BlueJ Blackbox Data Collection

Researchers' Handbook (version 1.7, ? January 2016)

Getting Started

This document acts as a manual for the BlueJ data collection project, “Blackbox”. It is intended to explain, in detail, the schema of the collected data, and how the data relates to the BlueJ IDE. It assumes a basic familiarity with BlueJ’s capabilities, such as the debugger, codepad, object bench and so on.

Chapter 1 explains the concepts, assumptions and caveats associated with the data recording. It is important to read this chapter before carrying out any detailed analysis, so that you do not proceed with false assumptions. Chapters 2 and 3 contain technical detail on the data schema.

Chapter 5 contains details on how to actually access the data (MySQL details, etc), and chapter 6 contains the data-use policies which we expect all researchers to read. Finally, chapter 8 has details on the example application we have provided, and chapter 9 has some details on post-processing we have in place.

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Chapter 1

Concepts and Caveats

There are several concepts involved in the Blackbox project, and it is very important when doing analysis on the data to understand the concepts involved, and particularly the limitations of the data collection. If you naively assume that one virtual user is one real person, you may draw false conclusions from your analysis.

1.1 Users

BlueJ stores its properties file in a per-user location. For example, on Linux, it uses `~/.bluej/bluej.properties`, whereas on Windows 7 it is (on a typical home installation) `C:\Users\Joe\bluej\bluej.properties`.

This properties file is the only mechanism that BlueJ has to have any sense of identity. If two physical people use the same account, they will appear to BlueJ as a single user (this is still quite common on home Windows systems). If someone uses BlueJ on a university machine, and on a laptop, and on a home machine, they will appear to be three users. If the computer is set up to not maintain a user's profile correctly (e.g. a school system which wipes a user's profile on logout – we know some systems do this!), they will get a new profile each time they load BlueJ, and thus will always appear to be a new user. If the same bluej.properties file is shared between many physical users (e.g. they all get the same profile on login), they will all appear to be the same user (operating with many parallel sessions).

The user's unique identifier or opt-out preference is stored in this properties file. Thus the concept of a "user" is tied to the properties file. It is important to understand this when reasoning about users.

1.2 Projects

BlueJ deals with projects. A project is a directory with a BlueJ project file, and source files (and class files, and maybe a README, and whatever else the user stores in the directory). In Blackbox terms, projects are associated with particular user ids. They are identified only by the associated user, and their full path (hashed, for anonymity).

If a user makes a copy of a project and opens it, it will appear to be an entirely separate project (though you could post-process the data to see that the project has the same source code as another of the user's projects). If a user has the project on a USB memory stick, and it gets assigned a different drive letter next time they plug the stick in, the project will appear to be different. If a person loads the project from two different machines, even if the project has the same path on both machines, they will appear as separate projects belonging to separate users.

1.3 Packages

A project will have at least one package (the unnamed, default Java package), and potentially many. BlueJ displays a main interface window for each package that the user opens within the project. Thus there can be as many codepads as there are packages in the project. Some BlueJ features are per-package (codepad, object bench), while others are per-project (debugger, version control).

1.4 Sessions

Each time that BlueJ is opened, we deem the time from the opening to the closing to be "a session". Each time BlueJ is loaded, the client generates a unique session identifier to label all events from that session with.

If a user loads many projects at once in a single instance of BlueJ, these will all count as one session. If a user loads BlueJ twice in parallel (e.g. by clicking the shortcut too many times), both sessions will be recorded. But for this reason, it is usually a good idea to use sessions and projects to process events, rather than solely relying on event timestamps (which will interleave events from the two sessions). If a user accidentally closes BlueJ and immediately re-opens it, that will count as two sessions (though you could spot this using the timestamps on the events in post-processing).

There is no time limit on how long a session can last – the client-generated identifier is relied upon to differentiate sessions. It is possible for a session to last for weeks if a user keeps BlueJ open on their always-on machine. One potentially common case is that if a user never shuts down their laptop, and instead always makes it sleep, the session can last for a long time if they leave BlueJ open on their laptop (but see Section 1.7 on page 8 for why they may not send us much data this way, if the session stops sending data at any point).

1.5 Participants

All the data in the BlueJ data collection is anonymous. Part of the intention of the project is to support local experiments, where you, the local researchers, collect additional information about users. The additional information should be held by you, and the experiment approved and conducted according to your local ethics committee.

To allow you to link your participant data with our data, we have a mechanism for BlueJ users to specify an experiment identifier and a participant identifier (strings, up to 32 characters). These two identifiers should be assigned by you, the local researcher. We request that you assign an experiment identifier that is unlikely to clash with other researcher's identifiers. The participant identifier is entirely up to you, although we would expect that you use a generic identifier (e.g. a number), and that you hold the mapping between the participant's real identity and the participant number, as is standard practice.

(That is: do not ask the participants to store their name, or university login or similar, in the participant identifier.)

As described in section Section 3.11 on page 33, you will be able to retrieve participant identifiers for a specific experiment identifier, and retrieve session data for known experiment identifiers and participant identifiers. This means that you will not be able to see experiment or participant identifiers for experiments for which you do not know the identifier. This is deliberate, to help protect information about experiment participation and participant identification.

1.6 Events

The BlueJ client sends a stream of events to the BlueJ server, which acknowledges them. Ultimately, all the information recorded on the server came by way of these discrete events. Things like users or sessions are reconstructed from the individual events that have been sent. Every event that the server receives, without exception, is recorded with an entry in the `master_events` table (see chapter 2 on page 11).

1.7 Interrupted Connections

There are potential problems with missing events or entire sessions in the event stream for a user. You should never assume you have a user's complete history of interaction with BlueJ. Notably, entire sessions might be missing due to users using BlueJ without an internet connection (e.g. on an aeroplane). Similarly, you should not assume that you can see all interactions with a project – source code could be edited outside BlueJ.

Within a session, you can assume that you have all events, sequentially consistent, from the first `bluej_start` event, up until the last event that is recorded in the session. This may not be the actual final event that the user performed in their real session – the user's internet connection may drop, or BlueJ may crash or get killed before a batch of events is sent, and so on. But there will never be a "hole" in the middle of a session where events are lost, then resumed again. **Any event that fails to send will cause the BlueJ client to stop sending for the rest of the session** – each event is only sent once the event before it in the session has succeeded.

It is a deliberate decision to not attempt to resume sending data if previous data has failed to send. Part of this decision is technical – we do not want to keep retrying a send if the user has no Internet connection (or if our own server is inaccessible for some reason), and we do not want to cache lots of events on the client in the hope that the connection one day re-appears.

The other reason is that analysis becomes much harder if events within a session may be missing – data consistency is a nightmare. For example, you may see that a user has closed an inspector, but not how that inspector appeared. Or you may see an execution take place, but not know what breakpoints are set in the code. If gaps are allowed in the event stream, we would have to send a lot more state information with each event to make analysis possible.

1.8 Spam

The BlueJ data collection project server is an open web server to which anyone can submit, and the BlueJ client is an open-source program. There is no technical way to guarantee that the data coming in is from an unmodified BlueJ client – it could be modified, or it could simply be made-up spam data being submitted. It remains to be seen whether this will be an issue.

1.9 Source Code Consistency

When a package is opened, the full state of the source code of the project is sent to the server. Similarly, when a class is added to the project while BlueJ is running, the full code is sent. For all other edit events within a session, a diff is sent between the last successfully sent source code state (during that session) and the new state. Using a diff minimises the amount of data sent and stored.

You can assume that the source code diffs within a session are consistent. However, you should not assume that you have seen the full state of the source code between sessions. Source code may be edited outside BlueJ or may be edited by BlueJ when the user has no Internet connection. You should be able to detect this by comparing the source code state between the end of one session and the start of the next.

1.10 The Debug VM

BlueJ has two virtual machines. One, generally known as the server VM, handles:

- The graphical interface
- Code editing
- Compilation

No user code is ever run on the server VM. All user code is run on a second VM, known as the client VM or the debug VM. (There is only ever one debug VM at a time, for each project.) So things like:

- Object construction
- Method invocations
- Codepad use
- JUnit tests

Are all run on the debug VM. When the debugger is used, the interface and control code are in the server VM, using hooks into the debug VM to do stepping and so on. Whenever user code is executed, it is possible that the result is that the debug VM terminates, but this does not mean that BlueJ has exited. User code that runs forever will not interrupt BlueJ, but will prevent further use of the debug VM.

1.11 Extensions

BlueJ has an extension mechanism that allows programmatic operation of BlueJ from third-party extensions. (Not to mention that BlueJ is open-source, anyway.) The extensions can trigger many of the events described in this document. We do not annotate which events are triggered by extensions and which are not. This annotation would be a lot of extra technical work, and probably for not much purpose, since we do not believe many BlueJ users use extensions that will trigger these events.

We do record which extensions are loaded in the blackbox data, so you can use this to rule out any extensions which could be problematic (or more likely, to whitelist extensions that are not an issue).

