Development of Noiseless Steganography Method in Role-Playing Game

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***Abstract*—Noiseless Steganography (Nostega) is a variant of steganography in which the method does not use or produce noise that can expose the message's existence in the media. A potential media for Nostega is role-playing game as it has an abundance of uncertain elements that can be used for embedding messages. Using the Nostega architecture, parameters, message encoder, and communications protocol and covert channels are defined and implemented in the game Empyrean Campaign as a case study. The method is then verified to be noiseless based on a survey result that respondents does not realize that a hidden message exists in the game.**

Keywords—steganography, noiseless steganography, role-playing game

I. Introduction

The advancements of technology has aided humanity in many ways, including connecting people between large distances. People can communicate and send information in a large number of ways such as telephone, instant messaging, email, etc. But as technology grows problems caused by it also grows and evolves, such as security. There are people that can access unauthorized information and use it to their own advantage. Private and sensitive information that concerns an important entity such as the government must be guarded, both in storage and transfer.

One such way of securing the transfer of information is the study of cryptography in which the information is transformed in such a way that it does not hold any meaning. After the message is transformed (encrypted) by the sender, it can only be transformed back to it's original state (decrypted) by the intended receiver using a key that both sides have agreed upon beforehand. Modern day cryptography has resulted in various methods of encrypting messages such as the RC4, MD5, Advanced Encryption Standard (AES), Rivest-Shamir-Adleman (RSA), etc.

Although cryptography prevents the message to be understood immediately, it it still a fact that other party knows of the existence of the message. Because of that, an alternative method called steganography is created where instead it conceals the existence of the message thus avoiding other parties' suspicion of the message. Steganography uses a cover media for embedding the message so that it is only seen as the used media, hiding the existence of the message.

Although steganography can be used to embed a message onto a media, most steganography methods uses or produces noise. Noise are unusual fluctuations in a media such as a highly saturated region in an image. The involvement of noise in steganography is a weakness because it can arise suspicion of other parties. One example is the Least Significant Bit (LSB) method that embeds bits of the message in the least significant bit of the pixels in an image. This method is now unreliable because the existence of the message can be revealed by studying the noise caused by the embedded bits. This study of revealing hidden messages based on steganography methods is called steganalysis.

To combat the weakness of steganography methods, a new variation of steganography method is proposed by Abdelrahman Desoky called Noiseless Steganography (Nostega). Nostega are steganography methods that does not use or produce noise in embedding messages. This is done by blending the message with the media so that it is visible in plain sight; unlike conventional steganography where the message is embedded on the media, in Nostega the message becomes part of the media. An example is the usage of graphs to hide a word or sentence. The letters on the message is converted into numbers and the numbers are used as data for the graph. The graph is then used in a writing, such as a newspaper article or a scientific journal. Other parties that are reading the graph cannot confirm the validity of the data if it comes from a respectable source, thus avoiding suspicion from them.

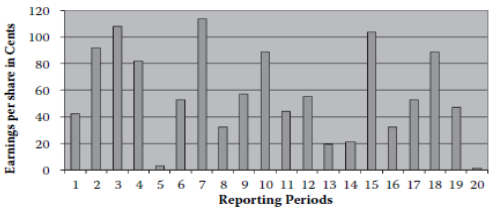

Figure I.1. A graph embedded with the message "Use my secret key"

Various media has been used as cover for steganography as well as Nostega, including games. Games is a potential media as it has a large degree of freedom and uncertain elements; these elements are the key aspects for embedding messages in

Nostega methods. There are already lots of Nostega methods using traditional games such as Chess (Desoky, 2012) and Go (Hernandez-Castro, Blasco-Lopez, Estevez-Tapiador, & Ribagorda-Garnacho, 2006) but also digital games such as Minesweeper (Mahato, S., Yadaf, K. D., & Khan, D. A., 2017). Another potential game genre to be used for Nostega is Role-Playing Game (RPG) because of the freedom of the player actions and uncertain elements such as damage calculation in the game. This paper will discuss the development of Nostega methods in role-playing game.

