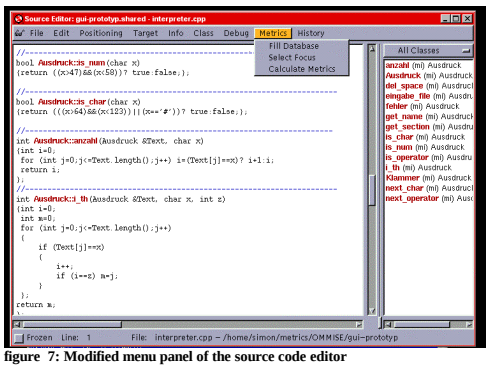


figure 7: Modified menu panel of the source code editor

4.3 Selection of the measurement context

After storing the structural data in the database the measurement context has to be set. This task is started with a corresponding command from the source editor, too. The resulting window of a specialized multiple selection context browser is shown in figure 8. It has a `SNiFF+` menu with display functions that allow to connect to the current open SNiFF+-session. Selected classes can be easily viewed by opening the SNIFF+ hierarchy browser or source editor.

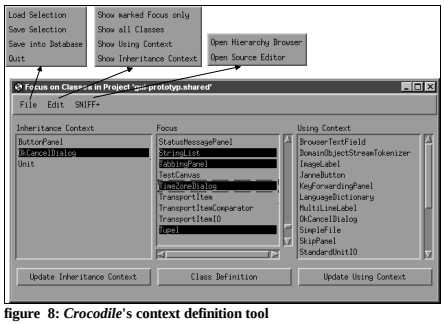


figure 8: *Crocodile*'s context definition tool

With the `File` menu commands a context selection from a previous *Crocodile* session can be loaded and also be saved for future work (for example to do some trend analysis with the same measurement context in different source code versions). After completing the definition of the measurement context and storing it in the data base the window can be closed.

Measurement and Interpretation of the results

The final step is to start the measurement calculation from the `Metrics` menu of the source editor. This opens a new visualise window as shown in figure 9.

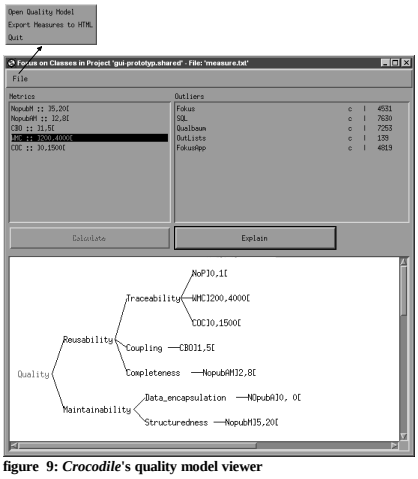


figure 9: *Crocodile*'s quality model viewer

After calculating the corresponding measures there are only those measures displayed for which critical values occurred. The right window pane shows the outliers (i.e. classes, methods, or attributes). Double-clicking such an object displays the corresponding code in the source editor. The `explain` button highlights the critical path for the current measure. The critical path consists of all nodes in the quality hierarchy that are affected by the outlier in a negative way. The more detailed the used quality model is the more information can be given to the *Crocodile* user. Alternative quality model configurations can be loaded and used with the same data.

To use the measurement results for further analyses an export function can be used to transform them into an HTML document. This allows for structured presentation or further statistical processing with spreadsheet tools.

5 Experiences and Future Work

Here, we briefly report about our experiences with the integration of the *Crocodile* tool into SNiFF+ and also about experiences with using the tool itself.

5.1 Experiences with SNiFF+ as Integration Platform

We use SNiFF+ version 2.3.1 running with the Solaris 2.5 operating system. In our group SNiFF+ was used as programming environment before. In the following we restrict the discussion only on the integration interfaces, namely *SNiFFaccess* and the *SymbolTable-API*. First of all, one has to say that SNiFF+ provides very reasonable interfaces for tool integration. However, we experienced the following limitations and would suggest some enhancements of the integration interfaces.

SNiFF+-Access

- No SNiFF+ browser allows for selecting multiple classes. Such class selection activities, particularly for setting the measurement context, have to be done within separate tools.
- It's not possible to use the browsers to output or highlight a set of selected classes. All output with lists of classes, particularly when showing classes that have critical measure values, requires a separate tool, too.
- SNiFFaccess has many problems with locating overloaded methods. When sending a request to show an implementation of an overloaded method in the source editor, the corresponding class is displayed but no method is selected. Thus, direct navigation to an overloaded method through SNiFFaccess isn't possible.

Particularly these restrictions didn't allow us to do all user interaction through SNiFF+, but made it necessary to implement specialized class browsers.

SymbolTable-API (ST).