1.12 Database Structure and Notes

The database is used as a persistence layer by our Ruby on Rails server, which uses an object-store model. Every table in the database, except many-to-many link tables, has an integer `id` field which acts as a primary key. Relations in the database are handled in two ways:

1. When the destination table is fixed and known – e.g. a master event has a user – there is a field in the `master_events` table named `user_id` which links to the `users` table.
2. When the destination table may vary, e.g. a master event has a subordinate "event" record which may be from one of many tables, there is both an `event_id` and an `event_type` field. The `event_type` field contains an uppercased camel-cased, non-underscored[1] version of the table name. So if a particular master event links to a compile event, the `event_type` field will have `"CompileEvent"`, and the `event_id` will correspond to an `id` in the `compile_events` table.

1.12.1 Interning

There are some tables in the database which are likely to feature the same information over and over again, such as the installation details. When the server comes to add a record to these tables with duplicate data to a previous record, it *may* reference the existing record instead, to save space, like interning strings. This is a performance optimisation that should have no effect on the semantics. Tables that do this are tagged as such.

[1] This is Rails' doing – don't ask.

Chapter 2

Master Events Table

The master events table is the place where all events are entered. There are lots of different types of events that can be received, each with a variety of different data, but all of them get one entry in the `master_events` table, with links to other tables where necessary.

Table 2.1: Schema for the `master_events` table.

Field Name	Type	Can Be Null?
`id`	`bigint`	`NO`
`client_address_id`	`bigint`	`NO`
`created_at`	`datetime`	`YES`
`event_id`	`bigint`	`YES`
`event_type`	`varchar(32)`	`YES`
`name`	`varchar(32)`	`NO`
`package_id`	`bigint`	`YES`
`participant_id`	`bigint`	`YES`
`project_id`	`bigint`	`YES`
`sequence_num`	`int`	`NO`
`session_id`	`bigint`	`NO`
`source_time`	`varchar(32)`	`NO`
`user_id`	`bigint`	`NO`

The most important field in the table is the `name` field, which describes which kind of event it is, and determines which of the other fields will be present. The possible values for the `name` field are given in Table 1 on page 5.

Each master event has links (as per Section 1.12 on page 10) to other tables:

- `user_id` – present for all events
- `session_id` – present for all events
- `project_id` – present for all events except `"bluej_start"` and `"bluej_finish"`
- `package_id` – present for some events (see further details below).

- event_id, event_type – present for some events (see further details below).
- participant_id – present for all events, if the user currently has participant information specified.
- client_address_id – present for all events.

The created_at field is a server-side, trustworthy datestamp of when the event was received. The source_time is the client-side time, which is likely (but not guaranteed) to be sequentially consistent, but should not be trusted to be accurate.

The sequence_num field is provided by the client to make sure events are received in correct sequence (within a given session). The server ensures that the sequence numbers are valid (i.e. that they begin at 1, and each subsequent event increments the sequence number by 1).

The participant_id field links to a hidden participants table. If you want to investigate this information, see Section 3.11 on page 33 on how to access this information.

The client_address_id field links to a hidden client_address table. Details on using client_address_id to get at user locations are given in chapter 4 on page 36.

The subsequent sections in this chapter describe the different possible values for the master_events.name field, and what that means for the other fields, especially what is linked to by the event_id and event_type fields. Each section title has a string, which is the value of the name field.

2.1 Start/Finish Events

Two bookend events are sent, one when BlueJ starts (before it has loaded up a project or done anything) and one when BlueJ exits (after it has closed all projects and finished everything). The data will likely contain more start events than finish events, for reasons explained in Section 1.7 on page 8.

2.1.1 "bluej_start" and "bluej_finish"

These two events have no extra accompanying event. They have no project_id and no package_id. However, the "bluej_start" event will have zero or more attached entries in the extensions table (see Section 3.4 on page 29) that link back to this master event – these are extensions loaded from the system directories.

The "bluej_start" event will always create a new entry in the sessions table (see Section 3.2 on page 28) – the installation details for this copy of BlueJ will be recorded there.

2.2 Project Events

When a project is opened or closed in BlueJ, corresponding events will be sent. See Section 1.2 on page 6 for details on how projects are distinguished. A project-open event will be followed by at least one package-open event.

2.2.1 "project_opening"

This event has no package_id.

This event will have zero or more entries in the extensions table (see Section 3.4 on page 29) linking back to this event, which represent extensions loaded from this project's directory.

2.2.2 "project_closing"

This event will no attached data, and will have no package_id.

2.3 Package Events

When a package is opened or closed in BlueJ, a corresponding event is generated. Note that each window in BlueJ actually belongs to a package.

2.3.1 "package_opening"

This event will have a package_id.

The event will have zero or more entries in the source_histories table (see Section 3.8 on page 31) that link back to this event. These represent the state of the files as the project is opened (as a complete snapshot, not a diff).

The event will link to an entry in the source_hashes table (event_type will be "SourceHash"), which will contain a hash of the source code in the package. The exact details of the hash are unimportant, but this hash can be used to quickly narrow down likely duplicate projects (for example, spotting the starting projects from the BlueJ book).

Table 2.2: Schema for the source_hashes table. This table may be interned, see Section 1.12.1 on page 10.

Field Name	Type	Can Be Null?
id	bigint	NO
source_hash	varchar(64)	YES

2.3.2 "package_closing"

This event will have a package_id, but no other associated data.

2.4 Editing

We do not capture all the different edit operations (e.g. paste, indent), we only capture the resulting effect on the source code.

2.4.1 `"edit"`

This event will have a `package_id`, pointing to the package of the class that is edited.

This event is the central editing event in BlueJ. These events are recorded when multiple lines are edited at once (e.g. via paste, or deleting a selection, or so on), or a single line has been edited and the caret has now left that edited line. An edit event is not generated by every single keystroke.

There is currently no guarantee as to how edits are grouped together into a single edit event (e.g. highlighting a selection and then pasting may appear as one event or two events, auto-indent may appear as one edit or several edits, and many other such examples), but an edit event will never span a compiler event, and all edits will be flushed before a compile event.

The event will always have exactly one associated entry in the `source_histories` table (see Section 3.8 on page 31), which will be a `"diff"` event.

2.4.2 `"file_add"`

This event will have a `package_id`, which indicates which package the file was added to.

This event is fired whenever a class is added to the BlueJ project. This may be via the New Class menu item, or via the Import Class menu item, or via version control.

The event will always have exactly one associated entry in the `source_histories` table (see Section 3.8 on page 31), which will be a `"complete"` event.

2.4.3 `"file_delete"`

This event will have a `package_id`, which indicates which package the file was deleted from.

This event is fired whenever a class is removed from a BlueJ project. This may be via the interface, or via version control.

The event will always have exactly one associated entry in the `source_histories` table (see Section 3.8 on page 31), which will be a `"file_delete"` event.

2.4.4 `"rename"`

This event will have a `package_id`, which indicates which package the file was renamed in.

This event is fired whenever a class is renamed in a BlueJ project. A rename occurs in BlueJ when a Java file is saved, and is parseable, and has a different top-level class name to the name of the file. At this point, BlueJ silently renames the file to match the class name. But note that until this save occurs, many more edits may take place, so the rename of the file may appear some time after the actual relevant source code edit takes place.

The event will always have exactly one associated entry in the `source_histories` table (see Section 3.8 on page 31), which will be a `rename` event.

2.4.5 `"stride_converted_to_java"`

This event will have a `package_id`, which indicates which package the file was renamed in.

This event is fired when the user permanently converts a Stride class to Java.

The event will always have exactly one associated entry in the `source_histories` table (see Section 3.8 on page 31), which will be a `stride_to_java` event.

2.4.6 "file_open", "file_select" and "file_close"

This event will have a package_id, which indicates which package the relevant file was in.

These three events will only be recorded in versions of BlueJ from 3.2.0 onwards, and in Greenfoot.

These three events do not affect the content of a file, but instead correspond to GUI actions: opening a source file for editing, focusing the editor of a source file, and closing a source file. A select or close should always be preceded in a session by an open event for the file, and an open event is typically immediately followed by a select event (but this may not always be the case, if the editor opens in the background). It should not be possible for two open events to occur for a file without a close event inbetween, but don't take that as a cast-iron guarantee.

A select event occurs when the user switches tab in an already-focused tabbed editor window, and for the current tab when the editor window receives the focus.

A close event occurs when the tab is closed, either individually or because the tabbed editor window was closed. It may be possible for a BlueJ session to finish without all editors being closed first.

Each event will always have exactly one associated entry in the source_files table (see Section 3.7 on page 31), indicating the relevant file.

2.5 Compilation

2.5.1 "compile"

This event will have a package_id if and only if all the compiled files were in the same package. However, having a package_id does not necessarily indicate that the user asked for the whole package to be compiled.

This event occurs whenever a compilation of the user's classes is triggered. (This does not include things like codepad interactions).

This master event will always have event_type set to "CompileEvent", and event_id will reference an entry in the compile_events table (see Section 2.5.4 on page 16). (In turn, that entry in the compile_events table, will be linked to by one or more compile_inputs and zero or more compile_outputs, but see the compile_events table (see Section 2.5.4 on page 16) for more details.)