II. NOISELESS STEGANOGRAPHY

A. *Steganography*

The word steganography is derived from the Greek word *steganographia* which means 'covered writing'. Steganography is the study of 'covering' messages under medias so that it is unknown to other parties that a message exists in the media. The origin of steganography dates back to the Roman ages where Histaeus embeds a message by shaving a slave's head until it is bald and tattooing the message on it's head. Overtime the slave's hair will grow and cover the tattooed message. As time passes steganography methods also evolve, such as embedding message on accessories and shoes, the usage of dots on text writing, invisible ink, etc. Modern steganography methods allows micro-sized messages that can be embedded in human skin and even a dot or comma in written text. (Katzenbeisser, 2000)

Consider a scenario where Alice wants to send Bob a message but needs to keep it hidden from Wendy who checks all items that Alice sends to Bob. The process of steganography is as follows: (Katzenbeisser, 2000)

1) The sender (Alice) creates a stego-object by combining the message with a cover. The resulting stego-object is similar to the unsuspicious cover object, thus preventing a third party (Wendy) from noticing that there is an embedded message in the object.

2) The receiver (Bob) then receives the stego-object and extracts the embedded message within. Optionally, a predetermined stego-key between the sender and receiver can be used to create the stego-object and extract the message within the stego-object.

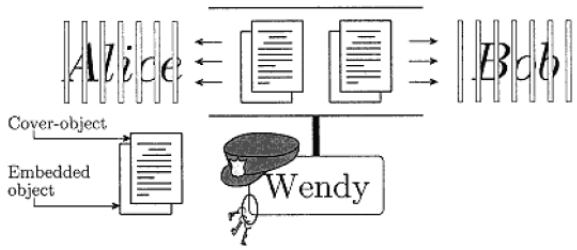

Figure II.1. An illustration of the steganography process

B. *Noiseless Steganography*

Noiseless Steganography (Nostega) is a variation of steganography method in which there is no noise used or produced in the stego-object. The key values of Nostega are the steganographic field, steganographic parameter, and communications protocol and covert channel. These 3 keys determine the shape of the stego-object and how the message is embedded in it. In order to understand more of these key values, an analysis of the Nostega architecture is needed. (Desoky, 2012)

The architecture of Nostega is as follows: (Desoky, 2012)

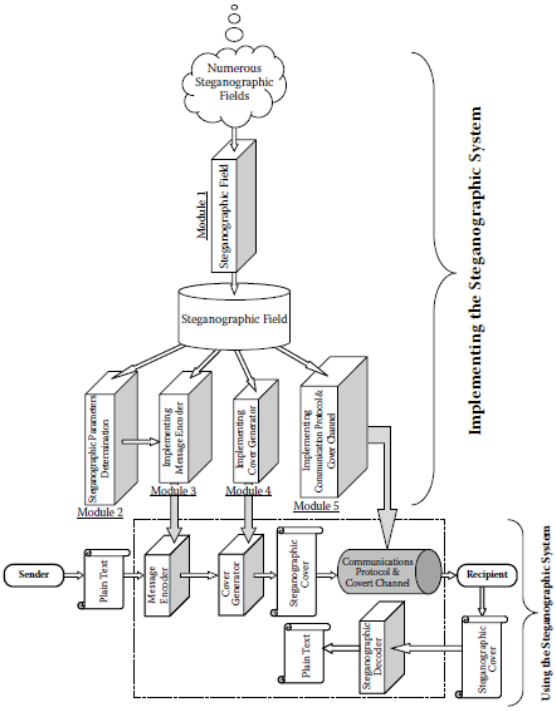

Figure II.2. The Noiseless Steganography architecture

1) Steganographic field determination
Determining the field to be used such as education, economics, statistics, etc.

2) Steganographic parameters determination
Determining the parameters to be used for embedding the message. The steganographic field determination affects how the message can be encoded in the cover object.

3) Implementing message encoder
Implements an application capable of encoding the message to the suitable form.

4) Implementing cover generator
Implements a generator or discover a contemporary tool for creating covers for message embedding.

5) Implementing communications protocol and covert channel
Defines the sender and receiver's interaction and how the stego-object is transferred. Also related to the chosen steganographic field.

C. *Gamestega*

Game Steganography or Gamestega are Nostega methods using games as the media. The sender gives the receiver

access to the game (whether giving a physical copy or online access) and the receiver plays the game and extracts the embedded message using the information from the game. Some of the examples are Chestega which uses chess, Minestega which uses Minesweeper, and StegoRogue which uses the roguelike game genre (Gibbs & Shashidhar, 2015). All these examples have one thing in common: the parameters used for embedding the message is dependent on the game; Chestega uses chess moves and pawn positions, Minesweeper uses the position of the mines, and StegoRogue uses the generated map to embed messages. The form of the message is also dependent to the parameter, which can be a value, a formation, or a combination of those. In addition, the usage of computer for calculating values such as the random position of the mines and the configuration of the rooms on the map makes it so that the player cannot deny the validity of the values; it is assumed to be "fairly" decided by the computer, even if those values are the message itself.

