Automating Data Aggregation for Collaborative Filtering in Ruby on Rails

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ABSTRACT

Collaborative filtering and information filtering are tried and proven methods of utilizing aggregated data about a website's users to provide catered content. Passive filters are one subset of such algorithms that utilize data about a user's interactions with a website in viewing content, purchasing items, etc. My work develops a set of extensions for Ruby on Rails that, when inserted into an existing application, will comprehensively log information associated with different types of user interactions to provide a sound base for many passive filter implementations. The extensions will log how users interact with the application server (content accessed, forms submitted, etc) as well as how users interact with that content on their own browser (scrolling, AJAX requests, JavaScript calls, etc). Given existing open-source collaborative filtering algorithms, the ability to automatically aggregate user-interaction data in any arbitrary Rails application significantly decreases the barrier to implementing passive filtering in an already efficient agile web development framework. Further, my work utilizes the logged data to implement a web interface to view analytic information about the components of an application.

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1 Introduction

1.1 Purpose of the Investigation

The primary goal of my work is to decrease the time required to develop web applications that in some form utilize data about past user interactions in providing content. Primarily, this encompasses applications which implement collaborative filtering or information filtering

The mechanism for streamlining such development will be providing an automated and packaged solution to collect and manage the necessary user interaction data for these various applications. Because a compressive log of user activity is also valuable in traffic analytics, I will provide an interface to view data across all users for an application's components. My thesis work will thus be divided in two pieces:

1. Develop a set of data aggregation tools for Ruby on Rails web applications that thoroughly monitor and record user interactions with an application
2. Provide a web interface to the logged data granting developers easy access to summary statistics about their application

1.2 Description of Problem

Aggregated information about a website's users and usage provides a decisive advantage for the creators to better tailor content suiting the end viewer. One facet of this is high-level data about a web site's access, for example, the frequency various components are accessed or what time periods are most heavily trafficked. However, it is also valuable to track more specific information about each individual user's interactions with an application. A record of pages accessed, components used, or actions performed can provide insight into what each individual likes to do or wants to see. It empowers the application to make automated decisions that improve the user experience by detecting patterns and catering content based on the user's history. Collaborative filtering and information filtering are two popular methods of selecting content relevant to individual users.

There are a plethora of enterprise website analytics programs that document and log data from web servers to monitor traffic and usage. There are also endless sites that develop application-specific means of logging user-interaction data. However, there currently is no good solution for the newer agile web development frameworks and the developer looking for a generic and fast-to-implement means of aggregating the described data. Frameworks such as Ruby on Rails and Django are quickly gaining popularity because they are efficient and significantly cut development lead times. They have empowered developers to the point where a single person can create a valuable and rich database-backed website in days. Rails significantly decreased the time from conceptualizing an application to implementing it. Similarly, my work will attempt to decrease the time required to realize an idea involving collaborative or information filters.

1.3 Collaborative and Information Filtering Background

Collaborative filtering is a generic term describing different processes that attempt to predict what a user wants based on what he has wanted in the past and what other users have wanted in the past. Many successful websites implement collaborative filtering engines and several, such as Pandora, derive almost nearly entire value from a powerful recommender system. The product recommendation system on Amazon.com is another example of another a popular collaborative filter. Since the web's inception, there has been there has been a great deal of research about how to leverage aggregated information about users. Collaborative filtering has been one successful solution. While algorithms vary greatly, most are some variant of the following:

- Collect data about what users like or dislike
- Infer how similar a user to other users based on what they like or dislike
- Predict what a user will like based on the preferences of other similar users

This computation can take many forms including Bayesian inference, mixture models, dimensionality reduction, and hybrid algorithms. However, conceptually all leverage information about many users to predict information about one.

Gathering information about what a user likes can obviously be done with explicit polling and rating. However, it is not always possible or practical to ask a user about their preferences. In these cases, it is still possible to infer such information by looking at what a user has done in the past.

Collaborative filtering systems thus divided into two categories based on the type of input data: active filtering and passive filtering. Active filtering systems infer information from explicit, self-reported data about a user's past preferences. In practice, this is usually some type of numerical rating. Passive filtering systems, however, rely on data that implicitly defines a user's preference as a replacement for explicit, self-reported data. Purchasing an item, viewing a page, or designating something as a 'favorite' are all actions that convey information about a user's relation with something and can thus be used as a base for passive filtering. More subtle information can also be valuable in inferring preferences, such as time a spent viewing a page or number of searches for some item.

In both passive and active collaborative filtering, the output of the process is either suggestions or predictions. Algorithms which produce suggestions are generating a set of items from data about all users and all items. They are attempting to infer what things a user would like that they may or may not know about. Amazon.com product recommendations fall into this category. Based on what items a user looks at and what they have purchased in the past, Amazon recommends new items to that user. Algorithms that output predictions are calculating the probability that a user would like a pre-defined item based on the data about all users and all items.

Similar to collaborative filtering, information filtering utilizes passively collected data to tailor content to a user. Instead of predicting specific items a user would like based on correlations with other users, information filtering just looks at a user and the attributes of items he interacted with or rated. For example, by looking at a record of tagged news articles, a website could infer that a user frequently reads articles about New Hampshire and steer such articles toward them.

1.3.1 Resources for Implementing Collaborative Filtering Systems

A developer interested in implementing a collaborative filtering system has a wealth of resources available. There are countless papers suggesting algorithms to implement or ways to improve accuracy of results and efficiency of computation. There are even a decent set of open-source libraries that implement collaborative filtering in C, PHP, Ruby, python, Matlab, and Java by relating generic objects to users.

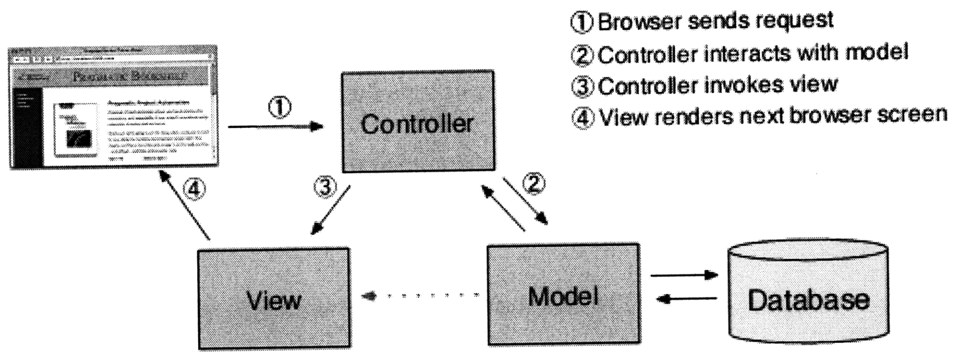
A developer can theoretically implement an active filtering system reasonably quickly because of simplicity of the input data: users' numerical ratings of some items. He can simply design a system for collecting and storing user ratings and interface that data with some open-source library. However, implementing a passive filtering system requires more time because of the complexity of aggregating data on user actions and interfacing it with a collaborative filter. If one has an existing web application, adding functionality to store user actions requires modifying server-side code pertinent to any action the developer is interested in logging.

1.4 Ruby on Rails Background

In order to understand the implementation and functionality of this project, it is necessary to have a rudimentary understanding of how a Ruby on Rails application works.

Rails is a development framework for creating database-backed web applications in Ruby, an object-oriented scripting language. It has gained widespread popularity over the recent years for its fast development times and efficient structure for creating Web 2.0 (AJAX-and JavaScript-heavy) applications. Both the Ruby language and the Rails framework have emphasized a simple syntax and code structure for developers.