Note that compilation will undergo an overhaul in BlueJ 3.2.0, and has already changed in Greenfoot 3.0.0. In Greenfoot 3.0.0 onwards, compilation is performed automatically in a number of different cases. This is/will be documented in the new reason column in the compile_events table (see Section 2.5.4 on page 16).

2.5.2 "shown_error"

Since BlueJ 3.2.0 (and in Greenfoot 3.0.0 onwards), error display has changed. Errors are no longer shown one at a time in BlueJ in the bottom pane. Instead, red underlines throughout the code (in Java and Stride editors) indicate an error. So when compilation has finished, the user will see one red underline for each error located. (Where error locations overlap, only one is shown, but due to technical difficulties we do not record this in Blackbox; the user will see a red underline at the location, but which one is not very important.) All errors are then marked as shown, but only in the sense that the red underline is shown.

For these software versions, an "shown_error" master event is generated when the user is actually shown the text of the error message, by using keyboard or mouse focus to hover in the location of the red underline. Each error (which is stored in the compile_outputs table (see Table 2.5.4 on page 17), below) will only get an "shown_error" event generated once, the first time it is shown. If another compilation occurs, an error with the same text at the same location will get a new entry in the compile_outputs table (see Table 2.5.4 on page 17), and thus be considered a new error.

The sub_event_type of "shown_error" events will be "CompileOutput" and the sub_event_id will contain an id from an entry in the compile_outputs table (see Table 2.5.4 on page 17).

In Stride, when an error is shown, it may be presented along with a list of quick fixes (e.g. correcting a typo in a variable name). In this case, there will be entries recorded in the quick_fixes table (see Table 2.5.4 on page 18) table. If one of these fixes is executed it will lead to a "fix_executed" event being generated.

2.5.3 "fix_executed"

As described in the previous section, a Stride error may be shown along with some suggested quick fixes. These are recorded in the quick_fixes table (see Table 2.5.4 on page 18). If the user selects to execute one of the quick fixes, a "fix_executed" master event is generated, where the sub_event_type is "QuickFix" and the sub_event_id is the id of an item in the quick_fixes table (see Table 2.5.4 on page 18).

2.5.4 Related Tables

The compile_events table records whether the compilation was a success (i.e. no errors – but there could be warnings) or not.

Table 2.3: Schema for the compile_events table.

Field Name	Type	Can Be Null?
id	bigint	NO
reason	varchar(255)	YES
success	tinyint	NO

The compile_events may then be linked to by entries in the compile_inputs and compile_outputs table. Note that the reason column is not yet added to the main Blackbox project, but will be soon. It is available for Greenfoot recordings. Possible values for reason are:

- "early" – A check in Stride for errors that can be spotted without full javac compilation, such as a slot being empty or having a parse error.
- "late" – A post-compilation check in Stride for errors which will have shown a compiler error, but for which we can show a more helpful error message, for example if the user has typoed a variable name.

- "invoke" – A compilation of some generated code, required to execute a user's invocation (e.g. when they right click on an object in the object bench to call a method).
- "rebuild" – A full rebuild of a project
- "extension" – Compilation was requested by an extension. This includes some cases in Greenfoot where the system requests compilation.
- "loaded" – Compilation triggered after loading a project or a new class.
- "modified" – Compilation caused by modifying code. This is the most common case.
- "new_class" – Compilation which happens after creating a new class.
- "user" – Explicitly requested compilation by the user. This can still happen for example in the Java editor, if the user modifies a line of code without moving the caret away, and then clicks the Compile button.

Table 2.4: Schema for the compile_inputs table.

Field Name	Type	Can Be Null?
id	bigint	NO
compile_event_id	bigint	NO
source_file_id	bigint	NO

The compile_inputs table is really just a link table, linking one compile event to many source files.

Table 2.5: Schema for the compile_outputs table.

Field Name	Type	Can Be Null?
id	bigint	NO
compile_event_id	bigint	NO
end_column	int	YES
end_line	int	YES
is_error	tinyint	NO
message	varchar(255)	YES
session_id	bigint	YES
session_sequence	int	YES
shown	tinyint	NO
source_file_id	bigint	YES
start_column	int	YES
start_line	int	YES
xml_end	int	YES
xml_start	int	YES
xpath	text	YES

The compile_outputs table has an entry for each warning and each error that occurred. Note that these warnings and errors are reported from the standard Java compiler from the JDK. However, BlueJ may alter the format of some messages, and will only display at most one error, and may ignore some warnings. The message recorded here is the altered format, and the shown flag indicates whether or not this error or warning was actually displayed to the user (but read on). The is_error flag indicates if it was an error (otherwise it was a warning), the message field shows the text that would be displayed to the user.

For Java errors, the line and column fields indicate the error's location, as reported by the compiler (lines and columns begin at 1, not 0), and the source file referenced is of course the Java file. For pure-Stride errors (e.g. early errors, where a slot is marked as an error for being empty, even without Java compilation), the start/end line/column fields are null, and the source file points to the Stride file. Instead, the xpath column gives an XPath path in the Stride source to the item causing an error, and xml_start and xml_end give start/end character locations within that item. For Java errors in Stride classes which occur in compilation, the error points to the Java file, fills in the start/end line/column fields and fills in the xpath, xml_start and xml_end fields.

Since BlueJ 3.2.0, which shows errors as a red underline, all errors are marked as shown (unless there is an unexpected problem, such as an invalid location) in this table, but see the details on the "shown_error" event above.

Table 2.6: Schema for the quick_fixes table.

Field Name	Type	Can Be Null?
id	bigint	NO
compile_output_id	bigint	YES
display	varchar(255)	YES
fix_order	int	YES

See earlier sections for the purpose of this table. The display field gives the text of the quick fix, the fix_order gives the index in the list (0 being first item) as it was presented to the user, and the compile_output_id points to the error (in the compile_outputs table (see Table 2.5.4 on page 17)) which these fixes were shown for.

2.6 Miscellaneous Events

2.6.1 "resetting_vm"

This event has no package_id, because the debug VM is per-project.

The event occurs when the VM is restarted due to an explicit user request (via a menu). Although it has the same effect as the debugger_terminate event, it is recorded separately.

2.6.2 "terminal_open" and "terminal_close"

These events have no package_id, because there is only one terminal per project.

These events occur when the terminal window is shown or closed. It may be shown either due to explicit triggered by the user (via a menu item) or because output has been generated by the debug VM (which causes the terminal to be shown if it is not already shown).

2.7 Debugger Events

Some, but not all, debugger events link to the debugger_events table, which can store thread names.

Table 2.7: Schema for the debugger_events table.

Field Name	Type	Can Be Null?
id	bigint	NO
thread_name	varchar(255)	NO

Other debugger events will link to the breakpoints table, which references a source file and a line number (line numbers begin at 1, not 0).

Table 2.8: Schema for the breakpoints table. This table may be interned, see Section 1.12.1 on page 10.

Field Name	Type	Can Be Null?
id	bigint	NO
line_number	int	YES
source_file_id	bigint	YES

2.7.1 "debugger_open" and "debugger_close"

These events have no package_id (because the debugger is per-project).

These events occur when the debugger window is opened or closed. The debugger may open because the user explicitly opened the debugger (via the menu), or because the code has hit a breakpoint. No further data is attached.

2.7.2 "debugger_terminate"

This event has no package_id (because the debugger is per-project).

This event occurs when the user clicks the Terminate button in the debugger. It kills the current debug VM (which will be subsequently restarted, but will be idle), and thus all currently-executing user code. No further data is attached.

2.7.3 "debugger_continue"

This event has no package_id (because the debugger is per-project).

This event occurs when the user clicks the Continue button in the debugger on a thread which is currently not executing. It makes the selected thread resume execution.

The event_type field will always be "DebuggerEvent", and the event_id will reference an entry in the debugger_events table (see Section 2.7 on page 19). The debugger_events entry will have the thread_name filled in, but there will be no further information.

2.7.4 "debugger_hit_breakpoint", "debugger_stepinto", "debugger_stepover" and "debugger_halt"

These events have no package_id (because the debugger is per-project).

These events occur when the user code in a thread becomes suspended, for different reasons. The debugger_hit_breakpoint event indicates that the suspension was due to hitting a breakpoint, while debugger_stepinto and debugger_stepover indicate that the thread has just completed a step request. (If a step request ends on a breakpoint, only the breakpoint is reported.) The debugger_halt is reported in the remaining case, that the user has clicked the Halt button in the debugger (which pauses execution of the thread).

For these events, the event_type field will be always be "DebuggerEvent", and the event_id will reference an entry in the debugger_events table (see Section 2.7 on page 19), which will have the thread_name filled in.

There will also be one or more entries in the stack_entries table (see Section 3.9 on page 32) which will link to the debugger_event (not the master event) via the fields in that table stack_entries.sub_event_type and stack_entries.sub_event_id.

