

# Virtual Crime: Forensic Artefacts from Second Life

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## Abstract

Second Life is an online virtual environment which is populated by users from all over the world. The virtual environment is split into a variety of public and private areas; these provide avatars with a chance to explore a wide range of environments and interact with other users. There is also an opportunity for users to create personalised environments; organisations such as the BCS have created customised environments to assist with education and training. Over the past few years the media has highlighted various legal cases involving virtual worlds; these cases cover both civil and criminal activities such as adultery, stalking and simulated child molestation. An analyst may potentially have an investigation where they need to understand the activity which goes on in a virtual environment and how to recover potential evidence. Digital Forensic Analysts may require training as they may not be familiar with how virtual worlds work and the types of digital artefacts left by their use. Previous research into Digital Forensics on Virtual Environments has primarily focused on their use to provide scenario based education. Little research has yet been published on methodologies for identifying artefacts relating to activities in virtual environments.

This paper highlights the requirement to provide focused training on both the criminal activity and digital artefacts relating to the use of virtual environments. The paper also describes a series of experiments that were conducted to ascertain the artefacts left after using Second Life. The experiments were conducted in virtual machines and aimed to replicate typical interaction between a user's avatar and the Second Life environment. This paper provides useful reference material for an analyst during an investigation, as it describes the artefacts identified as a result of this research. Finally this paper uses the results of this research to provide a basis for a discussion on the educational requirements for investigating crime in virtual environments.

## **1.0 Introduction**

Virtual environments provide an opportunity for a user to engage in activities that may not be possible in the real world. In the virtual world a user can engage with people in other locations in real time; a user can even create a virtual life complete with land, resources and friendships. Whilst residents of virtual environments generally use them for entertainment and relaxation, some users have found ways of engaging in criminal activity. Due to the potential for criminal or civil disputes, digital analysts may be required to identify artefacts relating to activity in virtual worlds.

This paper highlights the requirement for providing digital analysts with focused education on virtual environments; it identifies a requirement for training into the types of criminal activity that could be committed and for methodologies for identifying artefacts relating to such activity. This paper also describes the artefacts left by the Second Life virtual environment, providing a useful reference material for digital analysts.

The rest of this paper is structured as follows: Section 2 identifies related work; Second Life is discussed in Section 3. The methodology employed during this research is described in Section 4; Section 5 describes the artefacts identified in Second Life. In Section 6 the results of this research and their implication for education are discussed; Section 7 describes future work. Finally this paper is concluded in Section 8.

## **2.0 Related Research**

Generally virtual environments have a currency system which permits objects to be bought or traded; in Second Life a user can exchange their local currency for Linden Dollars to carry out financial transactions within the game environment (Brenner, 2008). Users can also exchange Linden Dollars for local currency; the ability to convert money provides opportunities for criminal activities such as theft and money laundering. Brenner suggests Second Life is not a traditional game as there is no goal or plot; this provides a wide range of opportunities for engaging in criminal activity.

A user may join a virtual environment with criminal intent; virtual worlds provide an opportunity for a user to interact with a large number of potential victims (U.S Department of Justice, 2012). Virtual environments also provide an opportunity for users to communicate covertly. A user may also engage in activities leading to Civil Court action such as virtual adultery (Pfeiffer, 2012); adultery in a virtual environment is generally regarded as a serious act which may lead to the breakdown of a real world relationship. Pfeiffer suggests that laws should be updated to take actions committed in the virtual world which lead to legally actionable conduct seriously.

Meek-Prieto (2008) argues that Second Life provides a platform for child abuse and related activities. It is suggested that it can be difficult to identify perpetrators and that this may lead to an increase in criminal activity within the virtual environment. Second life allows activities such as age play as well as a forum for discussion and exchanging of illegal objects. Meek-Prieto also suggests that laws should be updated to reflect potential activity in virtual environments.

Rakitienskaia (2011) provides a list of the possible categories of virtual crime and highlights the real world damage that could be caused by such activities. The paper also suggests methods for performing in world forensics; such methods could be used in combination with an analysis of a suspect's hard drive to maximise the potential evidence available.