The structure of a Ruby on Rails application is actually simple, but important to understand. Rails applications strictly follow the Model-View-Controller abstraction. In developing a rails application, one actually creates classes referred to as Models, Views and Controllers. The basic structure can be seen in the figure below. A browser accesses a URL mapped to a controller responsible for returning content. The controller interacts with the database, processes data, and passes it to a view via models. The view creates the actual HTML that is returned to the client's browser.



① Browser sends request
② Controller interacts with model
③ Controller invokes view
④ View renders next browser screen
Controller
View
Model
Database
①
②
③
④

Figure 1: Structure of Rails Application

1.4.1 Models

Ruby on Rails models are classes that inherit from a base class which implements functionality to completely abstract out the database from an application. Every table in a database has a corresponding model in the Rails application. Instead of using SQL to interact with a database, a developer most often user the model's build-in methods, for example, *User.find(1)* or *User.find_by_name('bob')*. All of a table's columns are data members of the corresponding model. Changing their values (*some_user.name = X)* and using a save method automatically updates the database freeing the developer from tedium and clutter of database code. Rails further implements a large set of support functions in Models to make validation, callbacks, and object relations simple. For example, adding *validates_numericality_of :age, :on=>'save'"* adds validation of age whenever an object is saved, but not created. Typically the developer will implement any utility functions to retrieve data or process it in the Model. This includes anything from complex SQL queries to a function that parses some field.

1.4.2 Controllers

Controllers handle logic necessary to render a page. While they do not necessarily coincide with Models (ie if there is a 'Book' model, there is a 'Books' controller), they often do. A controller is comprised of actions which represent different blocks of code to be executed on different URL hits. For example, a simple 'Books' controller may have actions for *save, view*, *edit*, and *delete*. After executing the necessary logic in an action, the controller sends data back to the user's browser. In some cases, an action would render a string of text or binary data (AJAX , downloads, etc), however, most often an action will render an HTML page by calling a function *render*(*view_name*), which processes a view and sends returned HTML to the client's browser.

1.4.3 Views

Views are typically RHTML files which function similarly to JSP files in java web applications. An RHTML file is simply an HTML file with interleaved ruby code to insert dynamic data and utilize conditional and looping control structures. The view has access to all variables declared in the controller rendering the view. For example, the controller may declare a variable *@book = Book.find(param[:id])* where Book is a Model. The view could then define an HTML and insert dynamic data using *@book.whatever*.

1.4.4 Database Errata

One of the benefits of rails is that the database is independent of the application. A user can use any database they choose (MySQL, Oracle, etc) and it does not affect how they code the application (only one configuration file). Further, Rails has implemented a system to specify specific data tables in Ruby called database migrations. A developer can use migrations to easily create, delete, or populate tables within a database. For example, creating a users table could be done with the following:

```
create_table "users", :force => true do |t|
    t.column :login ,                    :string
    t.column :crypted_password ,         :string, :limit => 40
    t.column :salt ,                     :string, :limit => 40
    t.column :created_at ,               :datetime
    t.column :updated_at ,              :datetime
    t.column :remember_token ,          :string
    t.column :remember_token_expires_at, :datetime
    t.column :patient_id ,              :integer
    t.column :doctor_id ,               :integer
    t.column :admin  ,                  :boolean
end
```

This is especially useful in designing Rails plug-ins. The plug-in developer can specify any necessary tables with high-level Ruby code, and Rails ensures they are correctly created in the plug-in user's database. A plug-in's developer can thus implement models, views, controllers, and migrations to wholly package functionality that another developer can insert into his existing application, even though the plug-in's developer knows nothing about the user's database or application.

1.4.5 Plug-in Errata

In addition to adding new models, controllers, views, and migrations, a plug-in can be used to modify or add functionality to an existing model or controller. A correctly structured plug-in will have a point-of-access function that, when declared in any class, will add functionality to it. For example, consider a "Book" model and a declared the point-of-access-function, *enable_writing_hi*. The plug-in would specify *enable_writing_hi* to insert an additional method to the base class "Book" called *write_hi* that's returns the text 'hi.' Now, anywhere in the Rails application, the *write_hi* method could be called from any Book object. While this is a simplistic example, the ability for a function to insert any arbitrary functionality into any model or controller is extremely valuable.

1.5 My Thesis and General Approach

The goal of my work is to enable developers to implement passive filtering algorithms in minimal time. I envision the end users to be small agile development teams or individuals attempting to quickly build an application, not developers of large established sites. Ruby on Rails has become increasingly popular because it allows developers to rapidly deploy complex web applications and it is thus frequently used by start-ups and in scenarios requiring fast development lead times. It is the go-to framework for quick agile development. I will thus be using this framework for implementing my solution.

The goal is to provide a package of functionality for logging data that can be implemented in any existing Ruby on Rails application. It should log sufficient data about user interactions so a developer can implement whatever passive collaborative or information filters suit his purpose. As described above, passive filtering algorithms can utilize a vast array of different user actions as base of information. Nearly all of these conceptual actions, however, map in practice to data stemming from page views, remote/AJAX interactions, and client-size JavaScript interactions. My work will attempt to provide sufficient functionality to log data about these events and relevant parameters that will later help developers provide catered content to users in their Ruby on Rails applications.

Beyond just aggregating this data, I will implement a web interface to view high-level statistics about the application. The data collected for passive filtering specifically relates single users to certain actions. However, the same log is also of interest at a higher level in analyzing how various components of the application relate to the entire userbase. The interface will provide statistics about the magnitude and nature of user interaction with each of its components.

Much of the convenience of Rails comes from plug-ins which package rich functionality that can be implemented into any application on-demand. I will use the plug-in format to create a re-usable and efficient solution that works properly irrespective of what else that application does. Though it is more difficult to develop and debug a plug-in as opposed to re-usable source code, the convenience and simplicity of a plug-in for the developer make it the obvious choice.

1.6 Criteria for Project Success

1.6.1 Success of Data Aggregation Tools

The success of the data aggregation tools depend ultimately on how valuable the aggregated data is to developers and the development cost of incorporating the tools into a web application.

The value of the data depends on its accuracy and depth. The logged data should be sufficient for a vast array of conceivable passive filter implementations, not just the standard types based on actions such as viewing items or searching for something. However, even these typical scenarios should benefit from depth of the data collected. A record of exactly how a user interacted with a page (time spent viewing it, whether they scrolled, etc) conveys more information about how a user likes that page than just a record that a user viewed the page. Equally important as depth is the data's structure and ease of access. It should be contained within the developer's application and easy to extract.

The cost of implementing the tools into a web application depends on several pieces. One critical component is convenience for the developer. If my design is successful, developers should understand how the tools work and be equipped to implement my solution with minimal time and with minimal documentation. It is also important that the actual installation procedure be quick and painless. Little or no configuration should be required after installing. This also encompasses the amount of additional coding required. Ideally, the application's existing code should not have to be changed, and minimal code should be required to declare what to log. Finally, it is important to consider performance costs. The aggregation tools should not be a significant drag on the application's overall performance.

1.6.2 Determining Success of Data Viewing Interface

The metrics for evaluating the data viewing interface are very straightforward. It should convey useful summary information and be easy to use. Similar to the data aggregation, implementing the functionality should minimally effect the existing application.

2 Design and Implementation

2.1 General Approach

Before beginning implementation, I had to specify what data would actually be aggregated. The overall goal was to track a user's interaction with a website, including any activity that could perceivably be of interest in implementing collaborative filters. In other words, any action that could give an implicit indication of how a user likes or dislikes something is relevant.

Recording what pages a user views and the duration of the views is a good starting point. In Rails, viewing a page actually means executing a certain action within a controller determined by the URL request. The log of the requests should be as specific as possible since the parameters of the request determine what content is rendered. It is also helpful to include additional information about the page view, such as whether or not the user scrolled down the page, the next and previous pages accessed, or even the pixel sizes of the web browser viewing the page.