2.7.5 "debugger_breakpoint_add" and "debugger_breakpoint_remove"

These events do have a package_id, which indicates the package that the involved source file is in.

These events occur when a user adds/removes a breakpoint. The event_type field will be "Breakpoint" and the event_id will reference an entry in the breakpoints table (see Table 2.7 on page 19), which details the location of the breakpoint.

2.8 Codepad

2.8.1 "codepad"

These events have a package_id, which indicates which package window the codepad being used corresponds to – more by accident than by design, each package window has its own codepad.

These events occur each time that the user types something into the codepad window, presses return and gets a response. The codepad event links to an item in the codepad_events table (the event_type will be "CodepadEvent", and the event_id will reference an entry in the codepad_events table).

Table 2.9: Schema for the codepad_events table.

Field Name	Type	Can Be Null?
id	bigint	NO
command	text	NO
error	varchar(255)	YES
exception	varchar(255)	YES
outcome	varchar(255)	YES
result	varchar(255)	YES

The outcome field indicates what happened when the code was executed. An outcome of "success" indicates that the code successfully compiled, and executed without throwing an exception or without exiting the VM early. In this case, the fields command and result will be filled in with the input and output respectively.

The outcome field being "error" indicates a compiler error occurred, or that the VM exited during execution: the command and error fields will be filled in with the input and error respectively. The outcome field being "exception" indicates an exception occurred: the command and exception fields will be filled in with the input and exception respectively.

2.9 Method Invocation

Method invocations reference the invocations table.

Table 2.10: Schema for the invocations table.

Field Name	Type	Can Be Null?
id	bigint	NO
bench_object_id	bigint	YES
code	text	YES
compile_error	varchar(255)	YES
exception_class	varchar(255)	YES
exception_message	text	YES
result	varchar(255)	YES
session_id	bigint	YES
session_subid	int	YES
test_id	bigint	YES
type_name	varchar(255)	YES

2.9.1 "invoke_method"

This event has a package_id field, which indicates which package window the method was invoked from. The method invoked is not guaranteed to be in this package, as the user may have used the call-library-class function to invoke a method on String, or any other class.

This event occurs when the user interactively (i.e. via a menu) invokes a static method on a class or an instance method on an object on the object bench, or uses the call-library-class menu function. The event_type will always be "Invocation" and the event_id will reference an entry in the invocations table.

In the invocations table, the code field will have the code that was generated to execute the invocation. The result field will have the result, which will be one of:

- "success" – method was invoked successfully, the bench_object_id field will link to an entry in the bench_objects table (see Section 3.10 on page 33) – if the result was added to the object bench, i.e. if the method was a constructor – and the the type_name field will have the type of the result.
- "compile_error" – an error occurred while compiling the generated code (e.g. because the user entered invalid parameters), the compile_error field will have the full message.
- "terminated" – the VM terminated during execution, e.g. due to a System.exit call.
- "exception" – an uncaught exception occurred during execution. The exception_class field will have the class of the exception, the exception_message field will have the message, and there will be associated entries in the stack_entries table (see Section 3.9 on page 32) linking to this event (the invocations entry, not the master_events entry).

2.10 Inspector

The inspector events reference the inspectors table.

Table 2.11: Schema for the inspectors table.

Field Name	Type	Can Be Null?
id	bigint	NO
bench_object_id	bigint	YES
class_name	varchar(255)	YES
display_name	varchar(255)	YES
session_id	bigint	NO
static_class	varchar(255)	YES
unique	varchar(32)	YES

2.10.1 "inspector_show" and "inspector_hide"

This event has a package_id field, which indicates which package window the inspection was invoked from. This is transitive, for occasions where users inspect an object in an inspector.

Both of these events link to an entry in the inspectors table: the event_type field will be "Inspector", and the event_id field will be a reference to an entry in the inspectors table.

For the inspector_show event, there are two cases:

1. The inspection was on a class. In this case, the `static_class` field will have the name of the class, and the other fields will be empty.

2. The inspection was on an object. In this case, the `class_name` field indicates the type of the object, the `display_name` (whatever is displayed on the left-hand side of the title in the object inspector) will be present, and the `bench_object_id` will link to a `bench_object` if the inspected object is on the object bench (regardless of whether that was how this object was reached for inspection).

In both cases, the `unique` will have some string that uniquely identifies an inspector within the session (this is useful during collection, and is of no use afterwards, because the record will be unique per inspector).

For the `inspector_hide` event, there will be a link back to the `inspectors` entry that was hidden.

2.11 Object Bench

2.11.1 "bench_get"

This event has a `package_id`, linking to which package the object bench is associated with.

The event occurs when a user is inspecting something (an object, class, or method result) and uses the Get button to transfer the object to the object bench – or when they drag a result object over from the codepad.

The event links to an entry in the `bench_objects` table (see Section 3.10 on page 33) (`event_type` will be `"BenchObject"`), indicating the object which was added to the bench.

If a test was being recorded at the time, the `bench_objects` entry will have a link to the `tests` table, indicating which test was being recorded.

2.11.2 "remove_object"

This event has a `package_id`, linking to which package the object bench is associated with.

The event occurs when a user explicitly removes an object from the object bench.

The event links to an entry in the `bench_objects` table (see Section 3.10 on page 33), indicating the object which was removed from the bench.

2.12 Executing Tests

2.12.1 "run_test"

This event has a `package_id`, linking to which package the test class is in.

The event occurs when the user executes a test, either by using the Test All command, or individually invoking a test. Each test that is run will get its own `run_test` event.

The event links to an entry in the `test_results` table.

Table 2.12: Schema for the test_results table.

Field Name	Type	Can Be Null?
id	bigint	NO
class_name	varchar(255)	NO
exception_message	text	YES
exception_trace	text	YES
method_name	varchar(255)	NO
result	varchar(16)	NO
run_time	int	NO

The class_name and method_name fields describe which test method was executed. The run_time field has the number of milliseconds that the test took to execute. The result field will have one of three values:

- "success" – the test passed, no further information is supplied.
- "failure" – the test failed with a failed assertion. The exception_message and exception_trace fields have more information.
- "error" – the test failed due to an exception (other than an assertion). The exception_message and exception_trace fields have more information.

2.13 Recording Tests

2.13.1 "start_test", "cancel_test" and "end_test"

This event has a package_id, linking to which package the test class is in.

These events relate to recording a test. The user performs various actions, and at the end of the recording, code is generated in a new test method to mirror the user's actions. Each of these events links to an entry in the tests table.

Table 2.13: Schema for the tests table.

Field Name	Type	Can Be Null?
id	bigint	NO
method_name	varchar(255)	YES
session_id	bigint	YES
session_subid	int	YES
source_file_id	bigint	YES
status	varchar(255)	YES

Each entry in the tests table is one attempt (either ongoing, successful, or aborted) at recording a test. The source_file_id links to the source file in which the final test method (named according to method_name) will be generated. The status field will be "Recording", "Recorded" or "Cancelled", according to the test's current status.

The session_subid field is an internal identifier used by the client to identify tests, and can be ignored. The session_id field links to the session in which the test was recorded.

2.13.2 "assertion"

This event has a package_id, linking to which package the test was recorded for.

The event links to an entry in the assertions table.

Table 2.14: Schema for the assertions table.

Field Name	Type	Can Be Null?
id	bigint	NO
assertion	varchar(255)	YES
invocation_id	bigint	YES
param1	varchar(255)	YES
param2	varchar(255)	YES
test_id	bigint	YES

The assertions table links to an entry in the invocations table that the assertion relates to, and to an entry in the tests table (see Section 2.13.1 on page 24) for the test which this assertion will be recorded into.

The assertion field is the JUnit function that will be recorded, e.g. "assertEquals". The param1 field and param2 fields are the other parameters to the assertion.

2.13.3 "bench_to_fixture" and "fixture_to_bench"

These events have a package_id, linking to the package in which the object bench and test class are.

These events occur when the user captures all the objects on the object bench and turns their creation into a test setup phase (bench to fixture) or runs a test setup to put the objects back onto the object bench (fixture to bench).

These events link to an entry in the fixtures table.

Table 2.15: Schema for the fixtures table.

Field Name	Type	Can Be Null?
id	bigint	NO
source_file_id	bigint	YES

Each entry in the fixtures table links to the source file holding the test class involved. A new fixture will be created for each "bench_to_fixture" or "fixture_to_bench" event.

Table 2.16: Schema for the bench_objects_fixtures table.

Field Name	Type	Can Be Null?
bench_object_id	bigint	YES
fixture_id	bigint	YES

The bench_objects_fixtures table is a simple link table that links object bench objects to test fixtures. In the case of "bench_to_fixture", these objects are already on the bench and will be removed by this event. In the case of "fixture_to_bench", these objects will be added to the bench, and are created by this event.

2.14 Version Control

Table 2.17: Schema for the version_control_events table.

Field Name	Type	Can Be Null?
id	bigint	NO
protocol	varchar(255)	YES
vcs_type	varchar(255)	NO

Table 2.18: Schema for the version_control_files table.

