Undergraduate Research Scholar

# Exploring Shape Grammar Induction as a Tool for Automated Design

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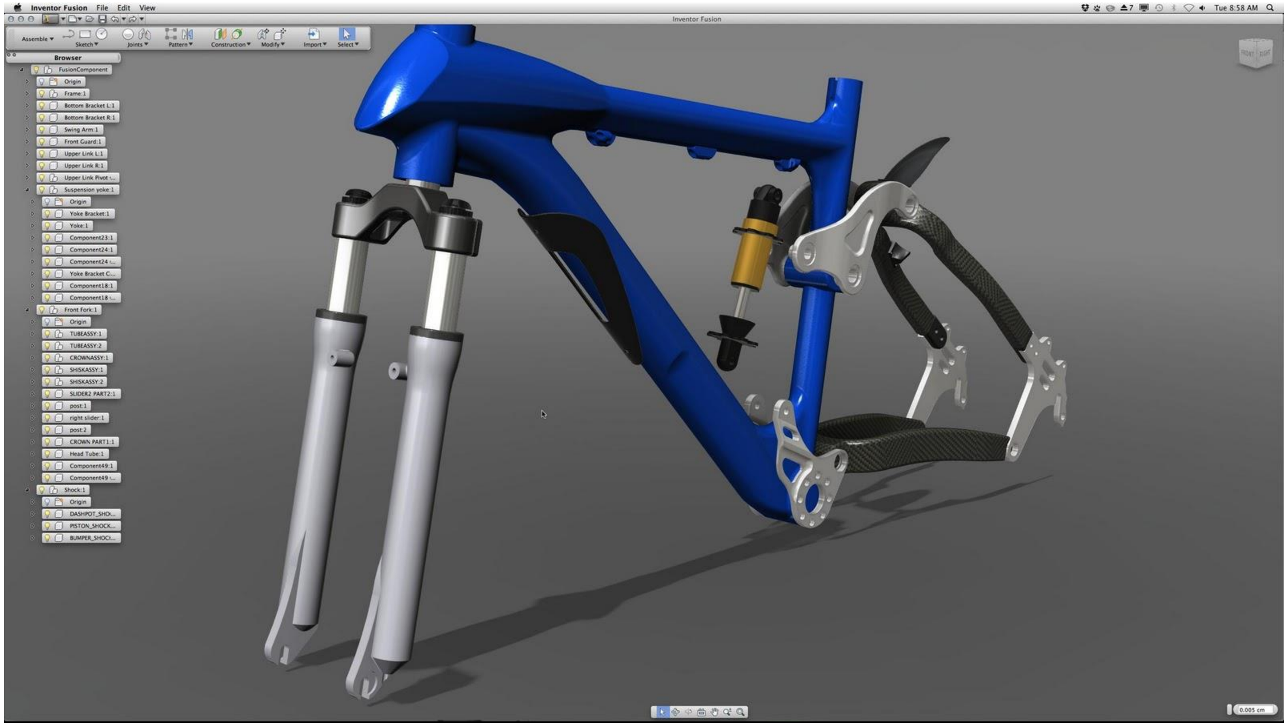
# INTRO: SHAPE GRAMMARS