III. ROLE-PLAYING GAME

A. *Definition*

Role-playing game (RPG) is a genre of game in which the player role plays as another character in the game. The player can also control multiple characters at once which are called a party. The player can then act as the character and choose decisions based on the characters' attitude or preference. The player then goes on an adventure and is presented with obstacles and challenges. To aid the player in tackling those challenges, the player's character(s) are given skills and abilities which grows as the player advances throughout the game. There are also other characters in the game that can be interacted with which are Non-Playable Characters (NPC).

The first iteration of RPG are tabletop RPGs which are played with a pen and some paper (thus often called 'pen and paper'). In it the players each control a character and goes on a quest determined by the Game Master (GM). The GM acts as an administrator and decides the events that plays out in the game. The GM also decides the outcome of the actions done by the characters. The players can do anything in the game as long is not prohibited by the GM. To balance things out, characters have stats that influence how good they can do certain things; in addition, a skillful character may also fail on their selected action by chance. Because of the usage of only pen and paper for noting stats, most of the game is imagined by the players thus providing a vast amount of freedom. This freedom results in an uncertainty of choices, thus becoming a potential for embedding messages.

B. *Digital RPG*

As technology evolves games began to shift into using computers, including RPGs. The availability of monitors means that RPGs no longer have to rely on pen and paper and more detail can be shown to the player. Graphics better help the player to understand what is happening as well as deciding what the best action to be done. Some advantages of digital RPG compared to tabletop RPG is as follows: (Salen & Zimmerman, 2004)

1) Immediate but Narrow Interactivity
Player's inputs can be instantly processed by the computer, but it cannot understand complex inputs that are not registered in the game such as a phrase or a sentence typed by the player.

2) Information Manipulation
Computers can use various information that GMs cannot utilize such as images, sounds, animations etc. Computers can also enforce rules to limit the player's scope of actions.

3) Automated Complex Systems
AI for enemies and automated price calculations for shop items can now be used to enhance gameplay; the player doesn't need to remember how to calculate such complex systems and can focus on other aspects of the game. The drawback is that the player doesn't understand how those systems work, which is called the "Black Box Syndrome".

4) Networked Communication
The usage of networks allows multiple players to play the same game from different places; this is not the case in tabletop RPGs where all the players and the GM must be in the same place to play the game.

C. *Aspects*

Aspects of RPG are as follows: (Ernest, 2010)

1) Theme
Each RPG has an underlying theme in it; whether it is saving a princess in a medieval world, defeating an alien threatening the universe in the far future, or trying to save your relative from gangsters in the current world setting. These themes decides the world where the player will go on their adventure.

2) Progression
The story in which the player plays if often divided into chapters where in each chapter the player is presented an area to explore and has to gain enough strength to advance to the next chapter and area. The player is given quests that gives power as the reward and at the end of each chapter the player needs to defeat a powerful foe so that they can be deemed worthy to continue the story. In addition, there exists additional quests that while not mandatory, it will help the player in getting stronger. The player is encouraged to explore the game and fully experience everything it has to offer.

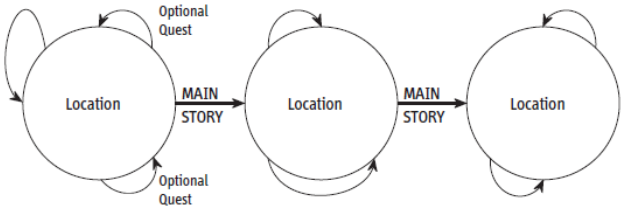

Figure III.1. Illustration of the progression in RPG

3) Gameplay Modes

RPG provide a large amount of activities and challenges for the player, such as exploration, tactical combat, stealth operations, conversation, buying and selling, and inventory management. The following is the major modes that is available in RPG:

a) Exploration and Tactical Combat

The player can choose certain characters and move around the map, select a formation for the characters, select an NPC to interact with, pick up objects, and using certain skills such as casting spells or detecting traps.

b) Conversation

After interacting with an NPC, a dialog popup will appear and the player can select a dialog option. Certain dialog option will result in a favorable or even a hostile response. The player can also gain more information related to the world.

c) Trade

Defeated enemies will drop some amount of currency. This currency can be used for buying items in certain NPCs. The player can also sell their unwanted items to gain more currency.

d) Inventory

Inventory is used to store the player's items. A realistic storage simulation is not feasible for a RPG because there are a large amount of items in the game. A solution is the usage of the weight system: each item has a predetermined weight and the character can only carry a certain amount of weight. This makes it so that item size is disregarded which allows scenarios such as the player carrying 5 sets of full body armor.