Field Name	Type	Can Be Null?
id	bigint	NO
master_event_id	bigint	NO
source_file_id	bigint	NO
status	varchar(255)	YES

Each version control event has an associated entry in the version_control_events table, with a vcs_type (built-in options: "CVS", "SVN") and a protocol (e.g. "http" or "svn+ssh").

2.14.1 "vcs_history" and "vcs_share"

These events get an associated entry in the version_control_events table, but no more data than that.

2.14.2 "vcs_commit" and "vcs_update"

These events get an associated entry in the version_control_events table, and also zero or more entries in the version_control_files table, with just the file field filled in.

2.14.3 "vcs_status"

This event gets an associated entry in the version_control_events table, and also zero or more entries in the version_control_files table, with the file field filled in, and the status field filled in.

2.15 Greenfoot Events

Data collection is not enabled for the mainstream release of Greenfoot, so these events will only occur in specialised builds of Greenfoot used for research projects. They will not occur in the main Blackbox data set, but are documented here for completeness.

2.15.1 "greenfoot_window_activated"

Event occurs when the main Greenfoot window (with the world display) is focused, which will cause Greenfoot to attempt to instantiate the world. There are no further details associated with this event.

Chapter 3

Other Database Tables

3.1 Users

Table 3.1: Schema for the users table.

Field Name	Type	Can Be Null?
id	bigint	NO
created_at	datetime	YES
last_update	datetime	YES
uuid	varchar(64)	NO

The uuid field is the unique user identifier, as discussed in Section 1.1 on page 6. The created_at field shows the time that this user record was created (the first time their UUID was seen), and the last_update field shows the last time that data was entered for this user.

3.2 Sessions

Table 3.2: Schema for the sessions table.

Field Name	Type	Can Be Null?
id	bigint	NO
created_at	datetime	NO
identifier	varchar(64)	NO
installation_details_id	bigint	NO
last_sequence_id	int	NO
participant_id	bigint	YES
user_id	bigint	NO

Each session is associated with a specific user. There is a link to the installation_details table (see Section 3.3 on page 29) – specifically, the entry that accompanied the bluej_start event that began this session. The identifier and last_sequence_id fields are used for internal book-keeping, and can be ignored. There is a link to an entry in the participants table (see Table 2 on page 12) if this user had participant information filled in during the last event that was added to this session.

3.3 Installation Details

Table 3.3: Schema for the installation_details table. This table may be interned, see Section 1.12.1 on page 10.

Field Name	Type	Can Be Null?
id	bigint	NO
bluej_version	varchar(255)	YES
interface_language	varchar(255)	YES
java_version	varchar(255)	YES
operating_system	varchar(255)	YES

The installation_details table contains the BlueJ interface_language – the possible options are listed in the bluej.defs file. The operating_system field glues together (with slashes) the output of Java's System.getProperty call for the keys "os.name", "os.arch" and "os.version". The bluej_version is the version of BlueJ they are running, and java_version is the Java version being used to run BlueJ.

3.4 Extensions

Table 3.4: Schema for the extensions table.

Field Name	Type	Can Be Null?
id	bigint	NO
master_event_id	bigint	NO
name	varchar(255)	NO
version	varchar(255)	NO

The extensions table contains the (self-reported) name and version of a BlueJ extension. BlueJ comes with the submitter extension installed by default.

3.5 Projects

Table 3.5: Schema for the `projects` table.

Field Name	Type	Can Be Null?
`id`	`bigint`	NO
`name`	`varchar(255)`	NO
`path_hash`	`varchar(255)`	YES
`user_id`	`bigint`	NO

Each project is associated with a specific user. A project is stored with the md5 hash of its full path (`path_hash`), to try to identify the project across multiple sessions. For anonymity purposes, the full path is not sent to the server (because it will typically have the user-name in the path), but the directory name of the project (`name`) is sent, as this may be informative.

Note that the `path_hash` uses the full path as read by the client. It is possible on a case-insensitive operating system for a user to change the case of their path (e.g. change `C:\BLUEJPROJ\proj1` to `C:\BlueJproj\proj1`) and thus alter their `path_hash` despite not really changing the effective location. Additionally, on an OS with symlinks, a user might access the same project from two different paths. We believe both cases are relatively rare.

3.6 Packages

Table 3.6: Schema for the `packages` table.

Field Name	Type	Can Be Null?
`id`	`bigint`	NO
`name`	`varchar(255)`	YES
`project_id`	`bigint`	YES

Each package belongs to a specific project. A package is identified by its fully-qualified package name. The default, unnamed package will have the empty string as its name.

3.7 Source Files

Table 3.7: Schema for the `source_files` table.

Field Name	Type	Can Be Null?
`id`	`bigint`	`NO`
`generated_from_source_file_id`	`int`	`YES`
`name`	`varchar(255)`	`NO`
`project_id`	`bigint`	`NO`
`source_type`	`varchar(255)`	`YES`

Each entry in the `source_files` table corresponds to a particular source path in a project. (That is, if you delete a source file and generate a new file with the same name, it may share the entry of the original file.)

Each source file will have its path relative to the base of the project. So files that are within packages will have a path with the parent package names as directories (which may use forward slash or backslash for separation).

3.8 Source Histories

Table 3.8: Schema for the `source_histories` table.

Field Name	Type	Can Be Null?
`id`	`bigint`	`NO`
`content`	`mediumtext`	`YES`
`master_event_id`	`bigint`	`NO`
`old_source_file_id`	`bigint`	`YES`
`source_file_id`	`bigint`	`NO`
`source_history_type`	`varchar(255)`	`YES`

Each entry in the `source_histories` table belongs to a particular `master_event`, and is associated with a given `source_file`. Based on the `source_history_type` field, there can be different meanings to the `content` field:

- `source_history_type` is `"complete"` – `content` has the complete text of the source file (anonymised). This will be used by file additions, and source histories added on loading a package.

- `source_history_type` is `"diff"` – `content` has the diff (in unified diff format) from the previous version of the file.

- `source_history_type` is `"rename"` – `old_source_file_id` will contain the id (in the `source_files` table) of the old file id before the rename. `content` will be blank. Note that renames were broken at the start of the project; if `old_source_file_id` is null, you should treat the rename as broken and ignore it.

- source_history_type is "stride_to_java" – old_source_file_id will contain the id (in the source_files table) of the old Stride file id before the conversion. content will be the new (Java) content of this source file.
- source_history_type is "file_delete" – content will be blank.

3.9 Stack Entries

Table 3.9: Schema for the stack_entries table.

Field Name	Type	Can Be Null?
id	bigint	NO
class_name	varchar(255)	YES
class_source_name	varchar(255)	YES
entry	int	YES
line_number	int	YES
sub_event_id	bigint	YES
sub_event_type	varchar(255)	YES

Any time that an event is associated with a stack trace, it will have zero or more entries in this table: one for each line in the stack trace. (Some stack traces may be filtered by BlueJ – the recorded trace will always be the filtered version, i.e. the version that the user actually sees.)

The entry field will be the index within the stack trace. The top line (typically, the actual location of the thrown exception, or breakpoint, etc) of the trace will have entry of zero, with an increasing entry index for each subsequent line.

The class_source_name field will be the name of the file involved, and line_number will be the line number (line numbers start at 1). So if an exception is thrown in an anonymous inner class of class Foo, this field will be "Foo.java" – even if Foo is inside a package. The source name loses all package information, but this can be recovered via the class_name field, which is the fully qualified name of the class at the specific source location.

The sub_event_id and sub_event_type fields are what is used to link the stack entries to their parent event – see documentation throughout the manual for events that have associated stack traces.

3.10 Bench Objects

Table 3.10: Schema for the `bench_objects` table.

Field Name	Type	Can Be Null?
`id`	`bigint`	`NO`
`class_name`	`varchar(255)`	`YES`
`name`	`varchar(255)`	`YES`
`package_id`	`bigint`	`YES`
`session_id`	`bigint`	`NO`
`test_id`	`bigint`	`YES`

Objects on the BlueJ object bench get an entry in the `bench_objects` table. The `name` field is the name/label of the object, and `class_name` is the type of the object. The `package_id` field links to the package which is associated with the object bench that this object is on. The `session_id` field links to the session during which this object existed.

The `test_id` field links to an entry in the `tests` table (see Section 2.13.1 on page 24) – this link is present if (and only if) the given test was being recorded when this object was added to the bench.

3.11 Participant Information

To keep participant information (see Section 1.5 on page 7) hidden, we hide the actual table involved, `participants`, and instead offer three database views of the information.

Table 3.11: Schema for the `participant_identifiers_for_experiment` table.

Field Name	Type	Can Be Null?
`participant_identifiers_for_experiment`	`varchar(32)`	`NO`

The `participant_identifiers_for_experiment` view allows you to see the available participant identifiers for a given experiment identifier. You can call the view using a statement such as:

```
select p.participant_identifier from
  (select @experiment:="myexperiment") unused,
  participant_identifiers_for_experiment p;
```

The inner select is a trick to set the `@experiment` parameter to be the experiment identifier. The view then retrieves a list of participant identifiers based on the experiment identifier that you supply.