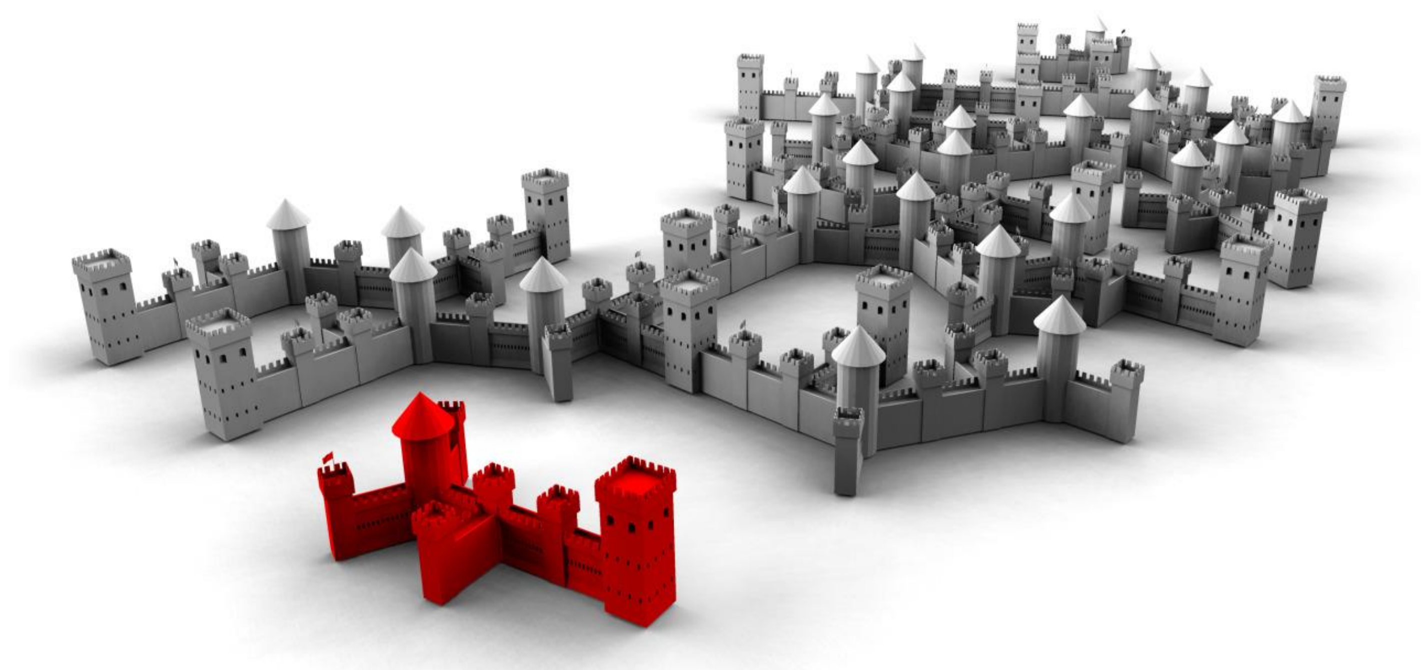
# Design: Hand-Crafting

- Intended for creating one specific object
- Prime criterion is accuracy



# Design: Procedural Generation

- Designs created by algorithms
- Emphasis on variation and novelty
- Captures a *class* of objects



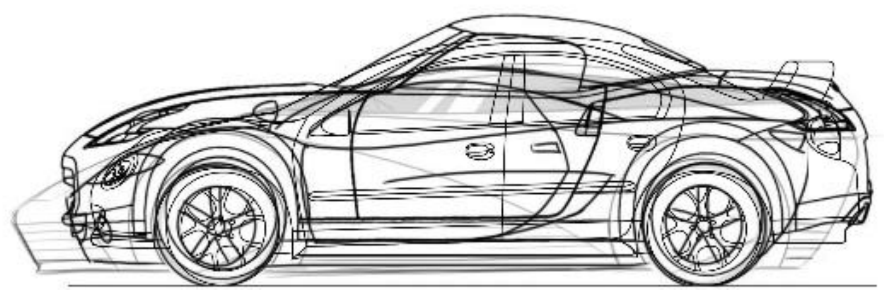
# Different objects in the same class have a common structure

Example:

- Cars come in all different shapes and sizes
- BUT there are some common attributes that an object needs to be considered a “car”