Similarly valuable in inferring information about how a user likes something is how they click and interact with the page. Specifically, actions which change or modify the content on a page should be recorded (for example, when the user clicks 'expand' to enlarge some information). With the exception of Flash or other plug-ins, content on an HTML page is modified using JavaScript. JavaScript can be purely client-side or can utilize AJAX to contact the server to retrieve new content. Both cases warrant being recorded and should be treated separately.

It was important that the logged data be easily accessible so was best stored and integrated with the existing Rails application. Storing logged data of user interactions in the same database as an application's user accounts makes interfacing with a collaborative filter much easier.

My general design is split amongst into two main components: the ActsAsLoggable plug-in and the LoggableStats plug-in (to be used in conjunction). The ActsAsLoggable plug-in is responsible for the functionality to actually log data. As described later, this means managing the database tables used in aggregating the data and dynamically inserting functionality on top of the application's existing controllers to actually log the relevant data. The LoggableStats plug-in is responsible for the web interface to view data. LoggableStats is an engine plug-in. An engine plug-in can be thought of as a separate rails application with its own views, models, and controllers that can be bundled within any other application. The existing application can utilize any of its various components, but its code remains isolated. The implementation of these two components is described in detail.

2.2 ActsAsLoggable Plug-in Implementation

The ActsAsLoggable plug-in's functionality can be split in three parts:

- Data logging functionality
- Database migrations and object models
- Installation mechanism

The data logging piece is responsible for providing functionality to an application's controllers and views to log a user's interactions with the page. The database migrations and models are Ruby classes that add support for the logging functionality by creating the necessary data tables defining the corresponding models. Utility functions pertinent to the data are implemented in the models. The installation mechanism simply provides the bridge between the logging source code and the existing application so a user can easily integrate the functionality.

2.2.1 Data Logging

The plug-in's data logging provides the following high-level functionality:

- Log hits to a page
- Log hits for remote (AJAX) functions
- Log JavaScript functions initiated by user-input events
- Log data about a user's browser

The functionality to do this is split amongst several components. The first is a helper file which overrides various Rails functions used to create HTML links between pages, to remote functions, or to purely client-side JavaScript. The overridden functions are implemented to provide the same functionality as before with interjected code to send events to the web server from the client's browser. Second, there is a Rails controller that accepts this data from the client browser, processes it, and stores it in the database. Finally, there are filters which wrap existing controllers with functionality to log data and instantiate objects that are later utilized by helper functions when the view is rendered.

The implementation of data logging will be described piece-wise by the type of data logged.

2.2.1.1 Page Views

As previously described, Ruby on Rails maps a URL to a particular action in a controller that is responsible for rendering an HTML file. In logging page hits, the plug-in is really logging instances where a particular action in some controller is executed. The plug-in maintains a table of *Pages* that represent the set of all actions that have been accessed as a page (as opposed to remotely through AJAX).

The plug-in also maintains a table of Page Views that correspond to a particular instance of a user accessing a page. The following information is logged on a page view:

- Numerical ID of the entry of the row in *Pages* of the page being accessed
- Time the *Page* was accessed
- The length of time the user viewed the *Page*
- The ID of the row in *Pages* of the next *Page* accessed
- Width and height in pixels of the browser used
- Width and height in pixels of the monitor used
- Time the user first scrolls down the page
- A polymorphic association to the User as defined by the existing Rails application

Although stored in unison, the various data pieces are actually gathered at several different points in the process of a user viewing a page. A set of initial access information is sent to the database by a function executed as a filter before processing an action of a controller that is being logged. This information includes who the user is, what page is being accessed, what time the page is accessed, and any other URL parameters of the request. Every controller that includes code to run the point-of-access function *acts_as_loggable* in its class definition will automatically call the filter defined by the plug-in to gather the necessary data and write it to the database.

This initial information is stored before HTML is even sent to the client. However, there is also dynamic information that cannot be determined until after the client's browser has loaded the page. This data includes the screen and window size, scrolling time, length viewed, and even next page accessed. The collection and storage of this dynamic data is slightly more complicated. All of this data is sent to the plug-in via remote AJAX calls at various points within a page view.

The plug-in defines a set of Rails helper functions that write the necessary JavaScript to gather certain information and initiate the relevant AJAX call. These include the following:

- *remote_report_page_view()*
- *remote_report_AJAX()*
- *remote_report_JavaScript()*

These functions retrieve information stored in JavaScript variables and through common JavaScript functions and send it back to the Rails application via AJAX. A final Rails helper, *loggable_header()*, produces the necessary JavaScript to initiate several timers and variables that are later accessed by the JavaScript produced from the above four functions.

While the four helper functions above produce the necessary JavaScript to report data, this JavaScript has to be executed only at controlled points based on time or activity. This happens two ways. First, the JavaScript code is called by events defined in the JavaScript produced by *loggable_header()*. For example, the AJAX call to report the duration of time a user viewed a page is executed on a *window.onunload* event. Second, the JavaScript functions are called by events interwoven in the links of page. In Ruby on Rails, the conventional method of linking a page is calling a helper function, *link_to,* in the .rhtml file that corresponds to the view for a given action. An example of such a call would be the following:

```
<%= link_to “some page”, :action=>”action1”,:controller=”c1”,:id=>”5”%>
```

The *link_to* function would generate the correct URL from the hash of parameters following "some page" and return a string in the form of :

<a href="[url]">some page</a>.

ActsAsLoggable overrides several similar Rails functions to insert additional functionality for sending data back to the application. The *link_to* function overridden by ActsAsLoggable would return a string of the following form:

<a onclick="[new javascript]" href="[url]">some page</a>.

This new JavaScript would include the JavaScript rendered by the *remote_report_page_view()* to initiate an AJAX call to the Rails Application reporting the time the user clicked the link, the next page they are accessing, etc. When a user clicks the link, they will be redirected to a new page and also initiate the remote call to report the page view data.

The page rendered to the client is thus equipped to send information back to the Rails application. ActsAsLoggable must also provide the relevant server-side code to parse and record the information passed back. This is done in a separate Rails controller class. To better illustrate this, the process of recording this information is shown in a figure below:

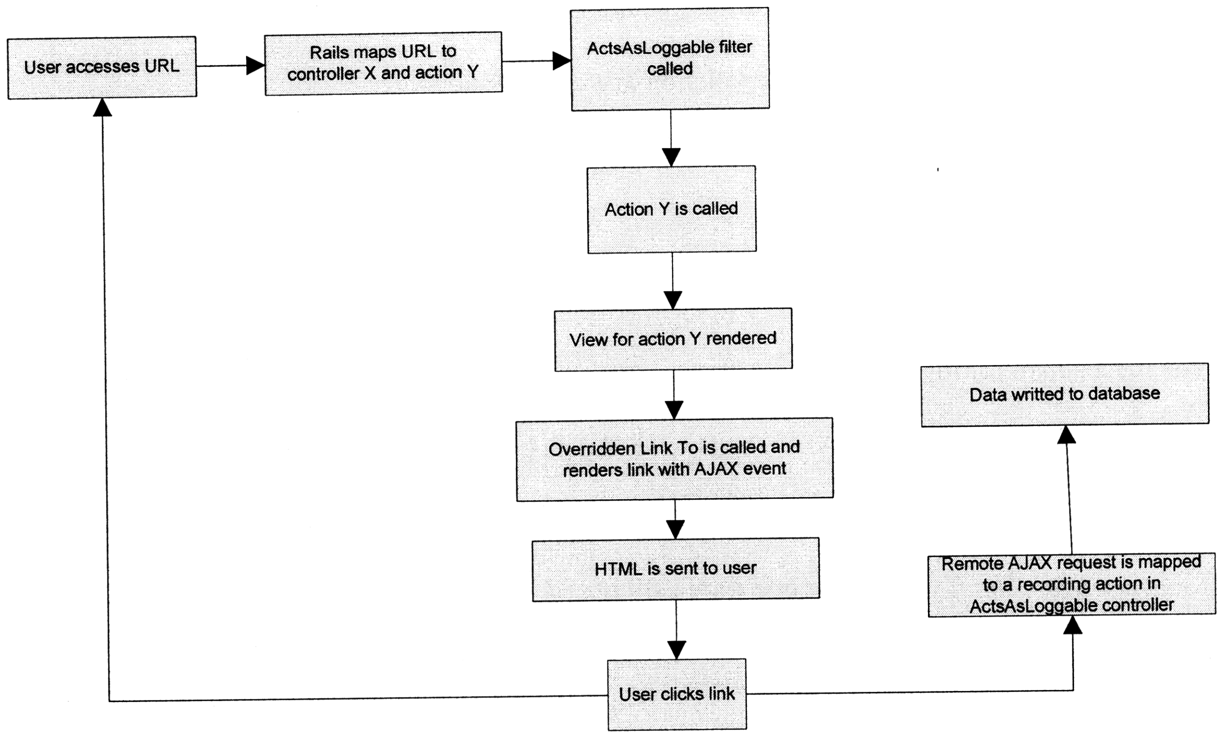

User accesses URL
Rails maps URL to controller X and action Y
ActsAsLoggable filter called
Action Y is called
View for action Y rendered
Overridden Link To is called and renders link with AJAX event
HTML is sent to user
User clicks link
Remote AJAX request is mapped to a recording action in ActsAsLoggable controller
Data writted to database

Figure 2: Logging Process

2.2.1.2 *Remote functions (AJAX)*

A remote function occurs when a client's browser accesses a Rails application via an http request from JavaScript on some rendered page. The request's URL still maps to a controller and action as before, however instead of defining a new page, the returned data is processed by JavaScript in the client browser to update the current page's content. ActsAsLoggable maintains a table of remote functions that represent the set of all actions which have been accessed as a remote function (as opposed to a page view).

ActsAsLoggable also maintains a table of Remote Calls that correspond to a particular instance of a user's browser calling that function. The following information is logged on a remote call:

- Numerical ID of the entry of the row in *Page Views* of the current page view
- Numerical ID of the remote function in *Remote Functions*
- Time from the loading when the remote function was called
- Date and time of call

The mechanism for logging remote calls is similar to the method described above: Rails helpers produce JavaScript to initiate AJAX calls to send data back to the Rails application. The means of calling these helpers, however, is slightly different. As described before, linking to a page in Rails is conventionally done just one way: calling *link_to*. Remote functions, however, can be called several ways.

First, and most frequently, a developer utilizes *link_to_remote*. *Link_to_remote's* parameters include a hash of arguments to construct the URL for the remote call. This URL hash includes a controller, an action, and any additional parameters. *Link_to_remote* also accepts the ID of a *div* or other HTML block to update with the HTML returned from the remote call. The final output of *link_to_remote* returns HTML to create a hyperlink, that, when clicked, executes a remote function and updates some HTML element.

Another method of executing remote calls is the helper function *remote_function*. This method returns a string of JavaScript to initiate an AJAX call for a remote function. This JavaScript can be inserted into any existing JavaScript function or even as an event on an HTML element. For example, a developer could write the following:

```
<div onclick="<%= remote_function ...%>>
```

Like with page views, the key to initializing the data-reporting AJAX calls back to the application is overriding the helper functions used by developers for creating links or remote calls. Luckily, the Rails implementation of *link_to_remote* utilizes the helper function *remote_function.* This means overriding *remote_function* to log data actually affects both typical means of executing AJAX in Rails.

The ActsAsLoggable implementation of *remote_function*, like the ActsAsLoggable implementation of *link_to,* provides the same functionality as the Rails default implementation, but inserts a new AJAX call to report an event. This means hitting the action *ActsAsLoggableController::report_remote_call.* Thus whenever the client's browser executes the JavaScript to initiate the developer's desired remote function, the additional remote function for logging data will also be executed.

It is important to note that AJAX calls could also have been logged using the same filter responsible for logging page views. In fact, the filter already infers whether or not the request is AJAX and only logs non-AJAX requests. However, had ActsAsLoggable used this method to log remote calls, it could not reliably associate a remote call to a given page view. The only information available to that filter is the time of the request, so it would have to assume a remote call came from the last recorded page view. This will be erroneous whenever a user has multiple tabs/windows open or navigates via a 'back' button and then executes a remote function. Instead, the ActsAsLoggable filter that is run before rending a normal page creates a new PageView row in the database and passes the row's ID to the view rendering the page. With access to this ID, the *remote_function* helper includes the page view ID in the AJAX calls back to the server so the remote call is correctly associated with the page view.

2.2.1.3 JavaScript Calls

The process for logging JavaScript data is simplistic. Like remote calls, JavaScript calls, are always associated with a page view.

The data stored for JavaScript calls includes:

- Numerical ID of the entry of the row in *Page Views* of the current page view
- Name of the function as described by developer
- Time from the loading when the JavaScript function was called
- Date and time of call

Unlike logging page views and remote calls, JavaScript functions are identified by a name specified by the developer. To this point, convention has been overwriting existing linking functions and logging based on the parameters passed to them (action, controller, URL parameters, etc). However, unlike *link_to* and *remote_function,* the helper function responsible for creating HTML links to JavaScript functions, *link_to_function*, cannot adequately classify the event from the parameters passed to it. *Link_to_function* has just two parameters: the HTML representing the item to be clicked and the JavaScript that will be executed. Neither of these can provide insight as to what the JavaScript actually does. The clickable HTML cannot offer context since it will most often be text, such as "show more," or an image, such as, *click_button.jpg*. Classifying the JavaScript call by the actual JavaScript code is also infeasible since this would require conceptually inferring what a block of code does, a problem far out of the scope of this project.

Because *link_to_function* has no means of deducing a good description for the function accessed, developers must pass a *log_name* parameter in the hash of arguments normally given to *link_to_function*. This implementation has a negative side effect: a JavaScript call will only be logged if the *log_name* parameter is present. This implies that the developer has to modify existing source code in the views in order to log JavaScript. Logging page views and remote calls, however, only requires the developer to specify *acts_as_loggable* in the controller. Fortunately, the converse of this is not true. A developer does not have undo the changes made to his source code if he wants to stop logging. All *link_to_function* calls that include the extra parameter will still work fine with the non-overridden Rail's default *link_to_function*. *S*hould ActsAsLoggable be removed, there is no need to modify the application source code.

2.2.1.4 Database Schema

All logged data stems from a particular page hit. Remote functions and JavaScript interactions are both separate tables in the database whose entries are associated with page hits. Data about a user's browser is stored in a page hit entry. The database schema is shown below:

javascript calls	parameters	pages	page views	remote calls
javascript_function_id	call_id	controller	page_id	remote_function_id
page_view_id	call_type	action	accessed_at	page_view_id
time_from_page_load	name		Duration	accessed_at
accessed_at	Value		next_page_id	time_from_page_load
			window_width	
			window_height	
			screen_width	
			screen_height	
			scrolled_at	
			user_id	
			user_type	

Figure 3: Database Schematic

These tables have all been previously described except *parameters*. This table is responsible for storing whatever parameters were passed in the URL to an action. It has a polymorphic association to *call* that could represent either a page view or remote call. Each entry in the table stores a parameter name and value for whatever object.

2.2.2 Data Migrations and Object Models

The plug-in's data migrations are straightforward and have the sole responsibility of constructing the tables necessary for the plug-in to operate. They are standard Rails data migrations and are compatible with any database for which Rails implements an adapter. The migrations are run a single time upon installing the plug-in.