### **3.0 Second Life**

Second Life is a virtual world which was originally launched on 23 June 2003 by Linden Labs. The virtual world is accessed through a viewer; the most common viewer can be downloaded from the Second Life website when a user first joins. The viewer software renders the world in 3D and permits interaction with the environment through the use of an avatar. In Second Life the environment is broken down into areas; an area can be public or private and may also be restricted based upon the user's age and content setting. Figure 1 shows the Second Life Viewer with a user logged in and currently in a typical environment. The current user is the avatar in the centre of the screen; if a user and their clothing have not yet fully downloaded they are represented by a white floating oval.

A user is known as a resident and can interact with objects and people within the environment. There are various guides for using Second Life (JISC, 2012), as well as mentors within the environment who assist new residents (Second Life, 2012). Within the environment a user can interact with other users and objects; a user has their own inventory and can buy and trade objects.

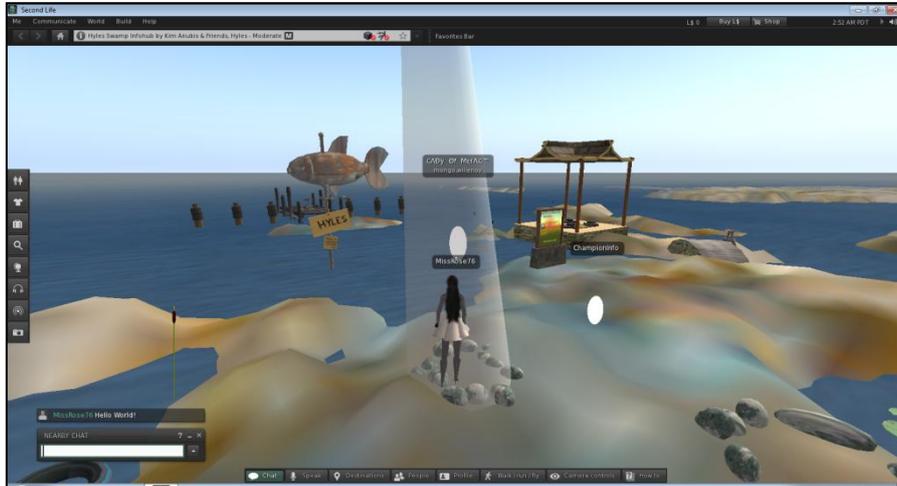


Figure 1: The Second Life Environment

## 4.0 Methodology

This research was performed on a Virtual Machine using VMWare 8; a clean virtual machine was created with a 20GB hard drive. Windows 7 Enterprise was installed using the default settings and a single user account was created. After Windows was successfully installed, the virtual machine was cloned; the original machine was kept to provide a baseline for the experiments (VM1). The Second Life viewer was installed on the cloned machine to provide a second baseline machine (VM2); this machine was cloned for each experiment. The experiments were designed to mimic typical user interaction with the Second Life viewer in order to ascertain the artefacts left by those activities. During the experiments all interaction with the Second Life environment was performed through the viewer software version 3.3.4.262321. The virtual machines were analysed using a variety of tools including Encase and WinHex.

## 5.0 Potentially Interesting Forensic Artefacts

A series of experiments were performed to ascertain the types of artefacts left on a system by Second Life, and the behaviour that led to their current state. The experiments were split into three areas: identifying the current user, learning about the world, and identifying other users and interactions. The following sections describe the experiments performed in each of the three identified areas and the artefacts that were recovered.

### 5.1 Artefacts Relating to the User

During an investigation involving a virtual environment one of the central questions is "What information is available about the User?". In a virtual environment a user may appear different to their physical self, both in their

appearance and their behaviour. This section examines the information that can be found about the Second Life user from their machine.

The first experiment performed in a virtual machine involved creating a character, and, once in the world, editing the character's profile. In a clone of VM1, Internet Explorer was used to navigate to the Second Life website (2012); after selecting to join the user was invited to select a pre-created avatar as shown in Figure 2. Upon selection of an avatar the user was asked to provide a unique username. The avatar was named MissRose76 to improve the chances of favourable interactions with the residents of Second Life (Fogel, 2002). The next stage in setting up an account asked for: an email address, date of birth, password and a security question as shown in Figure 3. Finally the free account was selected; after setting up an account the Second Life Viewer was then downloaded and installed using the default settings.