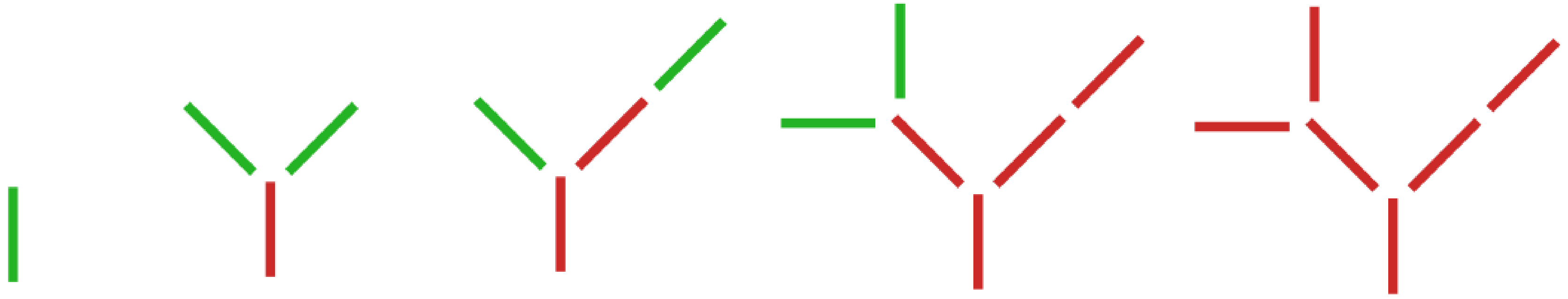




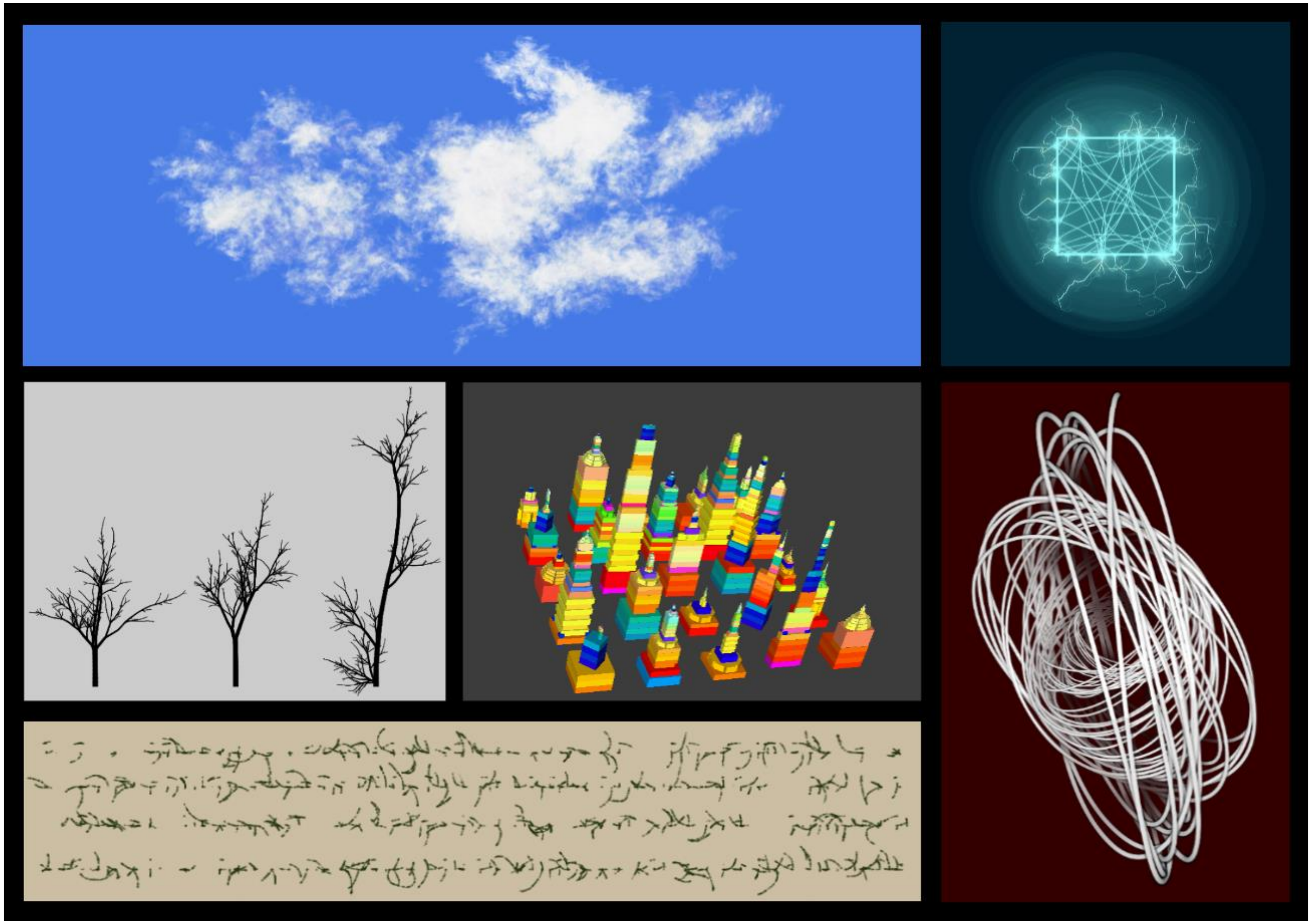


# Shape Grammar

- How could a computer store and interpret the design structure of a class of objects?
- Useful data structure: **shape grammar**
  - Randomly builds **designs** of objects based on **production rules**



# Shape Grammar Examples



Visit http://www.contextfreeart.org/ for more examples

# Grammar Parameters

- Typically hard-coded numbers
- Typically determined through trial-and-error
- Rule probabilities (red) will be the focus

