

# Procedural Story Generation with Transformers



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## **Abstract**

Procedural content generation (PCG) – the process of generating data algorithmically – is a technique that has applications across a variety of domains. In the research outlined in this report, focus is directed to the use of PCG as a means to generate novel-like stories. The challenge is twofold: research into procedural generation methods, as well as the structure and language of stories, addressing questions such as: “What are the elements of a good story?”. Finally, methods to codify these elements must be investigated, in such a way that they can be used by a procedural generation technique, effectively combining the two disciplines.

## **Declaration**

I herewith declare that I have produced this paper without the prohibited assistance of third parties and without making use of aids other than those specified; notions taken over directly or indirectly from other sources have been identified as such. This paper has not previously been presented in identical or similar form to any other Irish or foreign examination board.

The Final Year Project was conducted from 2019 to 2020 under the supervision of James Patten at University of Limerick.

Limerick, 2020

## **Acknowledgements**

First and foremost I would like to thank James Patten; both for his inspiration of the topic researched, and the constant helpful advice and motivation throughout. This extends to all of the lecturers and teaching assistants I have interacted with over the years, each of whom contributed to where I am today.

The wide breadth of open source code, lectures and tutorials available online were also essential in allowing me to carry out this project, as it was all new ground compared to schoolwork that came before it.

Shoutout Christina Applegate

# Contents

<b>List of Tables</b>	<b>v</b>
<b>List of Figures</b>	<b>vii</b>
<b>1 Introduction</b>	<b>1</b>
1.1 Aims and Objectives . . . . .	2
1.2 Methodology . . . . .	2
1.3 Research Contribution . . . . .	3
1.4 Report Outline . . . . .	3
<b>2 Related Research</b>	<b>5</b>
2.1 Stories . . . . .	5
2.1.1 Structure . . . . .	5
2.1.2 Elements . . . . .	6
2.1.3 Evaluation . . . . .	6
2.2 Formulations . . . . .	6
2.2.1 Abstractions . . . . .	6
2.3 Technology . . . . .	6
2.3.1 NLP . . . . .	6
2.3.2 Grammars . . . . .	6
2.3.3 Neural Networks . . . . .	6
2.3.3.1 Recurrent Neural Networks & LSTMs . . . . .	7
2.3.4 Transformers . . . . .	7
2.3.4.1 BERT . . . . .	7
2.3.4.2 GPT . . . . .	7

## CONTENTS

---

2.3.4.3	GPT-2 . . . . .	7
<b>3</b>	<b>Chapter 3</b>	<b>9</b>
3.1	Insert a Figure . . . . .	9
3.2	Creating a list . . . . .	10
3.2.1	Creating a Table . . . . .	10
3.3	Quote . . . . .	11
<b>4</b>	<b>Math formulae in Latex</b>	<b>13</b>
4.1	Math . . . . .	13
<b>5</b>	<b>Chapter 5</b>	<b>15</b>
5.1	References . . . . .	15
<b>6</b>	<b>Conclusions and Future Directions</b>	<b>17</b>
6.1	Summary . . . . .	17
6.2	Conclusions . . . . .	17
6.3	Contributions . . . . .	17
6.4	Future Work . . . . .	17
	<b>Appendix A: Insert figure in Appendix</b>	<b>19</b>
	<b>Appendix B: Insert Text in Appendix</b>	<b>21</b>
	<b>Appendix C: Insert C++/Java et al. Code in Appendix</b>	<b>25</b>
	<b>References</b>	<b>27</b>



# List of Tables

3.1	Table Title . . . . .	10
-----	-----------------------	----

## LIST OF TABLES

---

# List of Figures

3.1	Title of Figure . . . . .	9
1	Title of Figure . . . . .	19

## LIST OF FIGURES

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# 1

## Introduction

The overall goal of this report is to investigate what makes a good story, and then methods for algorithmically generating stories of this nature. The question of "Why?" may be asked. What makes stories important enough to warrant this kind of work?