4) Core Mechanics

The core mechanics of a RPG is as follows:

a) Chance

The usage of chance reflects the uncertainty of real life: an archer may miss it's shots the further away it is from it's target. It also prevents the player from taking certain actions and provides another layer of challenge in managing the chances the player takes.

b) Character Attributes

Character attributes are divded into functional attributes and cosmetic attributes where functional attributes is divided again into characterization attributes and status attributes.

i. Characterization Attributes

Characterization attributes are attributes that has long term change or does not change at all such as sex, race, character class, physical attributes, mental attributes, social attributes, etc.

ii. Status Attributes

Status attributes are attributes that has short term change such as health, mana, level, experience, etc.

iii. Cosmetic Attributes

Cosmetic attributes are attributes that contribute to the characters look. It usually has no effect to the gameplay and is only to satisfy the player's needs of a custom look of their characters.

c) Skills and Abilities

Characters can learn skills and abilities that will help them in defeating enemies and other various things. Each character can only learn skills corresponding to it's class and the quality of each skill is determined based on a certain stat. Skills are usually composed in a skill tree in which a character cannot learn a more advanced skill before learning a basic skill that it is tied to. When a character levels up, the character is given both attribute points to level up it's attribute and also skill points to learn a new skill or enhance a learned skill.

IV. RPGSTEGA

In this paper a new Nostega method using RPG is defined called RPG Steganography or RPGStega. Development of RPGStega is done based on the Nostega architecture.

1) Steganographic field determination

The chosen field is role-playing game.

2) Steganographic parameters determination

The defined parameters is as follows:

a) Character Attribute

Character attributes such as health, mana, strength (STR), intelligence (INT), dexterity (DEX), vitality (VIT) etc. can be used to embed messages in the form of numerical values because the player doesn't know the attributes of enemies before encountering them. For example a message of 4 numbers '6 7 4 5' can be embedded as character attributes:

Character Stats
STR : 6
INT : 7
DEX : 4
VIT : 5

Another example is a message of 4 numbers '10 12 11 13' can be embedded using enemy health:

Goblin 1 - HP 10/10
Goblin 2 - HP 12/12
Goblin 3 - HP 11/11
Goblin 4 - HP 13/13

In theory the capacity of message embedded using this parameter is infinite because in RPGs the player can continuously search for enemies at will thus having no limit to the amount of enemy characters for message embedding.

b) Damage Value

Received damage from enemies can be used as parameters because the player does not know the amount of damage an enemy is about to inflict to them. An example is a message of 4 numbers ’34 25 37 31’ can be embedded as received damage:

```
Character A received 34 damage!
Character A received 25 damage!
Character A received 37 damage!
Character A received 31 damage!
```

Similar to the character attribute parameter, in theory the capacity of message embedded using this parameter is infinite because in RPGs the player can continuously search for enemies at will thus having no limit to the amount of enemy characters that can inflict damage to the player. The player can also draw out battles so that more damage is inflicted to the player thus showing more of the embedded message.

c) Item Attribute

Item attributes such as item level, item level requirement, item bonus attributes, item price, etc. can be used as parameters because the player does not know what items (and item details) is available in a shop before accessing it. An example is a message of 4 numbers ’200 250 375 155’ can be embedded as item prices:

```
Item A | Price: 200
Item B | Price: 250
Item C | Price: 375
Item D | Price: 155
```

Unlike the other parameters, this parameter has a limitation of the capacity of a sales NPC multiplied by the number of sales NPC in the game although this issue can be alleviated with the usage of inventory cycling (the act of changing the items in the inventory with other items) of the sales NPC.

3) Implementing message encoder

Conversion of a binary message to numerical value is done by grouping n bits of the message and converting each group into it’s corresponding decimal value. For example, the message “game” has a binary value of 01100111 01100001 01101101 01100101. This value is then split into groups of 4 bits and becomes 0110 0111 0110 0001 0110 1101 0110 0101. Each group is then converted to it’s decimal value resulting in a set of numbers 6 7 6 1 6 13 6 5. These numbers will be embedded in the game using one of the parameters defined beforehand.