Once the viewer had been installed it was used to enter the Second Life environment. During the first experiment the avatar remained in the starting area and the user's profile was updated. A subsequent experiment involved changing the settings in the user's account to permit all content to be viewed to ascertain whether the level of access to content was stored locally. Further experiments involved signing up for a premium subscription, which provided a stipend of 300 Linden dollars a week, and the opportunity to set up a home within the world; this led to experiments involving buying items within the world and editing settings within the home environment.



Figure 2: Selecting an Avatar

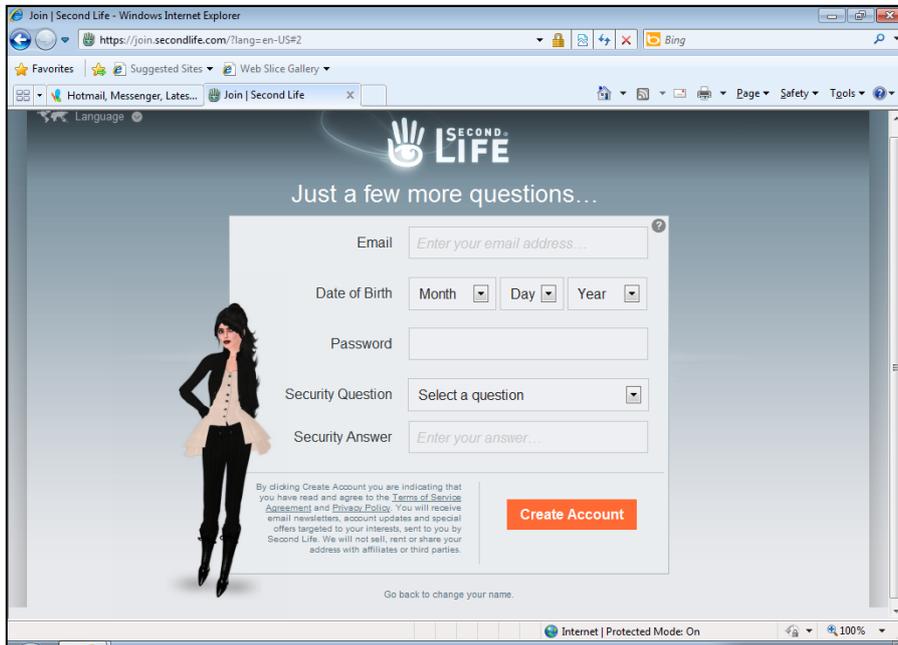


Figure 3: Joining Second Life requires very few personal details

### 5.1.1 Personal information

As shown in figure 4 the registry can provide information about the viewer used for accessing Second Life as well as the version number; this information can be used during experiments to identify relevant artefacts and behaviour. The user name of the Second Life resident can be found at C:\Users\[User\_Name]\Appdata\Roaming\SecondLife as shown in figure 5; a directory name is formed from the user's name followed by '\_resident'. Having identified the user name the file avatar\_name\_cache.xml can be used to find the user's unique identifier which is highlighted in figure 6. The entries within the avatar\_name\_cache.xml are stored in xml format and provide the first and last names, username and a unique identifier for each user.

Details on the user's PC, last location and some details about the user can be found at C:\Users\[User\_Name]\Appdata\Roaming\SecondLife\logs\ in the files Secondlife.log and Secondlife.old; these logs contain time and date information. Debug\_info.log also provides information on the PC configuration. The last log off time for the user on that machine can be found at C:\Users\[User\_Name]\Appdata\Roaming\SecondLife\[Resident\_Name]\_Resident\Settings\_per account.xml.