Without delving too much into the later content of this report, stories are widely believed to be incredibly useful for fostering an understanding of the shared human experience and questions of existence (Eder 2010), for educational communication (Birch and Heckler 1996) and at their most incisive, contributing to social and political change (Fuertes 2012). This is all in addition to the entertainment value we all gain from stories, whether they be written, recorded, or shared via word of mouth. These stories develop whole ideologies and cultures; one need only look at religions for evidence.

For these reasons, I believe this research to be incredibly worthwhile. If we can aid or expedite the writing process with the introduction of procedurally generated contributions, this should spur even more creativity in human writers. My inspiration for this is drawn from Google Deep Mind and their Alpha Go (Silver et al. 2017) research: an artificial intelligence (AI) program designed to tackle the ancient Chinese board game of Go. This is outside the scope of our research, but one takeaway from their research was that humans learned and became better for having played the AI program, in the same way they might improve while playing a superior human. We believe we can achieve similar

## 1. INTRODUCTION

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improvements in human writers with the help of an AI writer, as well as the AI's productions themselves.

### 1.1 Aims and Objectives

Two main questions are addressed by this research: what is a good story, and how they may be procedurally generated. In order to address this question, this work focuses on the following issues:

- Firstly, an examination of stories from a linguistic perspective. Older research or that which does not concern itself so much with technology. This includes things like story structures, character development, plot devices and so on. Creating a perfect definition for a "good story" may be implausible, but narrowing our definition would be good progress.
- Secondly, we must investigate algorithms for generating these stories; work that has been done to formulate these elements in a way that we could use in a program.
- Thirdly, we will delve into the technology side, researching advancements that have been made from early stages up through state-of-the-art. From here we will produce a prototype product which will generate stories and allow human users to interact and modify these stories as they go. In the same way that a human-computer combination has proved more effective than a human alone in chess (Michie 1972), we aim to create an interactive co-writing experience.

### 1.2 Methodology

In order to address these questions we will follow the methodology outlined in sequence above, before designing the system itself and implementing the product. Afterwards, we will reflect and perform various types of evaluation on the productions of the system, noting that it is not primarily intended to be run alone

but rather with human interaction. This will include known language generation metrics as well as human review.

## 1.3 Research Contribution

With this research, I hope to contribute a comprehensive history and discussion of what makes stories a worthwhile endeavour, how their quality and elements may be defined, and finally produce a prototype that allows us to see the potential of procedural story generation.

## 1.4 Report Outline

The remaining chapters of this report are as follows:

*Chapter Two* outlines and discusses the history and related research to this topic, from linguistic and technological perspectives.

*Chapter Three* relates to the design of my chosen system and the choices that were made with regard to models, architecture etc.

*Chapter Four* presents the implementation of the system, portions of interesting code, struggles that were faced and how I overcame them.

*Chapter Five* deals with the evaluation of productions from the system, both objective metrics and subjective human review.

*Chapter Six* draws conclusions and evaluates my satisfaction and areas for improvement. Lastly, it suggests possible future works and research.

## 1. INTRODUCTION

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## 2

# Related Research

Much research has been undertaken on this topic, with a variety of approaches.

## 2.1 Stories

First we must discuss the basic issue of what a good story even is, apart from the technology to produce one.

### 2.1.1 Structure

Structure was the first element to be researched, as the highest level of a story planning process. Popular methods include the Hero's Journey (Campbell 2008), which describes a cycle of sorts: a call to adventure, crossing from the known to the unknown, transformation etc. This is a more granular structure, most known for its application in Star Wars.