The models are responsible for representing the table rows as Rail's objects and provide additional utility functions. The models implement functions that simplify database queries for instances where developers want to search the various tables or aggregate statistics. The functions enable the developer to access the same information on various levels of specificity without having to construct complex queries. For example, one function *PageView.views_by_destination(params)* handles reporting the number of hits for the entire application, amongst all actions of a controller, amongst one action of a controller, or even filtered by parameters. Example calls respectively would have params be nil, {:controller=>"books"}, {:controller=>"books", :action=>"show"}, and {:controller=>"books", :action=>"show", :id=>"5"}. It is also possible to filter by dates and user IDs or access statistics, such as number of remote calls, in the same manner.

2.2.3 Installation Mechanism and Using Acts as Loggable

A developer implementing ActsAsLoggable would do the following:

1. *Run 'script/generate ActsAsLoggable' in the application's base directory*

   This simply copies the relevant source code to the application and executes the migrations to set up the database

2. *Declare acts_as_loggable in the relevant controllers*

   By doing so, the developer is actually calling a function which inserts new functions into the controller class. Since ruby is a scripting language, when interpreting the controller class definition, the *acts_loggable_line* will actually add methods to the class that enable the data storing functionality described previously.

The *acts_as_loggable* statement additionally tells the controller that whenever rendering an action, it should load the plug-in's helper files that overwrite the various linking functions to include AJAX calls to log the data.

3. *Insert function loggable_header in relevant views accessed as pages*

   Most likely this will only occur once. The *application.rhtml* layout typically wraps all views with the appropriate headers and footers so the view is only responsible for HTML between the "body" tags. Thus inserting this in *application.rhtml* is usually sufficient for the entire application.

2.2.4 Relating Actions to Users

Different Rails applications will use different classes to represent users. The structure of the user data tables will also be different. Anticipating this, the plug-in assumes only two things about how an application stores user data: there is a Rails model for whatever class represents a user and each user has a unique numerical ID. It is unrealistic to make any assumptions about what class represents a user or how the application knows who the current user is (usually some type session data).

ActsAsLoggable thus infers the current user with a robust method. Upon declaring the plug-in (*acts_as_loggable* in the controller), the developer must specify the model representing users and a fragment of code to get a current user's id. The *Page View* table and model have a polymorphic association to the user such that a logged event can be associated with any legitimate Rails class. The plug-in would be declared as follows:

```
acts_as_loggable :user_class=>User do
    [block]
end
```

Block would be any executable ruby code that, when executed in the context of a controller processing a request, returns the current user id on the last line. This block of code is executed whenever an action is stored. In many instances, the block's code would be very simple such as *session[:user_id]* or an existing function defined by a developed, such as *current_user()*. However, the only constraint on the code is that it must return an integer so the process of gathering a current user ID can be as complex or simple as required by the developer.

This generic means of relating records to users actually allows the logged data to relate to anything the developer wants, not just a person with a login id and password. For example, a news website may not have any registered users but still want to provide tailored articles to viewers based on what other viewers from their geographic location have been reading. In this instance a 'user' is not a specific person, but a set of people classified by location inferred from their IP address. This could give geographic location or even match a request to an institution, like a college. To log data in this scenario, instead of *users* table, a developer could implement a "*viewer_locations*" that just stores a city and state.

If the developer were to implement a function "get_loc_id(*ip_address)*" to match an IP address to the ID of a *viewer_location*, ActsAsLoggable could now be called in the following manner to log actions by *view_locations:*

```
acts_as_loggable :user_class=>ViewerLocations do
    get_loc_id(request.env['REMOTE_HOST'])
end
```

This is powerful because it enables logging (and thus collaborative filtering) without individual user accounts. An application can provide steered content to groups of users with ActsAsLoggable in the exact same fashion as with individual user accounts.

2.3 LoggableStats Plug-in Implementation

The data presentation interface shows summary data about the application's various components. The aggregated data about individual users' interactions with parts of the application can also be valuable when compounded across all users. The LoggableStats provides this information in a web interface that's glanceable and easy to access.

Views are implemented to show summary statistics for the following elements.

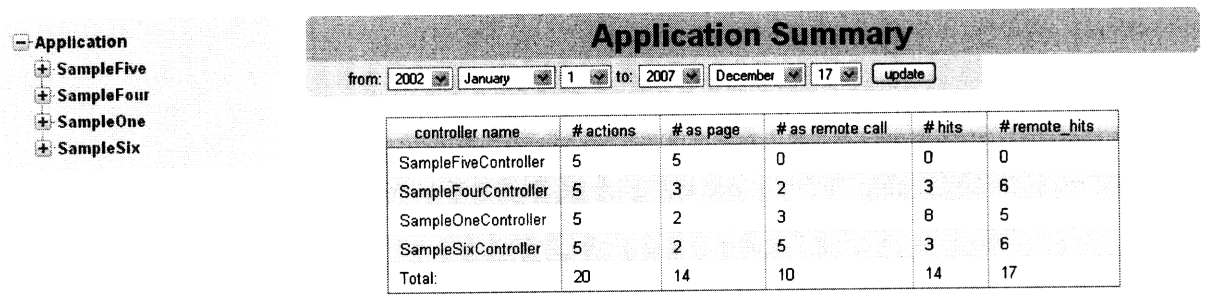
- Application summary
- Controller summary
- Action summary
- Remote call from page summary

The data for any page can be filtered down to a specified range of. All of the pages are built in standard rails practice under a single controller. All of the database logic is contained in the same Models used with ActsAsLoggable. The pages utilize the YAHOO user interface library in creating the tree navigation and sortable tables. Simple sessions are used to store the date information.

2.3.1 Application summary

The application summary shows statistics about each controller in the application as well as a total across all controllers. The data is presented in a single table with columns are as follows:

- Name – name of the controller
- Actions – the number of actions defined by the developer
- As page – the number of actions that have been accessed as a page view
- As remote call – the number of actions that have been accessed as an AJAX request
- Hits – sum of hits to all actions of the controller as a page view
- Remote Hits – sum of all remote requests to all actions of the controller



controller name	# actions	# as page	# as remote call	# hits	# remote_hits
SampleFiveController	5	5	0	0	0
SampleFourController	5	3	2	3	6
SampleOneController	5	2	3	8	5
SampleSixController	5	2	5	3	6
Total:	20	14	10	14	17

Figure 4: Screenshot of Application Summary

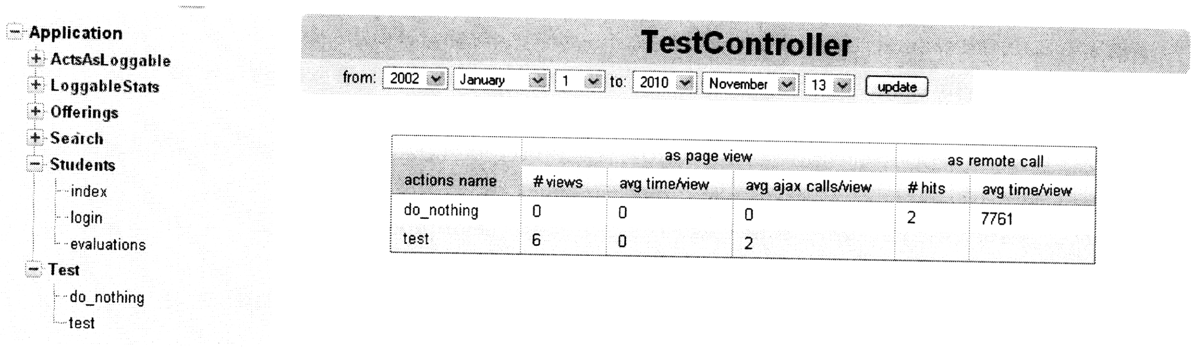
2.3.2 Controller Summary

The controller summary displays data for each action of a controller. Two column headers divide the information for each action between 'page view' and 'remote call.' The columns are as follows:

- Action name

- Views – number times accessed as a page view
- Avg time – average amount of time spend on the page
- Avg AJAX calls – average number of remote functions called (excluding logging)
- Hits – average number of times accessed as remote call
- Avg time – the average duration of time elapsed between loading page and remote call

.