- Until now there is no complete implementation of the functionality for accessing the symbol table as described in the reference manual ([SNIF96], chapter 35). Even the functionality to extract the necessary structure data for our application is only available from most recent version (SNiFF+ 2.3.1).figure 22
- The extent of data accessible through ST is still minimal. Information particularly useful for measurement like the number of lines of source code (LOC), logical statements, or the number of decisions (to calculate control flow complexity) could be easily made available but is not accessible now.
- For trend analysis over different program versions it would be very useful to get the version information through ST.
- Porting our tool to MS-Windows95/NT failed due to the fact that ST isn't available on this platform.
- Using the ST causes a second full SNiFF+ client to be started, thereby opening all windows like for an interactive session. However, no user interaction is necessary and all windows are just closed after the data extraction. This might confuse users. A „silent" SNiFF+ client would be very useful in this situation.
- The second SNiFF+ client need a separate license, too. This cuts the number of actually available licences for extended SNiFFs to one half.

5.2 Experiences with Using Crocodile

After very encouraging experiments with a previous prototype of a simpler metrics tool (cf. [ErLe96]), we are currently using the *Crocodile* tool for two kinds of software development projects:

1) Together with industrial partners we are reviewing large programs written in Java and C++ (several hundred classes). We are measuring these source codes to prepare and support the developers' review activities. This is done by focusing the review to classes, methods or attributes that got the most critical measurement values.
   Applying *Crocodile* to these programs we were able to show that
   - *Crocodile* is just as stable and reliable as SNiFF+ itself. There were no problems encountered with projects of about 200 classes, several thousands methods and several hundred KLOC of code.
   - In most cases large projects are composed of several subprojects. *Crocodile* benefits from SNiFF's capabilities to handle such subprojects restricting the measurement context in a quite natural way.

   - With an appropriate set of metrics *Crocodile*'s analysis results succeed to point out suspicious measurement entities (classes /methods or attributes), which prove to be good starting points for review.

2) At classroom level students are using *Crocodile* for object-oriented design and re-engineering. It helps them to
   - learn object-oriented concepts: Programs written in an object-oriented language without object-oriented thinking are easily detected by *Crocodile*. By using reduced quality models the attention of the students can be directed towards special properties of object-oriented programs (e.g. data encapsulation can be checked with the measure **`number_of_public_attributes`**).
   - judge the effectiveness of re-engineering and consolidation steps: Comparisons between measurement values „before" and „after" can validate the effects of restructuring activities.

Crocodile provides quite simple but powerful means to create a specialized measurement process. The quality models can be easily adapted to the user's specific goals and can be used to support different activities in engineering and re-engineering of object oriented applications. Due to *Crocodile*'s integration into a CASE-environment like SNiFF+ the measurement activities are smoothly integrated into existing software development processes. It can help to improve the quality of the produced software and, therefore, it seems to be a useful tool for the individual software engineer as well as for quality management.

5.3 Future Work

The key issue of our future work are the theoretical and empirical validation of existing measures and a framework for their exact and unambiguous definition.
A second point is to demonstrate the effectiveness of the integrated measurement approach in industrial software projects. Further on, we will integrate *Crocodile* into other CASE environments to provide a broader platform for experimentation.

Authors' affiliation and address:

Prof. Dr. Claus Lewerentz
Frank Simon

Lehrstuhl Software-Systemtechnik
Brandenburgische Technische Universität Cottbus
Ewald-Haase-Str. 13, D-03044 Cottbus

{lewerentz | simon}@informatik.tu-cottbus.de
phone/fax +49-355-69.3881/3810

6 References

[Balz98] Helmut Balzert: „*Lehrbuch der Software-Technik: Software-Management, Software-Qualitätssicherung, Unternehmensmodellierung*", Spektrum Akademischer Verlag GmbH Heidelberg, 1998

[ErLe96] Karin Erni, Claus Lewerentz: „*Applying Design-Metrics to Object-Oriented Frameworks*" in „*Software Metrics Symposium*", p. 64-74, IEEE Computer Society Press, 1996

[Erni96] Karin Erni: „*Anwendung multipler Metriken bei der Entwicklung objektorientierter Frameworks*", Krehl Verlag Münster, 1996

[Fent95] Norman Fenton: „*Software Metrics, a rigorous approach*", International Thomson Computer Press London, 1992

[ISO9126] International Organisation for Standardisation, Information technology: „*Software product evaluation - Quality characteristics and guide lines for their use*", ISO/IEC IS 9126, 1991

[MeNä97] K. Mehlhorn, St. Näher: „*The LEDA Platform of Combinatorial and Geometric Computing*", Cambridge University Press, 1997.

[ReJo95] Kevin Reichard und Eric F. Johnson: „*A free, portable GUI toolkit*" in Unix Review, November 1995, Vol 13, No 12, pp. 87-90 (available via http://www.unixreview.com)

[Robi98] Helge Robitzsch, „*mSQL2 - Ein leichtes Datenbanksystem*", dPunkt-Verlag Heidelberg, 1998

[SiPa94] Hans-Werner Six, Bernd-Uwe Pagel: „*Software Engineering - Die Phasen der Softwareentwicklung*", Addison-Wesley GmbH Deutschland, 1994

[Take96] Advertising material from TakeFive Software GmbH, Jakob-Haringer-Strasse 8, 5020 Salzburg, http://www.takefive.co.at

[SNIF96] „*SNiFF+, the industrial-strength programming environment for Unix C and C++ development: User's Guide and Reference*", in [Take96]