Another method is the three (or five) act structure (Trottier 1998), wherein the story is broken down into distinct sections, typically: setup, confrontation, resolution. This is a bit more versatile, which was something to consider for the later steps of “filling in the gaps” with PCG. There was a balance to be struck: providing some structure so that the generation has some level of cogency, but also allowing flexibility so that not all stories are the same. Following this, a tree-based approach became appealing, at the higher levels resembling more of a novel plan with plot points, and is eventually fleshed out below into sentences

## **2. RELATED RESEARCH**

---

and phrases. This is a familiar concept in Computer Science, and it seems like the best way to maintain a coherent story. Some optional user interaction would be ideal – e.g. “Tell me a story about a dog with superpowers” – a kind of “seed”. These could also be generated autonomously.

### **2.1.2 Elements**

You can learn more about Latex by clicking [here](#).

### **2.1.3 Evaluation**

But how?!

## **2.2 Formulations**

Propp!

### **2.2.1 Abstractions**

Marriage, villain, etc.

## **2.3 Technology**

NLP!

### **2.3.1 NLP**

Definitions, brief history

### **2.3.2 Grammars**

CFG, Context Free, old and unworkable

### **2.3.3 Neural Networks**

So hot right now.

### 2.3.3.1 Recurrent Neural Networks & LSTMs

Better, and best for a while, but still not great.

### 2.3.4 Transformers

vaswani et al, Attention is all you need, faster, longer range dependencies

#### 2.3.4.1 BERT

Google

#### 2.3.4.2 GPT

First attempt

#### 2.3.4.3 GPT-2

New and improved!

## 2. RELATED RESEARCH

---

# 3

## Chapter 3

### 3.1 Insert a Figure

We refer to a figure in the text like this: (Figure 3.1).



**Figure 3.1:** Title of Figure - Description. [Source: (?)]

### 3. CHAPTER 3

---

## 3.2 Creating a list

- (2000) item 1.
- (2004) item 2.
- (2010) item 3.
- (2013) item 4.

### 3.2.1 Creating a Table

**Table 3.1:** Table Title

	Resolution	Min	Max
Gyroscope	4.5mV / °/s	0.27 °/s	406 °/s
Accelerometer	600mV /g	0.002g	2g
Magnetometer	385mV/ gauss	0.317 gauss	6 gauss

### 3.3 Quote

An in-text quote is declared in the following way:

Recycling is the way forward! Recycling is the way forward! Recycling  
is the way forward! Recycling is the way forward! Recycling is the  
way forward! Recycling is the way forward! Recycling is the way  
forward! Recycling is the way forward! Recycling is the way forward!  
Recycling is the way forward! Recycling is the way forward! Recycling  
is the way forward! Recycling is the way forward! Recycling is the  
way forward! Recycling is the way forward! Recycling is the way  
forward! Recycling is the way forward! Recycling is the way forward!  
Recycling is the way forward! (CommonSense, p. 0)

Another way of doing it is:

*There are in our existence spots of time,  
That with distinct pre-eminence retain  
A renovating virtue, whence-depressed  
By false opinion and contentious thought,  
Or aught of heavier or more deadly weight,  
In trivial occupations, and the round  
Of ordinary intercourse-our minds  
Are nourished and invisibly repaired;  
A virtue, by which pleasure is enhanced,  
That penetrates, enables us to mount,  
When high, more high, and lifts us up when fallen.*

(?, verses 208-218)

### 3. CHAPTER 3

---



# 4

## Math formulae in Latex

### 4.1 Math

In-text Math

- A vector vector  $\hat{A}_{ba}\{x_{ba}, y_{ba}, z_{ba}\}$
- Another vector  $R^b\{\hat{t}_{1b}, \hat{t}_{2b}, \hat{t}_{3b}\}$  as:

A series of Equations:

$$\hat{t}_{1b} = \hat{A}_{ba} \tag{4.1}$$

$$\hat{t}_{2b} = \frac{\hat{A}_{ba} \times \hat{M}_{bm}}{|\hat{A}_{ba} \times \hat{M}_{bm}|} \tag{4.2}$$

$$\hat{t}_{3b} = \hat{t}_{1b} \times \hat{t}_{2b} \tag{4.3}$$

$$R^a = R^b(R^i)^T = [\hat{t}_{1b}, \hat{t}_{2b}, \hat{t}_{3b}][\hat{t}_{1i}, \hat{t}_{2i}, \hat{t}_{3i}]^T \tag{4.4}$$

where the symbol  $^T$  denotes transposition.