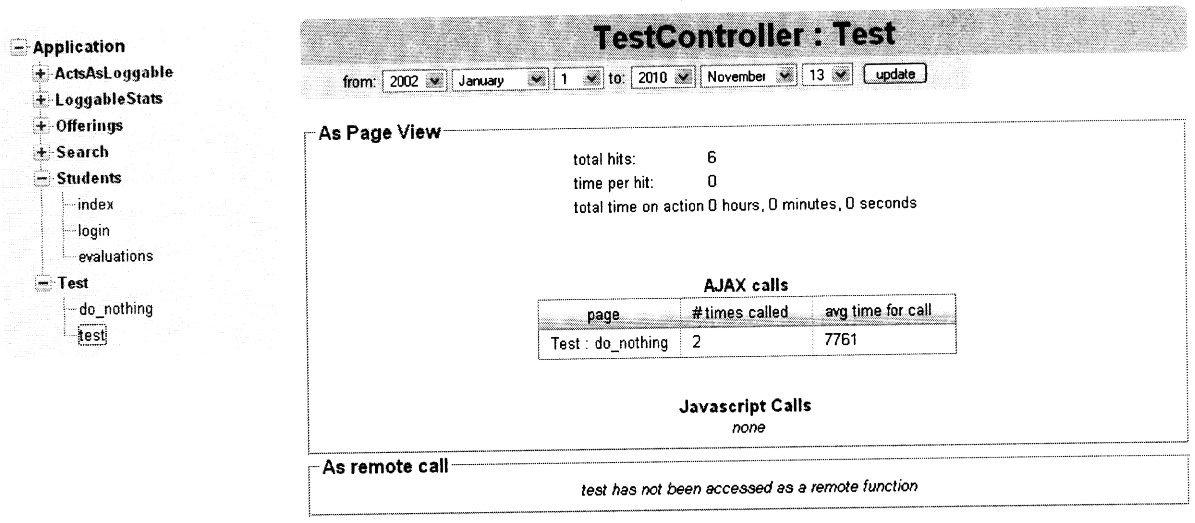


	as page view			as remote call	
actions name	# views	avg time/view	avg ajax calls/view	# hits	avg time/view
do_nothing	0	0	0	2	7761
test	6	0	2		

Figure 5: Screenshot of Controller Summary

2.3.3 Action Summary

The action summary data is broken into two pieces, the first to display summary information about the action as a page view and the second to display summary data about the action as a remote call. This is necessary because in many cases an action can be used in both contexts. In the box displaying page view information, there are two nested table displaying information for AJAX calls and JavaScript calls.



TestController : Test

As Page View

total hits: 6
time per hit: 0
total time on action 0 hours, 0 minutes, 0 seconds

AJAX calls

page	#times called	avg time for call
Test : do_nothing	2	7761

Javascript Calls
none

As remote call
test has not been accessed as a remote function

Figure 6: Screenshot of Action Summary

3 Results and Discussion

The designed system does in fact achieve the desired functionality. As described previously, the goals of the plug-in were to:

- Aggregate data sufficient for implementing a vast array of collaborative filters, information filters, or any other systems that in some way utilizes past user actions
- Require minimal effort and documentation for developers to implement
- Not significantly affect the existing application

Utilizing Rails plug-ins enabled positive results by all metrics. The functionality is successfully interjected into an existing application to log data. The end package has a very streamlined and painless implementation procedure. Nearly all configuration to set-up the developer's application and database could be done automatically by the plug-ins.

3.1 Value of Data

ActsAsLoggable gives developers access to a lot of information about user activity. Once incorporated into a Rails application, it maintains a database of page views, AJAX calls, and JavaScript interactions that can be used in many ways to infer information about users of the application or the application itself.

3.1.1 Value for Application Analytics

With ActsAsLoggable, the developer has access to typical analytic information. Like any other log of web activity, one can see where traffic goes and how it varies in time. However, the unique value provided by the comprehensive logging is information about the nature of user interactions with the various components of the application. Not only can a developer tell how frequently a page is accessed, he can tell how long the page is typically accessed for, the frequency of remote calls from that page, whether users scroll, how frequently JavaScript is executed, or what pages are accessed prior and after.

An added benefit is that this information can be easily retrieved at any level. It is just as easy to find the described information averaged across every page in the application as it is to find the described information for a specific action or item. In others words the same function can tell a developer statistics for the action that is used to display a book for sale or just when that action is executed to display a certain book.

Having this information stored in-line with the rest of the application's database further enhances its value. For example, a developer could group users by attributes from their personal information and see how usage statistics vary amongst its users with little hassle. Or, a developer can easily mine the data to find patterns between usage of pages showing items and the attributes of those items.

The LoggableStats plug-in is also beneficial because it provides a visual interface to view the statistics broken down by components requiring no computation from the developer. This will by no means come close to the feature set of Google Analytics, however, a simple command line installation of the plug-in adds a reasonably good summary information interface to any Rails application in seconds.

3.1.2 Value for Collaborative and Information Filtering

The information provided enables a vast array of passive filtering possibilities. ActsLoggable records nearly everything a user does. By utilizing this data one could develop many ways of implicitly defining a user's like of some component or item. A few simple examples include:

- Number of times a user has viewed an item
- Length of time spent viewing some item versus average time viewing any item
- If and at what point a user scrolls viewing an item
- Frequency with which a user scrolls or clicks a JavaScript link when viewing an item
- Number and list of remote calls

To illustrate how this data applies to collaborative filtering in practice, consider a simple example of website where users create blogs. Initially, this site wants to provide tailored links to blog entries that may be of interest to a reader upon login. As convention in rails, the site would have a controller *blogs_entries* and an action to render a blog entry, *show*, which takes a URL parameter 'id' to denote the numerical identity of the article in the database.

A first attempt, one could implement some filtering algorithm looking at the amount of time a user spends reading an article normalized over his average time reading articles. Conceptually, the collaborative filter would match users who have spent significant time viewing similar articles and recommend unviewed articles to users that were read in depth by the similar users. In this case, passing relevant data to a passive filter is simple: the filter's objects are article IDs and the filters users are user IDs. The entire universe of instances where a user looked at any blog entry can be accessed by ActsAsLoggable's *PageView.find_by_destination(url, time_period, user_id),* where *URL* would be a hash with controller=*blog_entries* and action=*show*. Finding instances where a user read a specific entry just requires including an *ID* in the *URL* hash. To find all instances where any user read any entry would entail excluding the *user_id* parameter. The developer can access statistics, such as the average time spent viewing the page, with a function that operates identically with arbitrarily deep filtering. Thus it is simplistic for the developer to grab whatever data is necessary for the collaborative filter or constructs a data input matrix of scores by user and article. Because ActsAsLoggable is comprehensive in logging interactions, the developer can tweak his scoring method to include other information (such as remote functions or scrolling) without any additional work. This gives added benefit of letting a developer experiment using different data types without having to incrementally modify his application to gather the data.

A developer can also utilize submitted form data in the same manner as page views. For example, the blog site may want to steer content based on what readers search for. An important thing to note is that GET and POST requests are treated identically in Rails and thus in the logging system. Both handled the same way in mapping to an action and controller. In this situation, some arbitrary action within the blog application accepts a set of URL parameters from a form's data and process the search, say based on location and favorite music genre. The values of the form data will be stored as key/value pairs in parameters and accessible same as before through page views. Again, utilizing the built in filters by destination, the application can find instances where a user performed a certain search or all searches performed by a user.