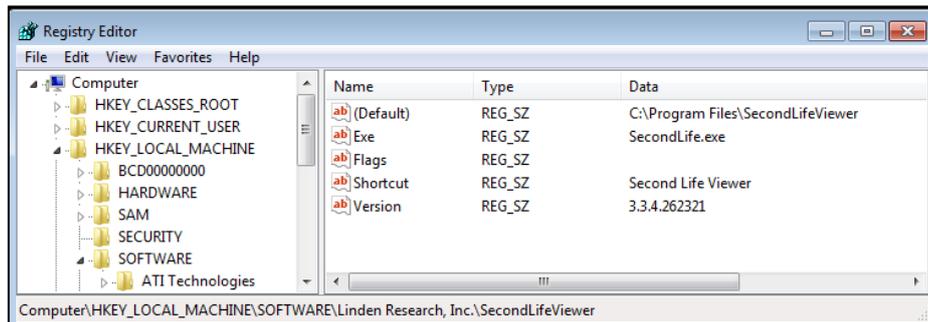


Figure 4: Registry Data for the Second Life Viewer

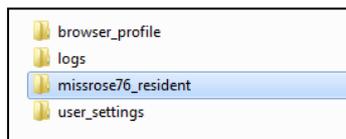


Figure 5: Second Life user names associated with a user area on a Windows 7 PC

```

</map>
<key>3d405b76-6869-452f-9709-5277426dd5b8</key>
<map>
<key>display_name</key>
<string>MissRose76</string>
<key>display_name_expires</key>
<date>2012-07-31T10:48:50.04Z</date>
<key>display_name_next_update</key>
<date>1970-01-01T00:00:00Z</date>
<key>is_display_name_default</key>
<boolean>1</boolean>
<key>legacy_first_name</key>
<string>MissRose76</string>
<key>legacy_last_name</key>
<string>Resident</string>
<key>username</key>
<string>missrose76</string>
</map>
<key>4e286953-dc92-4fcc-b5c6-709447a5d71b</key>

```

Figure 6: The entry for the current user in avatar\_name\_cache.xml

### 5.1.2 Account status

During the initial experiment a free account was used; the account was upgraded during this experiment to ascertain if any artefacts relating to the upgrade were available. During this research no artefacts were identified relating to the account status; however if the user upgraded using the Second Life, website traces may be available in an Internet Cache.

## 5.2 Artefacts Relating to the World

Using a clone of the virtual machine with the avatar set up, a series of experiments were performed to identify artefacts relating to the Second Life World. The initial experiment involved selecting and transporting the avatar to some of the destinations listed on the opening screen of the viewer. Destinations with unusual names were selected to make searching for potential artefacts simpler. A further series of experiments were conducted by selecting a single environment and interacting with objects in it; each object and the type of interaction was documented. Finally the avatar visited a series of restricted areas including two private residences and an adult rated area.

### 5.2.1 List of Locations

Information on locations the user has visited can be found at C:\Users\[User\_Name]\Appdata\Roaming\SecondLife\[Resident\_Name]\_Resident in teleport\_history.txt and typed\_locations.txt. Teleport\_history contains a list with times of visits to different areas within the environment; the location of each area is also recorded. An extract from a teleport\_history file is shown in figure 7. Typed\_locations stores areas the user has visited by manually typing in the name. A screenshot of the last location of the user is also stored within this directory (screen\_last.bmp); this may be useful in identifying the state of the environment when the user left it.

```
{'date':d"2012-07-30T11:08:56.05z", 'global_pos':[r264085,r267907,r27.1183], 'title':'Destination Island, Destination Island 11'}
```

```
{'date':d"2012-07-30T11:11:56.80z", 'global_pos':[r293907,r309284,r55.5], 'title':'Destination Island, LR 28'}
```

```
{'date':d"2012-07-30T11:12:02.16z", 'global_pos':[r293907,r309284,r39.3794], 'title':'Summoning Circle, LR 28'}
```

```
{'date':d"2012-07-31T09:47:20.20z", 'global_pos':[r258602,r259872,r23.5491], 'title':'Hyles Swamp Infohub by Kim Anubis & Friends, Hyles'}
```

```
{'date':d"2012-07-31T10:21:12.52z", 'global_pos':[r258661,r259895,r23.2537], 'title':'Hyles Info Center, Hyles'}
```

Figure 7: An extract from teleport\_history.txt

### 5.2.2 Restricted Areas

During this research no artefacts were identified when a user had successfully managed to enter a restricted area; if a user unsuccessfully attempts to visit a restricted area it is recorded in the secondlife.log described in Section 5.1.1.

### 5.3 Artefacts Relating to Other Users

Digital investigations involving Second Life are likely to involve several users within the environment; therefore identifying artefacts relating to communication between avatars is important. There are several commonly used methods of communication within Second Life: text based open conversations, text based private messages, and audio conversations. Separate experiments were carried out for each of the three common communication methods; in each experiment the user interacted with three other avatars. In text based communications unusual keywords were added to assist with identifying artefacts. A further set of experiments were performed by watching other users perform actions in the environment. Finally items from the user's inventory were given to other avatars and different items were received in exchange.