$$\hat{t}_{2b} = \frac{\hat{A}_{ba} \times \hat{M}_{bm}}{|\hat{A}_{ba} \times \hat{M}_{bm}|} \tag{4.5}$$

#### 4. MATH FORMULAE IN LATEX

---

$$\begin{aligned}
&= \frac{(y_{ba}z_{bm} - y_{bm}z_{ba}, z_{ba}x_{bm} - z_{bm}x_{ba}, x_{ba}y_{bm} - x_{bm}y_{ba})}{|A_{ba}| |M_{bm}| \sqrt{1 - (\hat{A}_{ba} \cdot \hat{M}_{bm})^2}} \\
&= \frac{-0.2338, -0.0931, -0.0651}{0.2601} \\
&= (-0.8989, -0.3579, -0.2503)
\end{aligned}$$

which if normalised gives:

$$= (-0.8995, -0.3581, -0.2504)$$

A matrix

$$R^b = [\hat{t}_{1b}, \hat{t}_{2b}, \hat{t}_{3b}] = \begin{pmatrix} -0.2698 & -0.8995 & 0.3439 \\ 0.0035 & -0.3581 & -0.9337 \\ 0.9629 & -0.2504 & 0.0997 \end{pmatrix}$$

# 5

## Chapter 5

### 5.1 References

Open the file ‘references\_myphd’ with BibTex. The file is located in ‘/7\_references/’

The file contains a series of templates for the proper formatting of references according to the Harvard referencing style. Click on each reference in the text below to see how Latex has formatted the reference on the References section.

- **Book:** (?, p. 10) (page number required only if referring to an in-text quote)
- **Book Chapter:** (?)
- **Book Contribution:** (?)
- **MUSIC CD/DVD:** (?)
- **Journal Article:** (?)
- **Patent:** (?)
- **PhD/Master Dissertation:** (?)
- **Conference Paper:** (?)
- **Technical Report:** (?)

## 5. CHAPTER 5

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- **Unpublished Report:** (?)
- **Web Videos(?)** (. . . not the name of the person who uploaded the video though)
- **Web Paper:** (?)
- **Web Journal Article:** (?)
- **Webpage:** (?)
- **Downloaded Images or Sounds:** (?)

You can also use this kind of referencing if needed in the text:  
Surname (?) said that . . .

# 6

## Conclusions and Future Directions

### 6.1 Summary

### 6.2 Conclusions

### 6.3 Contributions

### 6.4 Future Work

## 6. CONCLUSIONS AND FUTURE DIRECTIONS

---

# Appendix A

Insert a figure



**Figure 1:** Title of Figure - Description. [Source: (?)]

## Appendix

---



# Appendix B

## Title

Type here you text as usual . . .

## Appendix

---

# Appendix C

## Code for estimating attitude

### AHRS\_TRIAD.C

```
/*
 *
 * Copyright (c) 2013, Giuseppe Torre
 * All rights reserved.
 *
 * Redistribution and use in source and binary forms, with or without
 * modification, are permitted provided that the following conditions are met:
 *     * Redistributions of source code must retain the above copyright
 *       notice, this list of conditions and the following disclaimer.
 *     * Redistributions in binary form must reproduce the above copyright
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 * LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND
 * ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
 * (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
 * SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
 */

#include "ext.h"
#include "ext.mess.h"
#include <string.h>
#include <stdio.h>
#include <math.h>
#define EPSILON 1e-6

//*****CALIBRATION STUFF*****//
/* INTRODUCE THE OFFSET VALUES IN THE FOLLOWING VARIABLES IN ADC values */
#define ACCELX_OFFSET 2043 //initial offset in accelerometer X
#define ACELEY_OFFSET 2053 // initial offset in accelerometer Y
#define ACCELZ_OFFSET 2264//initial offset in accelerometer Z

#define MagX_OFFSET 1917 //initial offset in Magnetometer X
```