A developer is also free to utilize remote requests and form submissions in the same manner as page views and regular form submissions. Often a site will use AJAX to allow a user to add an item to his shopping cart or comment on some content. These actions can both be valuable inputs to a collaborative filter. Remote functions information is stored and accessed very similarly to page views and ActsAsLoggable utility functions operate the same so the developer is not constrained.

3.2 Implementation and Developer Considerations

A strongpoint of the implementation is the convenience for developers. First, the installation procedure is quick and painless. One typical shortcoming of rails plug-ins is the complexity or lack of documentation about installing the plug-in to get it running. As easy as the installation or usage of many actually are, they lose their convenience if a developer has to spend time trying to understand and configure the plug-in to make it operational. As seen in the Appendix, there is a very simple one-page summary that informs developers how to install ActsAsLoggable and how to declare controllers to be logged. End-to-end, adding the ActsAsLoggable plug-in and AppStats plug-in takes under a minute excluding download times.

Equally important as installation is the plug-in's output. The logged information is stored in an intuitive and simple structure right in line with the existing application's database. The developer thus has immediate access to the logged data, as opposed to many logging solutions, whose output requires additional processing or parsing. All of the logged information is stored alongside user account information and everything else in the application.

The included classes to define the data tables' corresponding Rails models means the developer's application is ready to start logging right after installation. For example, adding the code *has_many :page_views,* enables a developer to call a function *page_views* on his user class the queries the database and returns a vector of all page views for a user. *User.page_view[0].remote_calls* or *User.page_views[0].javascript_calls* would return a vector of remote calls or JavaScript calls respectively. Thus with a simple installation and one-line declaration, the developer is immediately able to utilize the logged information in his application.

3.3 Effect on Existing Application

In addition to timeliness, the implemented solution is minimally obtrusive to the existing application. First and foremost, all of the source for the plug-ins is contained within a single directory under the "vendor" folder of the Rails application skeleton. Although the web interface to the statistics data are accessible alongside any of the other controllers in whatever server is running the application, they were implemented as an engine plug-in, so all of the code for the models, layouts, views, controllers, and js/css files are entirely separated from the user's core application directory structure but are still part of the application.

Second, and importantly, the choice to implement the logging functionality by overwriting the base Rails linking functions means that a developer does not even need to modify existing code to implement the plug-in. Without overwriting these functions, logging would require creating special functions like *logged_link* to be used in place of *link_to.* This entails that the views which log data would throw errors whenever their controller stops being logged or ActsAsLoggable is uninstalled. However, overriding the functions means the application's views are identical whether or not they are being logged. A developer can simply declare "acts_as_loggable" in the controller, and all of its associated views will now log. Further, the user can now toggle between logging and not logging his information in the controller without ever having to modify other source. When logging *link_to* will log, when not, *link_to* will perform as defined in Rails.

3.4 Limitations and Shortcomings

3.4.1 JavaScript

The implementation of JavaScript logging is limited in that it only records the event if a user has defined the *:log_name* parameter to *:link_to_function.* This has two negative effects. First, a user has to modify any *link_to_function* statements to get them to log. Second, ActsAsLoggable will only log JavaScript functions called as a result of a user's clicking a link. Realistically, a developer using this plug-in is primarily interested in functions that are called as a result of user activity (clicking a link or image, for example a 'show' or 'hide' button). Since the convention in Rails to implement such functionality is the *link_to_function* helper, ActsAsLoggable is suitable for many cases.

However, there are different situations in which a developer would want to log JavaScript. The recent popularity of Script.aculo.us, YUI, and other JavaScript UI frameworks have enabled more widespread use of drag/dropping and other complex interactions. These types of activities are not logged with ActsAsLoggable but can be equally valuable in implementing a passive filter.

3.4.2 Changing Names

If a developer decides to change the names of actions, controllers, or JavaScript functions he must either manually update the existing data or recognize in his code that action a used to be called action b when querying the database.

3.4.3 Routing Actions

Frequently in Rails applications a developer will route from one action to another. In other words a URL will call action X in controller Y and after some logic, action X will redirect to action W and controller Z. In this scenario, the ActsAsLoggable plug-in will record both of these actions. Further, the remote calls and JavaScript calls will all be recorded in association with the last action that was executed. While intuitively one can imagine wanting to comprehensively log all the actions on one URL request, there is no option to do otherwise.

3.4.4 Complex Relations to User Requests

All of the logging for a request operates under the assumption that the information describing what a user is requesting is contained with-in the URL. In most cases, this is completely true. In some complex situations where a page rendered is dependent on session data or another other external factor, that information will not be logged and thus accessible later. To illustrate this, consider a web application with users and cooking recipes. Typically a user viewing recipe X of id 5 would hit a URL in the form recipes/show/5. Now imagine the site has a 'recipe of the day' link on the homepage. There are two ways of doing this. In the first way, the action rending the homepage would retrieve the ID of today's recipe and display a link to recipes/show/5 in its view. The second way is for the view for the home page to like to recipes/show_todays. When clicked, the show_todays action would find today's recipe. In good practice, that action would then redirect to recipes/show/5, however, it also possible to retrieve the recipe and simply render the view for 'show' without exciting the action. In the first situation ActsAsLoggable would record the event of a user viewing recipe 5. In the second situation with redirecting, ActsAsLoggable would record the event of a user viewing today's recipe and a user viewing recipe 5. In the second situation without redirecting, ActsAsLoggable would never record that a user viewed recipe 5. A developer implementing such an application would still be able to manually log that data by utilizing the Models provided with ActsAsLoggable. However, by default, that information would not be logged.

3.4.5 Performance

The plug-in do have an impact on the performance of a Rails application in several places. First, there are added transactions with the database on any regular page view as the plug-in's filter sends information about the page view before the page is rendered. This should no add any noticeable time delay for the user, but will increase the load on the database server.

Second, there are additional AJAX calls to the rails application for reporting data from the user's browser. New AJAX calls occur whenever a *remote_function* (or *link_to_remote*) is clicked, when a regular *link_to* is clicked, whenever a *link_to_function* is clicked, and when exiting the page. The size of the data sent is extremely small (several integers and short strings) and there is no data returned by the rails application. However, this will increase the load on the web server which is responsible for processing these requests.

4 Conclusion

The ActsAsLoggable and LoggableStats plug-ins provide valuable functionality for Ruby on Rails developers. Not only do they provide a means of logging user interactions with an application, they also provide an interface to view summary statistics about the application. It assists developers in aggregating and viewing data to provide more relevant content for users.

The implementation empowers developers to rapidly develop and deploy systems utilizing passive collaborative or information filtering. Developers already have a wealth of resources available to implement the computational component of collaborative filtering. Automating the data aggregation helps a developer implement a passive filtering system for any application he desires simply by simply incorporating two pre-packaged components.

The implication is that collaborative filtering should be more appealing with ActsAsLoggable. The value of collaborative filtering has been proven throughout the web. Removing a barrier to implementation should make developers more likely to utilize such systems. Ruby on Rails has fractionalized the time it takes to realize concepts as fully-functional web applications. By streamlining the implantation procedure of passive filters, developers can now rapidly realize concepts incorporating collaborative filtering. Similarly, developers can now conveniently experiment with passive collaborative filters in existing applications.

ActsAsLoggable is ideal from a developer's perspective because it is an easy-to-to-understand black box. The implementation is done at a level that is primarily transparent for the developer such that he can utilize his same existing source code and gain logging functionality without modification. The command-line installation procedure is painless and quickly accomplished.