Table 3.12: Schema for the sessions_for_experiment table.

Field Name	Type	Can Be Null?
id	bigint	NO
created_at	datetime	NO
identifier	varchar(64)	NO
installation_details_id	bigint	NO
last_sequence_id	int	NO
participant_id	bigint	YES
participant_identifier	varchar(32)	NO
user_id	bigint	NO

The sessions_for_experiment view allows you to retrieve information for all the sessions associated with a given experiment identifier. A session is associated with an experiment identifier (and similarly with a participant identifier) if during the last event logged in that session, the user had their experiment identifier set to the given value. So if a user sets their identifiers partway through a session (and does not change it again before the end of the session), the whole session is deemed to be part of the experiment.

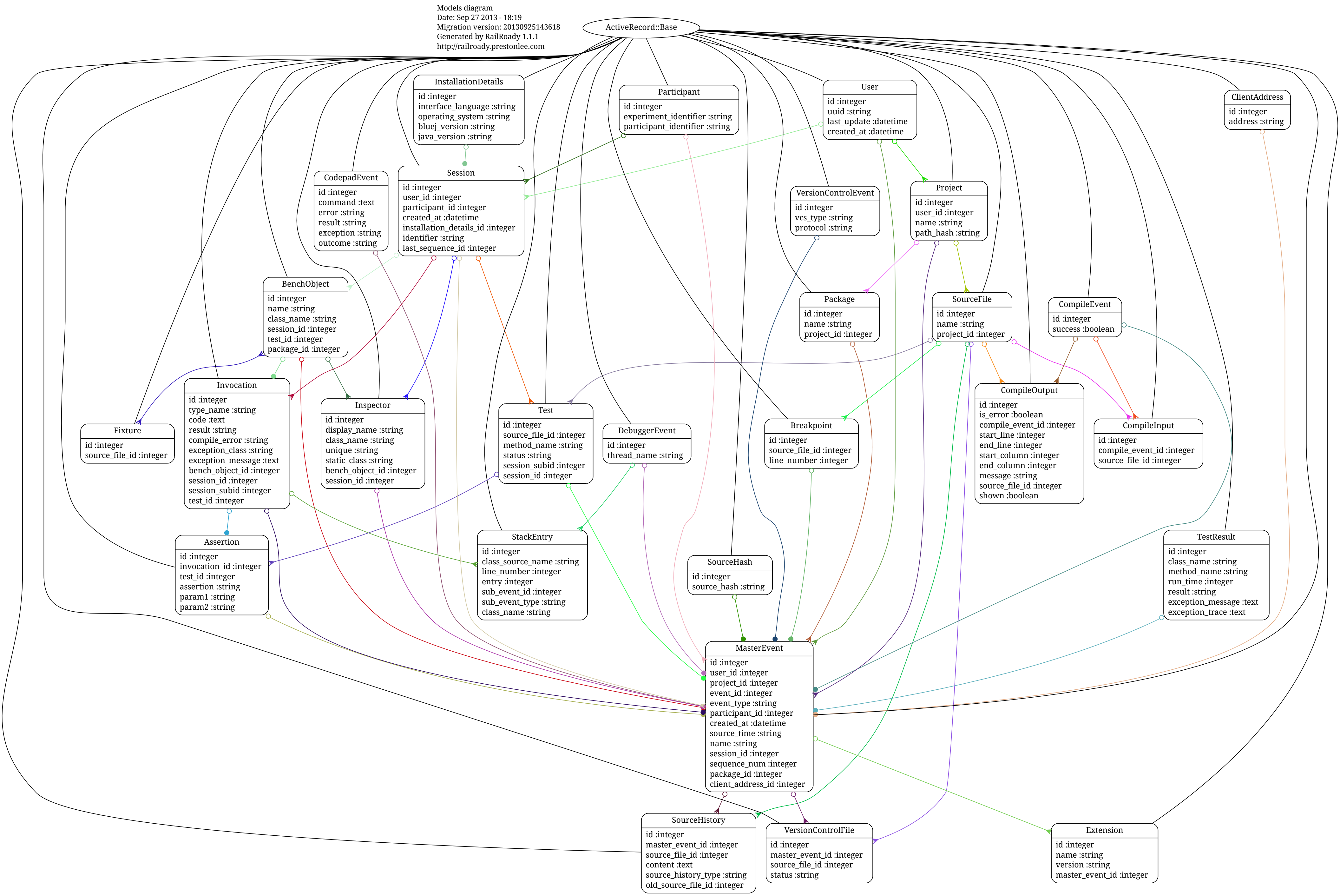
The columns returned are those from the sessions table (see Section 3.2 on page 28), plus the participant_identifier column.

The view can be called using a statement such as:

```
select s.* from
  (select @experiment:="myexperiment") unused,
  sessions_for_experiment s;
```

3.12 Schema Diagram

The next page has an overview diagram for all the tables in the database, and how they connect



Models diagram
Date: Sep 27 2013 - 18:19
Migration version: 20130925143618
Generated by RailRoady 1.1.1
http://railroady.prestonlee.com

Chapter 4

Locations

For some research questions, you may be interested in the location of a given user. If you want to go as far as individual institutions, you will need to get the users to tag themselves explicitly – see Section 1.5 on page 7. If you just want country information, then you can access that without any additional effort.

There is a `geocodes` database with a `geocoded` table. This table has four columns:

- `client_address_id` – This should be matched with the `client_address_id` column in the `master_events` table.
- `country_code` – A two letter code identifying the country.
- `country_name` – The name of the country.
- `continent` – The continent which the country is located in.

You will generally involve this `geocoded` table in an inner join with the `master_events` table when you want to retrieve country information, or narrow your search to specific regions. For example, the following query counts the number of compile events in North America:

```
select count(id)
  from master_events
    inner join geocoded.geocodes
      on master_events.client_address_id = geocodes.client_address_id
  where
    name = "compile" and continent = "North␣America"
```

This query shows the number of sessions by country:

```
select geocodes.country_name, count(id) as sessions
  from master_events
    inner join geocoded.geocodes
      on master_events.client_address_id=geocodes.client_address_id
  where name="bluej_start"
  group by geocodes.country_code
  order by sessions desc;
```

The locations are determined by looking up the client's IP address in the Geolite2 database created by Maxmind, available at http://dev.maxmind.com/geoip/geoip2/geolite2/. So it is vulnerable to any mistakes in that database, or use of a proxy in another country. But generally, it should be trustworthy.

Note also that the `client_address_id` is stored with each master event. Each event sent to Blackbox is a separate HTTP request, so it is possible for the requests in a session to come from different IPs (e.g. if the user's DSL connection reconnects during their BlueJ session). It is hard to conceive of many situations where a user would have IPs from multiple countries during a session, so in general it seems sensible to assume the country is stable per-session. However, it is a little more likely that a user may send events from multiple countries over the course of several months, so be more wary about assuming a one-to-one mapping between user and country.

Chapter 5

Data Access

The data collection project involves two machines, running Ubuntu. Each machine has two 6-core hyperthreaded 2.5Ghz Xeon processors, with 32GB of RAM, and four 2TB drives set up in RAID 5 configuration to hold the database.

One machine, nicknamed black, is responsible for collecting the data. It solely runs the MySQL database, and the Ruby on Rails server.

The second machine, nicknamed white, has a live-cloned database (named `blackbox_production`) from the recording machine. White is the machine to which you will have an account, and be able to log in and perform data analysis. The intention is that this way, nothing that anyone does while examining the database on white can affect the recording on black.

5.1 SSH Access

The white machine can be accessed by SSHing to `white.kent.ac.uk` on the standard port (22). The machine runs Ubuntu. If you need any software installed, then we can install any standard Ubuntu packages for you (email `blackbox-admin@bluej.org`).

5.2 MySQL

The white machine runs MySQL on the standard port (3306) on the localhost interface. If you want to access the database directly from your own machine, you can use an SSH tunnel:

```
ssh -L 3307:localhost:3306 ssh_username@white.kent.ac.uk
```

While that SSH session is open, you can access the database by running:

```
mysql -h 127.0.0.1 -P 3307 -u username -p blackbox_production
```

You will have been given the MySQL details separately when you got an account on the machine.

5.3 Feed

To get familiarity with the data collection, we provide a mechanism to observe a live feed of your own data. The live feed is available, from the white machine, on `http://localhost:3080/feed`. It is probably easiest to port-forward 3080 to your local machine using:

```
ssh -L 3080:localhost:3080 ssh_username@white.kent.ac.uk
```

Then access `http://localhost:3080/feed` on your own machine. You can find your own UUID in your `bluej.properties` file – look for the line `blackbox.uuid=...`. If you paste your UUID into the feed page and click the button, it will refresh every five seconds until closed (be warned!) to show you the data for that UUID. Looking at this webpage while running BlueJ should give a good feel for what is being recorded.