## Appendix

---

```
#define MagY_OFFSET 1813 // initial offset in Magnetometer Y
#define MagZ_OFFSET 1667 // initial offset in Magnetometer Z
/* WE SHOULD CALIBRATE THE FOLLOWING VALUES FOR EACH PARTICULAR IMU axis */
#define ACCELX_Resolution 536
#define ACCELY_Resolution 661
#define ACCELZ_Resolution 559
#define MagX_Resolution 186
#define MagY_Resolution 189
#define MagZ_Resolution 170
//***** END CALIBRATION STUFF *****//

void *this_class; // Required. Global pointing to this class

typedef struct _triad // Data structure for this object
{
    t_object m_ob; // Must always be the first field; used by Max

    Atom m_args[9]; // we want our inlet to be receiving a list of 10 elements

    long m_value; //inlet

    void *m_R1; //these are all the outlets for the 3 X 3 Matrix
    void *m_R2; // R1 --> firts top left cell ..R2 middle cell of the first
        row ...and so on
    void *m_R3; //
    void *m_R4; // End Outlets
} t_triad;

void *triad_new(long value);

void triad_assist(t_triad *triad, void *b, long msg, long arg, char *
s);
void triad_free(t_triad *triad);

void triad_list(t_triad *x, Symbol *s, short argc, t_atom *argv);

void MatrixByMatrix(double *Result, double *MatrixLeft, double *
MatrixRight);

void Matrix2Quat(double *Quat, double *Matrix);
void Quat2Matrix(double *Matrix, double *Quat);
void inverseQuat(double *InvQuat, double *RegQuat);
void NormQuat(double *YesQuat, double *NotQuat);
void Slerp(double *NewQuat, double *OldQuat, double *CurrentQuat);
void NormVect(double *YesVect, double *NotVect);
double orientationMatrix[9];
double Result[9];
int i;
double InvorientationMatrix[9];

double temp[6];
double ref[6];
double vectAx[3];
double vectAy[3];
double vectAz[3];
double vectBx[3];
double vectBy[3];
double vectBz[3];
double MagnCrosProd_A;
double MagnCrosProd_B;
double accnorm, magnorm, earthnorm, VectAynorm, VectAznorm,
VectBynorm, VectBznorm;
```

---

```

double m[9], n[9];
double quat_e[4];
double invquat_e[4];
double mult;
double quat_new[4];
double quat_old[4];
double ecs, accex_ADCnumber, y, accey_ADCnumber, z, accez_ADCnumber, mx,
magnx_ADCnumber, my, magny_ADCnumber, mz, magnz_ADCnumber;

// SLERP Variables
double trace, Suca;
double tol[4], omega, sinom, cosom, scale0, scale1, tez,
orientationMatrixA[9];

int main(void)
{
    // set up our class: create a class definition
    setup((t_messlist**) &this_class, (method)triad_new, (method)triad_free, (short)
sizeof(t_triad), 0L, A_GIMME, 0);
    address((method)triad_list, "list", A_GIMME, 0);
    address((method)triad_assist, "assist", A_CANT, 0);
    finder_addclass("Maths", "triad");
    post(".... I 'm TRIAD_Object !.... from AHRS_Library ...", 0);
    return 0;
}

/* -----triad_new -----*/

void *triad_new(long value)
{
    t_triad *triad;
    triad = (t_triad *)newobject(this_class); // create the new instance and return
a pointer to it
    triad->m_R4 = floatout(triad);
    triad->m_R3 = floatout(triad);
    triad->m_R2 = floatout(triad);
    triad->m_R1 = floatout(triad);

    return(triad);
}

etc.

etc.

```

## Appendix

---

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