While the data aggregated is a solid foundation, it does not cover every desirable application. It will provide data for passive filters based on user actions pertaining to URL requests both normal and AJAX. There is additional functionality for typical click-and-execute-JavaScript interactions, but not yet advanced user-interface features such as drag and drop.

The end product is definitely better suited for the agile developer interested in rapidly deploying. As an application scales, it may be more desirable performance-wise to implement logging at the web-server level to avoid all of the AJAX calls and ruby processes that result from logging data. There is an unavoidable trade-off between generalizability and convenience with performance and specificity of data. However, ActsAsLoggable should function for the developer desiring a quick and robust solution.

5 Recommendations on Future Work

One worthwhile endeavor would be packaging ActsAsLoggable with various open-source collaborative filters into one all-encompassing 'passive-filtering' plug-in. While often a collaborative filtering algorithm is application-specific, it may still be of value to create a generic plug-in that provides functionality on both ends to even further decrease the barrier to implement passive filtering. The difficulty of doing this, however, is how to relate the logged to data to the passive filter inputs. To be of value, the user must be able to specify many types of relations. If one could design a scheme where a developer could specify an Item's class, ID, and action to filter by (ie time spent looking), this combined plug-in could be very valuable.

The other area of work worthwhile is extending functionality to the advanced user-interface applications. Websites will continue to progress toward the fluidity desktop applications. This trend will likely be accomplished by heavier usage of JavaScript. Extending ActsAsLoggable to be more verbose in aggregating JavaScript information would definitely be of value. The ability to work seamlessly with script.aculo.us-type libraries would expand the applications suited by ActsAsLoggable.

6 Appendix

6.1 Plugin Installation Overview for Developers

ActsAsLoggable

1. Run script/install [svn_url]://acts_as_loggable
2. Run script/generate acts_as_loggable
3. Declare ActsAsLoggable in controller you which to have monitored as the following:

   ```
   acts_as_loggable :user_class=>ClassName do
         code to find current user id
   end
   ```

   where *ClassName* is the user model class in your application (not a string) and *code to find current user id* is a block of code that when executed will return the current user's id.
4. *Enjoy!!!*

Any instance where a user clicks a link generated by *link_to* or *link_to_remote* will be logged as will any instance where *remote_function* is executred. To log JavaScript interactions utilize

logged_link_to_function*(link name,log_name,*args, &blk);*

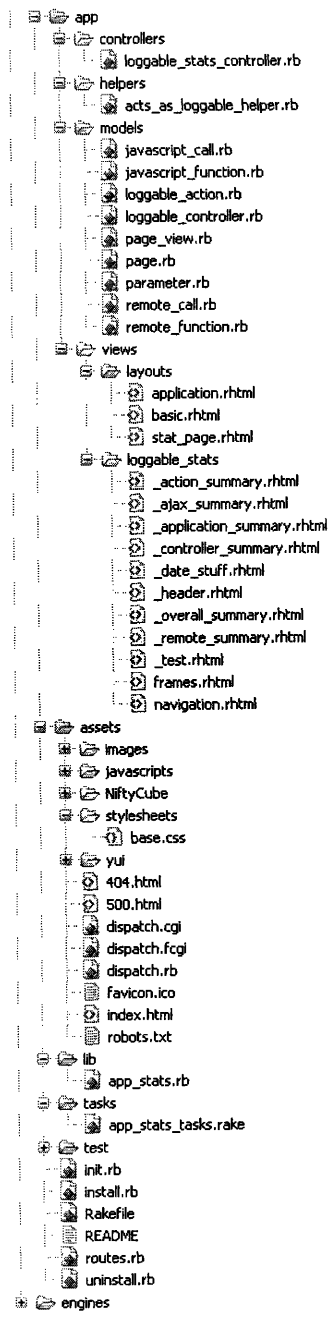
which operated identically to *link_to_function* but adds a name to record as *log_name*.

LoggableStats

1. If not already installed, run script/install http://svn.rails-engines.org/plugins/engines
2. Run script/install [svn_url]://app_stats
3. Pages accessible by [server_url]/LoggableStats/frames

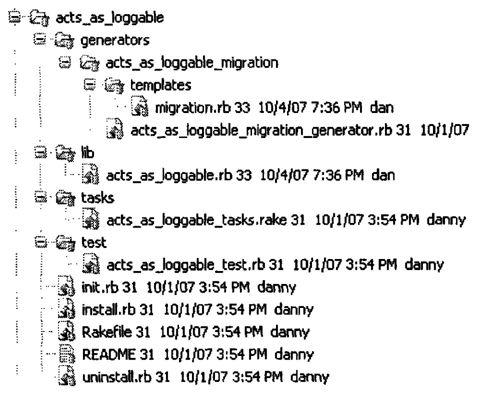
6.2 Plug-in Source Files

Figure 7: LoggableStats File Structure



```
app
  controllers
    loggable_stats_controller.rb
  helpers
    acts_as_loggable_helper.rb
  models
    javascript_call.rb
    javascript_function.rb
    loggable_action.rb
    loggable_controller.rb
    page_view.rb
    page.rb
    parameter.rb
    remote_call.rb
    remote_function.rb
  views
    layouts
      application.rhtml
      basic.rhtml
      stat_page.rhtml
    loggable_stats
      _action_summary.rhtml
      _ajax_summary.rhtml
      _application_summary.rhtml
      _controller_summary.rhtml
      _date_stuff.rhtml
      _header.rhtml
      _overall_summary.rhtml
      _remote_summary.rhtml
      _test.rhtml
      frames.rhtml
      navigation.rhtml
assets
  images
  javascripts
  NiftyCube
  stylesheets
    base.css
  yui
  404.html
  500.html
  dispatch.cgi
  dispatch.fcgi
  dispatch.rb
  favicon.ico
  index.html
  robots.txt
lib
  app_stats.rb
tasks
  app_stats_tasks.rake
test
init.rb
install.rb
Rakefile
README
routes.rb
uninstall.rb
engines
```

Figure 8: ActsAsLoggable File Structure



```
acts_as_loggable
  generators
    acts_as_loggable_migration
      templates
        migration.rb 33  10/4/07 7:36 PM  dan
      acts_as_loggable_migration_generator.rb 31  10/1/07
  lib
    acts_as_loggable.rb 33  10/4/07 7:36 PM  dan
  tasks
    acts_as_loggable_tasks.rake 31  10/1/07 3:54 PM  danny
  test
    acts_as_loggable_test.rb 31  10/1/07 3:54 PM  danny
  init.rb 31  10/1/07 3:54 PM  danny
  install.rb 31  10/1/07 3:54 PM  danny
  Rakefile 31  10/1/07 3:54 PM  danny
  README 31  10/1/07 3:54 PM  danny
  uninstall.rb 31  10/1/07 3:54 PM  danny
```

7 Bibliography

Lukas Brozovsky. ColFi - Recommender System for a Dating Service (**2006**)

Prem Melville, Raymond J. Mooney, and Ramadass Nagarajan. Content-Boosted Collaborative Filtering for Improved Recommendations (**2002**)

Jon Kleinberg, Mark Sandler. Using Mixture Models for Collaborative Filtering (**2004**).

Ajith Abraham, Vitorino Ramos. Web Usage Mining Using Artificial Ant Colony Clustering and Genetic Programming (**2003**).

Badrul Sarwar, George Karypis, Joseph Konstan, and John Riedl. Item-based Collaborative Filtering Recommendation Algorithms (**2001**).

Badrul M. Sarwar, George Karypis, Joseph A. Konstan, John T. Riedl. Application of Dimensionality Reduction in Recommender System (**2000**),

David M. NIchols (Computing Department, Lancaster University). Implicit Rating and Filtering (**1997**),

Yung-Hsin Chen and Edward I. George. A Bayesian Model for Collaborative Filtering (**2000**),