#### 5.3.1 Other Residents

A list of residents that have been in the same area as the current user is stored at C:\Users\[User\_Name]\Appdata\Local\SecondLife in avatar\_name\_cache.xml. The entries contain a unique identifier, first name, last name, and user name for each resident; the list does not show who the user had contact with.

#### 5.3.2 Interactions with other Residents

It is possible to extract a general chat log from C:\Users\[User\_Name]\Appdata\Roaming\SecondLife\[Resident\_Name]\_Resident\chat.txt. The public chat log shows the public written chat in the areas the resident has been and includes date and time information. Private written chats are stored in text files for each resident, for example a conversation with Identatron would be held in Identatron.txt. Below is an extract from a private chat log named Identatron.txt which was created during this experiment:

```
[2012/07/21 03:15] Identatron: hello
[2012/07/21 03:15] Second Life: secondlife:///app/agent/a9af9687-a64a-4137-bff3-5ce918510640/about is offering friendship.

Would you be my friend?

(By default, you will be able to see each other's online status.)
[2012/07/21 03:15] Second Life: Friendship offer accepted.
```

```
[2012/07/21 03:15] Second Life: <nolink> Identatron </nolink> is
Online
[2012/07/21 03:16] Identatron: hello
[2012/07/21 03:17] MissRose76: Hi :)
[2012/07/21 03:19] Second Life: secondlife:///app/agent/ a9af9687-
a64a-4137-bff3-5ce918510640/about has given you this folder:
secondlife:///app/inventory/ a9af9687-a64a-4137-bff3-
5ce918510640/select?name=Shops
[2012/07/21 03:20] Second Life: secondlife:///app/agent/ a9af9687-
a64a-4137-bff3-5ce918510640/about has offered to teleport you to
their location:

"Join me in Hyles"
[2012/07/21 03:25] Second Life: <nolink> Identatron </nolink> is
Offline
```

As can be seen above the private chat records store the date and time for each entry; the entire conversation from both parties is recorded by default. Parts of the private conversation may include friendship requests which allow you to see when another resident is online. In the example above at 03:18 Identatron gave MissRose76 an item from his Inventory; the item is linked to Identatron's unique identifier. At 03:20 Identatron offered to teleport MissRose76 to another location; Identatron was already in the new location when this request was sent.

When a user buys an object from another user or shop a log of the transaction is stored, the log contains the date and time of the transaction. The log also contains details of the user from which the object was purchased, the price of the object and a brief description. The log can be found at C:\Users\[User\_Name]\Appdata\Roaming\SecondLife\[Resident\_Name]\_Resident\Open\_notifications.xml.

During this research verbal methods of communication were used during some experiments; no records of the verbal communications were identified during the analysis.

## 5.4 Summary

In summary section 5 has provided an overview of the experiments performed using Second Life; the artefacts identified are provided in table 1.

**Table 1: A summary of the artefacts identified during this research**

Location	Information Contained within the Artefact
C:\Users\[User_Name]\AppData\Local\SecondLife\avatar_name_cache.xml	Information of residents who have been in the same areas as the current user (name, username, unique identifier) This list also contains details on the current user
C:\Users\[User_Name]\AppData\Local\SecondLife\name_cache.xml	Information of residents who have been in the same areas as the current user (username, unique identifier, time) This list also contains details on the current user
C:\Users\[User_Name]\AppData\Roaming\SecondLife\logs\debug_info.log	Information on user's PC Last location in world User information
C:\Users\[User_Name]\AppData\Roaming\SecondLife\logs\secondlife.log	Thorough log of viewer activity Contains username Shows access to another residents profile Details of users with times
C:\Users\[User_Name]\AppData\Roaming\SecondLife\logs\secondlife.old	Older version of secondlife.log
C:\Users\[User_Name]\AppData\Roaming\SecondLife\[Resident_Name]_Resident\chat.txt	Public chat log from the areas the user has visited
C:\Users\[User_Name]\AppData\Roaming\SecondLife\[Resident_Name]_Resident\[other_resident].txt	Private chat log with another resident Contains details of friendship requests, any objects given / received, requests for teleports
C:\Users\[User_Name]\AppData\Roaming\SecondLife\[Resident_Name]_Resident\Open_notifications.xml	Payment details for transactions – includes who it was bought from, the price and an item description
C:\Users\[User_Name]\AppData\Roaming\SecondLife\[Resident_Name]_Resident\Settings_per_account.xml	Date and time of last log off on the current machine