4) Implementing cover generator

The RPG as the cover used for RPGStega is different compared to covers in conventional Nostega methods in which the same game can be used multiple times to send different messages but in exchange of difficulty in producing said game. This is because the values in a game differs from each game instance, and creating a game needs a large amount of assets which takes time to produce.

5) Implementing communications protocol and covert channel

The defined communications protocol and covert channel is as follows:

a) Game developer and tester

The sender as a game developer embeds the message in a game he/she developed and asks the receiver as a game tester to play his/her game for feedback. The receiver then plays the game and extracts the embedded message. This protocol allows the sender to send multiple instances of the same game because of the iterative process of receiving feedback and applying changes to the game.

b) Game enthusiast

The sender as a game enthusiast embeds the message in an existing game and recommends the receiver as another game enthusiast to play it. The receiver then plays the game and extracts the embedded message. The end process is the same as the previous protocol but it does not support multiple instances of the same game because a game enthusiast has no reason to send the same game multiple times.

V. IMPLEMENTATION

Implementation of RPGStega is done using the game Empyrean Campaign. Empyrean Campaign is a game created by the developers of Flare which is an open source game engine for 2D action RPG. Created using C++, the configuration files of Flare is made in text format so that people with little to none programming experience can modify the game easily.

Figure V.1. Screenshot of the Empyrean Campaign game

The implementation of the method is as follows:

1) Character Attributes

Message is embedded into enemy health. Each screen a certain amount will spawn and one of the enemy will have the message as it’s health value. To differentiate between multiple enemies, a system is used where if the message has an odd value, all the other enemies will have an even amount of health. The opposite also applies where if the message has an even value, all the other enemies will have an odd amount of health.

Figure V.2. Implementation of the Character Attribute parameter

2) Damage Values

Message is embedded into damage values taken by the player. Because the game's combat is real time based, the damage will pop up without delay thus demanding the focus of the player on the damage values. To add complexity to the parameter, an interval system is used where the message will only appear in every n hits where n is a predetermined value by the sender. This value can also be used as a stego-key for further reinforcement of the method.

Figure V.3. Implementation of the Damage Values parameter

3) Item Attributes

Message is embedded into item prices in the sales NPC. To aid this parameter, a random item feature is added to the game where the items provided by the sales NPC is randomized. This will allow varying item prices to exist in the shop.

Figure V.4. Implementation of the Item Attributes parameter

4) Game Values Digit

To allow vastly varying message values in the game, the game values digit is altered so that all the message values is always in the scope of the generated game values; for example if the message values have a range of 100-1000 then an acceptable game values range is 0-2000.

VI. VALIDATION

Validation is done in 3 aspects which are noise detection, security, and capacity. For noise detection, a survey is done to 30 RPG enthusiasts using the game developer and tester protocol. This means that the written goal of the survey is to receive feedback, but in reality it is only for checking whether any of the them realizes there is a message hidden in the game's values. The result are very promising in which 100% of respondents does not realize the existence of the message, thus proving that RPGStega is a Nostega method.

On the security aspect, certain values which are similar values and zero are embedded in the game to see if it has any effect. The similar values has no apparent effect on the game mechanics, but it is very likely to arise suspicion because the chances of similar values appearing one after another is very small especially in large digit numbers. Unfortunately, embedding of the value zero causes the character attribute and item attribute to fail functioning thus breaking the game mechanics.

For the capacity aspect, as theorized beforehand there is no message capacity limit for the character attribute and damage value parameters; but, as the size of the message grows, the more enemies the player have to face: a 1 KB message will require the player to encounter around 300-1000 enemies which is almost impossible and will take a large amount of time. On the other hand the message limit for the item attribute is around 3 KB. This is caused not only by the limited sales NPC in the game but also the group bit value limit. It is found that the largest group bit value possible is 22 and any value above that will cause the game's values to be larger than the maximum value of an integer and overflow thus making the game unplayable.

VII. SUMMARY

RPGStega is indeed a Nostega method and can be used to embed messages within the game's values. The defined parameters which are character attributes, damage values and item attributes can successfully hidden the message's presence. The communication protocol and covert channel also legitimizes the interaction between sender and receiver thus preventing suspicion by other parties.

In the future it is hoped that RPGStega can be implemented in other RPGs. There is also room for improvements such as new parameters that cannot be covered by this implementation, the usage of compression algorithms, the processing of message values to avoid similar and zero values, and new communication protocols and covert channel that allows various interaction between the sender and receiver.

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