5.4 Analysis Process

We anticipate that researchers will do some of their analysis on the white machine, and some on their own machine. The advantage of using the white machine is that it is high-powered, and has immediate access to all of the data, without needing to copy the data across the Internet. The disadvantage is that it can be a bit restrictive to operate on a remote machine for all analysis. Researchers may therefore want to do a split, with some pre-processing on the white machine, followed by more investigation on their own machine.

5.5 Data Snapshot

When researchers publish their data, they will specify their data source. It is worth remembering that the Blackbox data is continually being added to, so it is also necessary to specify which time period data was used from. We suggest choosing a cut-off date (e.g. the beginning date of the analysis) and ensuring that only data up until that cut-off date is used, so that the source of the data can be correctly specified as "the Blackbox data repository was used, up until 2013-03-31". You can use the date stamps in the `master_events` table (see chapter 2 on page 11) to decide which data to use in your study. (Bear in mind that this may bisect some sessions – make sure you do not process the events in a session which fall outside your cut-off date).

Chapter 6

Data Use Policies

The data that we collect is not public. This is part of our ethics approval – it is only visible to us, and selected researchers (i.e. those to whom we give an account on the white machine).

6.1 Data Caching/Copying

We realise that researchers will ultimately end up taking some data (probably processed) on to their own machine, as a pragmatic step during the analysis. We ask that you act responsibly, and make sure that the raw data is not made public, and also that you take care to not let your account on the white machine be compromised. If you need multiple researchers at your institution to have access, we would prefer giving them all accounts rather than encouraging the practice of sharing accounts (and thus passwords).

6.2 Data Use

The data is intended for education research, and is anonymous. We expect you to not attempt to identify any students or data within the database, except your own, and that of any participants in a study for which you have ethical approval. In particular, we forbid any use of the data for the purposes of plagiarism detection (and similar) in students at your local institution. The participation of the users in the experiment is conditional on the data being anonymous, and should not have any negative impacts for the participants.

6.3 Sharing and Publication

Researchers should not share the data with anyone – any other researchers wanting access should ask us for accounts. Obviously, at some point, researchers may want to publish their findings. We expect that the data will either be published in an aggregated form (which thus retains anonymity), and that any individual case studies/vignettes will be manually anonymised, if necessary.

Chapter 7

Blackbox Bugs and Interruptions

7.1 Known Interruptions

From time to time, the Blackbox data recording may be interrupted, for routine maintenance or to deploy changes/fixes to the data recording mechanism. Unless otherwise noted below, the effects are the same each time: all sessions that attempt to send data during the time that the server is unavailable will stop sending data. So many sessions will simply end when the server is taken down, and recording will only be resumed for that user next time they start BlueJ. Known outages of longer than 1 minute are listed below:

- 28 Jun 2013, approx 0722 to 0724 UTC (2 minutes), before master event 731142
- 16 Sep 2013, approx 0942 to 0949 UTC (7 minutes), before master event 15537698
- 17 Sep 2013, approx 1345 to 1351 UTC (6 minutes), before master event 15884081
- 23 Sep 2013, approx 1338 to 1354 UTC (16 minutes), before master event 21192150
- 31 Dec 2013. There was a DNS issue surrounding the bluej.org domain name, which affected Blackbox. For a few days (approx 31 December 2013 to 3rd January 2014 inclusive), the DNS problem prevented most users sending data to Blackbox. It is hard to pinpoint how many and for how long, as we can't know if they were able to use the cached DNS value, or when the new DNS arrived on their nameservers.
- 28 Jan 2015, approx 1543 to 1550 UTC (7 minutes), before master event 553795798
- 12 Jan 2016, approx 1627 to 1649 UTC (22 minutes), service intermittent between master event 1040343453 and 1040346172 exclusive

7.2 Known Recording Bugs/Changes

These sections are roughly ordered by the date at which they were fixed.

7.2.1 Project Name Length

From the beginning of the project until 28 June 2013 (master event 731142), the project name field was 64 characters. A small handful of projects exceeded this length and were thus not recorded. The length of the field was extended to 255 characters.

7.2.2 Renames

From the beginning of the project until 16 September 2013 (master event 15537698), renames were not being handled properly by the server. These were relatively rare: for the 30 days leading up to the fix, there were around five renames each day. Details are noted in the section on renames (essentially, the `old_source_file_id` column was added to fix this; if this is NULL for a rename event, it's because it predates the fix.)

7.2.3 Case Sensitivity

From the beginning of the project until 23 September 2013 (master event 21192150), the database was using a case-insensitive comparison on all fields. This affected the following features.

Objects on the object bench would be located via a case-insensitive search for their name. This means that if the user had two objects on the object bench with names that differ only by case (e.g. "Obj1" and "obj1"), further events like method invocations may have referenced the wrong object. Although you cannot be certain when the wrong object is referenced, it is possible to find if a session/package had two objects whose names differed only by case (i.e. where the error *could* have occurred). As of 26 September 2013, shortly after the fix, of 80567 sessions that used the object bench, 464 had objects with names that differed only in case (0.6% of all sessions).

Packages within a project would be found via a case-insensitive search for their name. Thus, if the user had two packages in the same project that differed only by case (e.g. "MyPKG" and "mypkg"), further events may have referenced the wrong package. Note that this problem is irrelevant on Windows, as it has a case-insensitive file system that would not permit two packages which differ only by case. Having said that, changes to the case of a package may not have been correctly recorded by the system. Use of any packages other than the default is relatively rare: less than 3% of projects have a non-default package at the time of writing (26 September 2013).

Source files within a project would be found via a case-insensitive search for their name. Thus, if the user had two source files in the same project that differed only by case (e.g. "FOO.java" and "Foo.java"), further events may have referenced the wrong source file until the start of a new session after the server was fixed. Note again that this problem is not possible on Windows.

Changes in the case of a source file (e.g. if a user renames their class from "FOO" to "Foo", causing a rename of the file from "FOO.java" to "Foo.java") would not have been noticed by the server: the case of the filename would not be kept up to date on the server side. This would also have upset the source hash generated for this project thereafter. Around 2% of source hashes during the period were affected by these problematic renames.

7.2.4 Source Hashes

From the beginning of the project until 17 September 2013 (master event 15884081), source hashes were *potentially* different for two projects with the same contents. Specifically, the order in which the source files were fed into the hashing was arbitrary. Thus, assuming no interference from the case sensitivity mentioned above, a project with one file would always have generated the same hash. A project with two files would have generated one of two different hashes, a project with three files would have generated one of six different hashes and so on. During the period affected, around half of all source hashes were potentially affected (hashing was done when the source files were not in alphabetical order).

There is now a table available, named `source_hash_fix`, in a supplementary database also named `source_hash_fix` (on the same machine, with access available to the relevant MySQL users) that contains a list of fixed hashes to cope with the problems of ordering. The `source_hash_fix` table has two columns: `master_event_id` (integer) and `source_hash` (string). Simply, `master_event_id` is the `id` from the `master_events` table of a `"package_opening"` event, and `source_hash` is the fixed source hash for that `"package_opening"` event. Running this query (which looks long due to including all the prefixes) shows us how many hashes were broken:

```
select (blackbox_production.source_hashes.source_hash
         = source_hash_fix.source_hash_fix.source_hash) as matches,
      count(*) as count
  from blackbox_production.master_events
    inner join (blackbox_production.source_hashes, source_hash_fix.source_hash_fix)
      on (blackbox_production.master_events.event_id =
               blackbox_production.source_hashes.id
          and blackbox_production.master_events.id =
               source_hash_fix.source_hash_fix.master_event_id)
  where blackbox_production.master_events.name="package_opening"
        and blackbox_production.master_events.id < 15884081 group by matches
```

The output is:

```
 matches   count
    0      242457
    1      297968
```

Which is to say, 242,457 hashes were broken – slightly under half of them. To give an example of how you might use this fixed hash table, here is some SQL code I had written before I realised that the hashes were broken. It retrieves all known hashes for a given project name:

```
select source_hash
  from source_hashes
    inner join (master_events, projects)
      on (master_events.project_id = projects.id
          and master_events.event_id = source_hashes.id)
  where master_events.name='package_opening' and projects.name = ?
```

Afterwards, the same code concatenates the results of two queries:

```
select source_hash
  from source_hashes
```

```
    inner join (master_events, projects)
      on (master_events.project_id = projects.id
          and master_events.event_id = source_hashes.id)
  where master_events.id >= 15884081
        and master_events.name='package_opening'
        and projects.name = ?

select source_hash
  from source_hash_fix.source_hash_fix
    inner join (master_events, projects)
      on (master_events.project_id = projects.id
          and master_events.id = source_hash_fix.source_hash_fix.master_event_id)
  where master_events.id < 15884081
        and master_events.name='package_opening'
        and projects.name=?
```

7.2.5 Missing Data

From the beginning of the project until 17 September 2013 (master event 15884081), the server was running slowly enough that we believe some data was lost. This would manifest as some sessions ending early (as if the internet connection to the server had been severed) – all received data should still be internally consistent and complete over the duration of the session until it cut out. We believe this affected roughly the period from 26th August to 17th September (increasingly so towards the end of the period).