## 6.0 Discussion

This paper has identified the forensic artefacts found from Second Life after common user interactions are performed. The Second Life viewer installed was provided from the Second Life website, but other viewers are available which may provide different artefacts. The results show information can be obtained about the user such as: their username, appearance, finances, and inventory. Information on the user may also be retrievable from an Internet cache. For example, if the user

joined recently or logged on to their account through the Second Life website; this may provide an additional source of corroboration.

The artefacts identified also provide information about the world and in particular where a user has been and at what time. This information could be plotted on an event timeline to follow a user's actions; if multiple users were added to the timeline any time spent together could be identified. Chat logs were stored in plain text and separate files; the global chat log and each resident that had been privately chatted with had separate files. The files contained date and time information as well as other types of interaction such as friendship requests and inventory items exchanging hands. The plain text nature of the log makes it simple for an analyst to extract the logs and perform a keyword search. A large amount of the artefacts found were stored in an XML format which an analyst could read and interpret without specialist software or knowledge. The majority of the information stored was in a readable format; the main challenge was identifying the types of behaviour which could be performed and forming relationships between activities and the logs.

Virtual worlds provide an opportunity for users to develop a fantasy environment tailored to their unique specifications; a user can be anyone they want to be in any environment. Environments such as Second Life provide a wide range of potential opportunities for engaging in inappropriate activities; such activities may result in civil or criminal prosecutions. Virtual worlds and associated software are also regularly updated, which means artefacts and their related behaviour may alter. To ascertain the artefacts produced by the wide range of possible activities would require significant resources and regularly updating. It is therefore suggested that a more suitable use of resources would be to educate practitioners in how virtual worlds work and to teach them methodologies for analysing virtual world activity.

One of the outcomes of this research was the realisation that researching a topic may not provide sufficient information to replicate real world activity. For example, it is possible to read forums and literature, such as those discussed in Section 3 which document how to interact with Second Life, but such literature does not cover every aspect of a virtual life. Throughout the experiments several regular Second Life residents commented on the fact it was clear the experimenter was new to the world; this was despite changing the avatars appearance and having used the environment for several days in preparation. Whilst most of the residents were friendly and helpful, it is also to be noted that, despite the relatively short length of time spent in the environment, the avatar was still subjected to some less friendly interaction. Interactions with a variety of regular residents provided extra information about interacting with the environment which enabled more realistic behaviour simulation.

In order for an analyst to successfully investigate virtual activity it will be necessary to provide focused training on the subject. This training could be done within a virtual environment to aid familiarisation with the topic and permit the analyst to explore the world first hand. Providing information on the differences

between virtual environments and both the real world and other types of digital crime environments is an important educational requirement; virtual worlds may not be considered a game, for example a user could create an entire life within the world which is separate to their real world life.

## **7.0 Future Work**

This paper provides an introduction to the requirement for focused training on digital crimes in virtual worlds. Further work into both Second Life and other Virtual environments is required. It is hoped that a general methodology for the investigation of virtual world crime could also be created. Finally, a substantial piece of future work would involve developing an educational program to teach practitioners about virtual environments and crime in virtual worlds; the educational program would also need to include information on identifying relevant artefacts left on the digital device and the behaviour it represents.

## **8.0 Conclusion**

In conclusion, this paper has shown that virtual worlds are a unique environment where a character may be completely different to the real world identity controlling it. Virtual worlds can be involved in a large variety of criminal activity and therefore an analyst may be required to identify artefacts relating to them. This paper has used Second Life as an example to show the types of interactions that can occur within a virtual environment and the related artefacts.

Experiments performed to identify the effect of interacting with a virtual environment need to reflect typical user behaviour; therefore analysts require training in interaction with virtual environments. Due to the changing nature of virtual environments, education should aim to provide a methodology to enable analysts to identify relevant artefacts themselves; rather than to provide information on the artefacts relating to a specific build version of a virtual world.

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