We are using figure 7.2.5 – our guess is as good as yours as to exactly how long before the fix we were losing data. The cap on server load looks to have been around 15,000 events and it looks like this was reached the week beginning 26 August. So the period of lost data might be around 26 August to 21 September. Note that we would expect that the ramp-up from 24 August would not necessarily be proportional to the number of sessions – because term starts in September, users are likely to use BlueJ for longer periods. For example, compare the ratio of events to sessions or users in July (when we were unlikely to have been losing data) to the latest data in September: it is clear that the ratio is not constant.

7.2.6 Edits on Deleted Files

There was a bug in BlueJ 3.1.0 and 3.1.1 where if you had edited a file immediately prior to its deletion, the events would be sent in the wrong order: the deletion event would be sent, followed by the pending edit. This is relatively benign, but you must write your analysis software to cope: if you simply silently ignore all edits that occur on currently-deleted files, there should no negative consequence. (It is unlikely you care what the edit was, given that the file was deleted immediately after, but if you do care you could just look for this situation and apply the edit before the deletion.) This bug will be fixed in versions of BlueJ after 3.1.1.

7.2.7 Renames and Bad Diffs

There was a bug in BlueJ 3.1.0 and 3.1.1 that could occur surrounding renamed files and diffs. There are two situations:

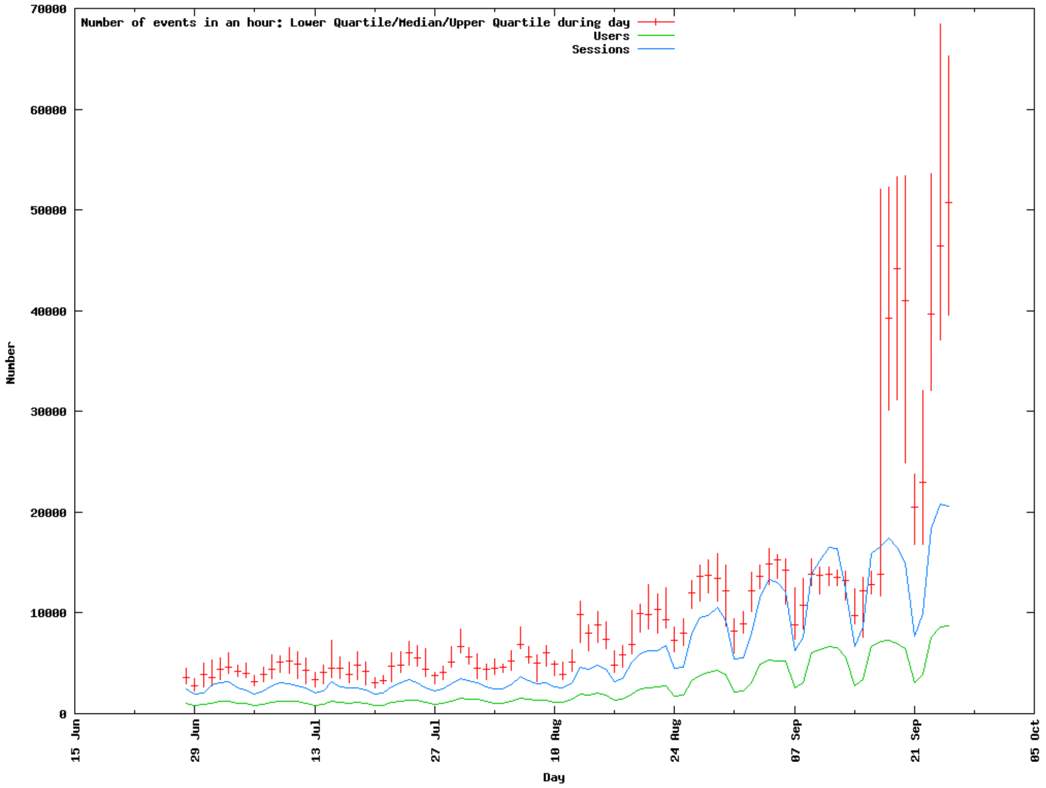


Figure 7.1: A graph up to 25 September 2013 illustrating the data loss until 17 September 2013. The green line shows the number of users on each day, and the blue line shows the number of sessions on each day. The weekly cycle is obvious. You can see that the number of users and sessions did not increase after the date of the fix. However, the amount of events received did increase markedly, as shown by the red bars. To generate the red bars, we take the 24 hours of each day and work out the number of events in each hour. Then we order the hours by their activity, and use the upper quartile (roughly, the 6th busiest hour), median (12th busiest) and lower quartile (18th busiest) to plot the bar which gives the spread of activity during the day.

- If the destination file name had not existed before in this project and session, the next diff to the file would be against a blank file, not against the contents of the file just before it was renamed.

- If the destination file name had existed in this project and session (but had been deleted, or itself had been renamed), the next diff would be against the old destination file (the deleted/renamed one) not the file that is the source of the rename.

In each case, it should be possible to work around this issue during the analysis stage by looking up the state of the destination file. This problem will be fixed in versions of BlueJ after 3.1.1.

Chapter 8

Analysis Example: CodeView

We have created a simple proof-of-concept analysis tool ("CodeView") to give a quick idea of how analysis might work. It appears to have a lot of code, but almost all of it (in the `bluej.*` packages) is ripped from BlueJ – code for displaying the editor.

In the default package are five classes. `IdName` is a simple data holder, and `ListDialog` is a class to ask the user to pick an item from a list. The class `DatabaseInterface` has some Java code for interfacing with the database. It connects to localhost (assuming you are running the SSH tunnel as described in section 5.2). It demonstrates running a few queries, given the UUID, to find a user's projects, and the files within a chosen project. For that file, the full history of the file is pulled.

The `SourceHistory` class uses the command-line `patch` application (available on all Unix-like systems) or any to put the histories back together. The `Viewer` class ties all this together, and displays the source in a BlueJ editor window, and binds the scroll wheel to moving backwards and forwards through the version history.

(Note: the sample has a slight irritation that the cursor is always moved to the end of the file during scrolling, but the point is to demonstrate the database queries and diffs and so on.)

Chapter 9

Additional Tools

In time we will set up an area for this kind of information, but for now, here are some details on tools and postprocessing tasks that we have running on the "white" machine to aid analysis.

9.1 Extracted Compile Inputs

The main likely area of analysis in the Blackbox project is looking at the source code, especially at compilation time. The way that the source code is stored in the database (as a series of complete snapshots, plus a stream of diffs) makes it a bit irritating to do the source code analysis of compilations directly, as you have to reconsitute the state of the source at each compilation.

To ease this process and save shared effort, we have a task that pulls out the state of the source files each time they are compiled. The task runs overnight (GMT) in order to process the previous day. In the directory `/data/compile-inputs/` there is a series of files, one per day, with all the compile inputs for that day.

The files named payload-YYYY-MM-DD are just one long stream of UTF8 strings; to slice it up correctly you need to cross-reference index-YYYY-MM-DD. The index files are a long sequence of records, with 32 bytes per record – in order, they are:

- 64-bit integer for source file id. (Corresponds to "id" column in `source_files` table (see Section 3.7 on page 31).)
- 64-bit integer for master event id for the compilation event. (Corresponds to "id" column in `master_events` table (see chapter 2 on page 11).)
- 64-bit integer for the starting position within the payload file. (Byte position in file, not character position in UTF8 string.)
- 32-bit integer for the length within the payload file. (Again, byte length, not character length.)
- 32-bit integer that is 1 if the compile was successful, 0 if it was an error. (Copied from database for easy reference.)

All integers are big-endian. If all you want to do is work through all sources, you can just go through each index-payload pair in turn, using the index records to slice the payload into different inputs. Otherwise, you can work forwards from the database: once you find a compilation event you're interested in (say, one with a particular error), look at the day on the master event. Load the index-payload for that day, and scan through to find the master event id that you're looking for. Obviously you can speed things up by preloading all the indexes and forming a few hash maps or whatever.

9.2 Tools

In /tools/nccb/bin there are a couple of tools that you can use.

- `/tools/nccb/bin/print-source-hashes` takes a project name and then prints a frequency table of source hashes for projects with that name. You can use the `--`*`min-freq N`* flag to set a minimum frequency (defaults to 5). For example:

  ```
  /tools/nccb/bin/print-source-hashes shapes --min-freq 50
  ```

- `/tools/nccb/bin/print-compile-input` takes a path to the post-processed compile inputs (`/data/compile-inputs` and then a numeric (denary) source file identifier and master event identifier. It then prints out the exact state of the source file at that compilation master event. For example:

  ```
  /tools/nccb/bin/print-compile-input /data/compile-inputs 1246 35238
  ```

- `/tools/nccb/bin/view-source-history` takes a source file identifier and then allows you to scroll through the file, its source history and compile history. For example:

  ```
  view-source-historyview-source-history 1234
  ```

(Any other tools in /home/nccb/bin are irrelevant dependencies.)