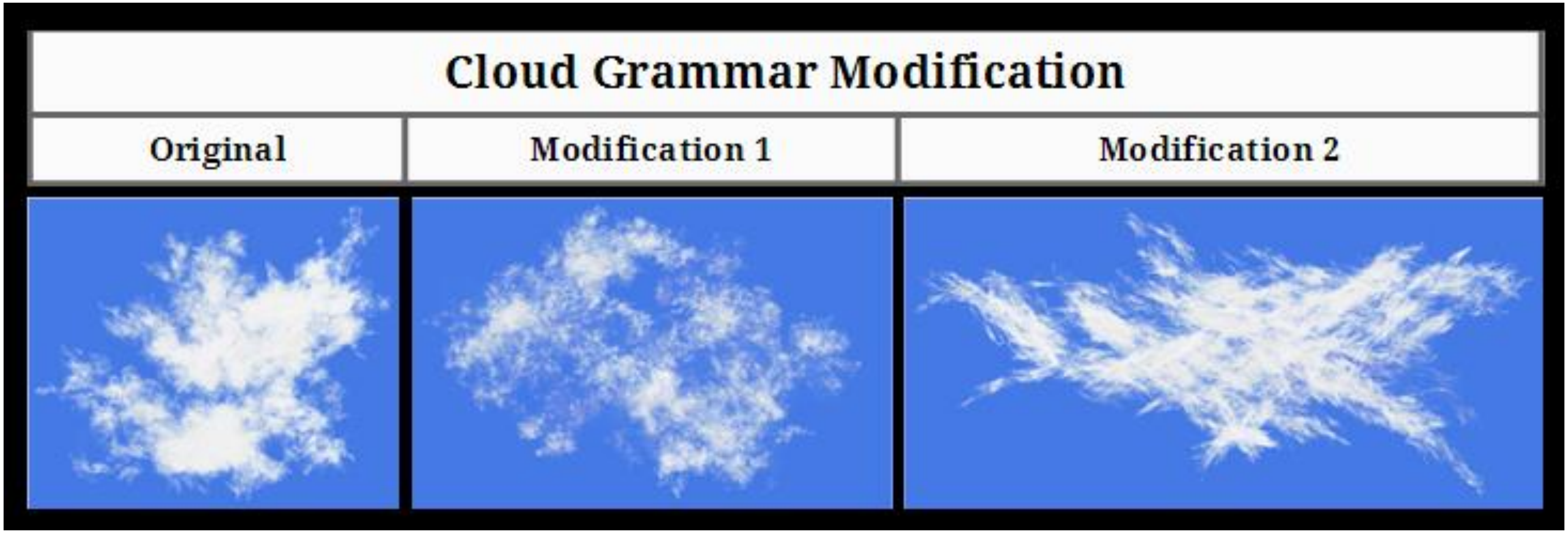
```
startshape BRANCH

shape BRANCH
rule 0.5
{
        line []
}
rule 0.3
{
        line []
        BRANCH [ y 11 ]
}
rule 0.2
{
        line []
        BRANCH [ y 11 x -2 r 45 ]
        BRANCH [ y 11 x 2 r -45 ]
}

shape line
rule
{
        loop 10 [ y 1 ]
        {
                SQUARE []
        }
}
```

# Grammar Modification

- Making small changes to the parameters, especially rule probabilities, results in **drastic changes** in the designs



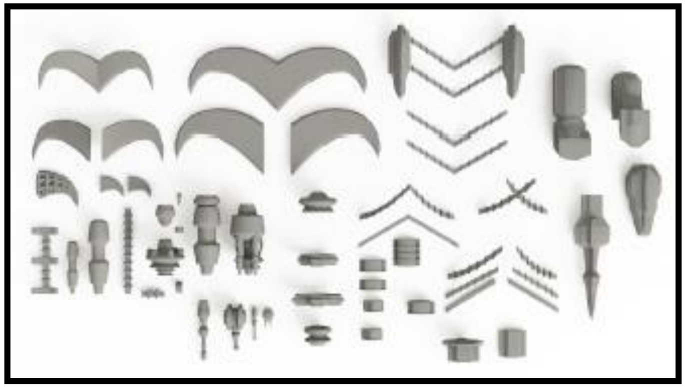
# GRAMMAR INDUCTION

# Definition

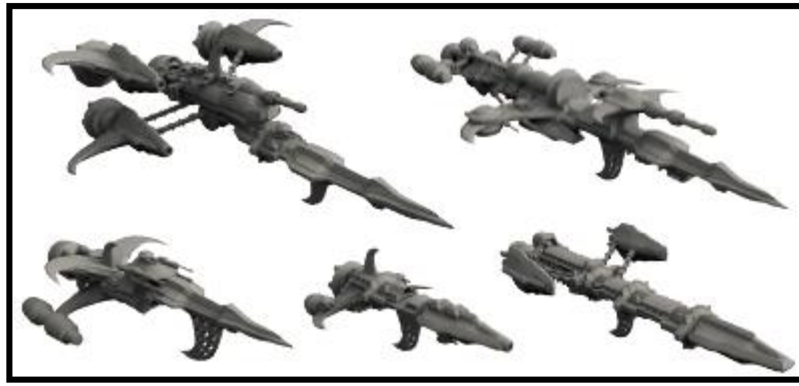
- The process of taking a set of **exemplar designs** and creating a grammar that can replicate those exemplars
- A form of machine learning- the computer is "trained" to create a grammar through human-tailored example

# Induction Examples: Spaceships

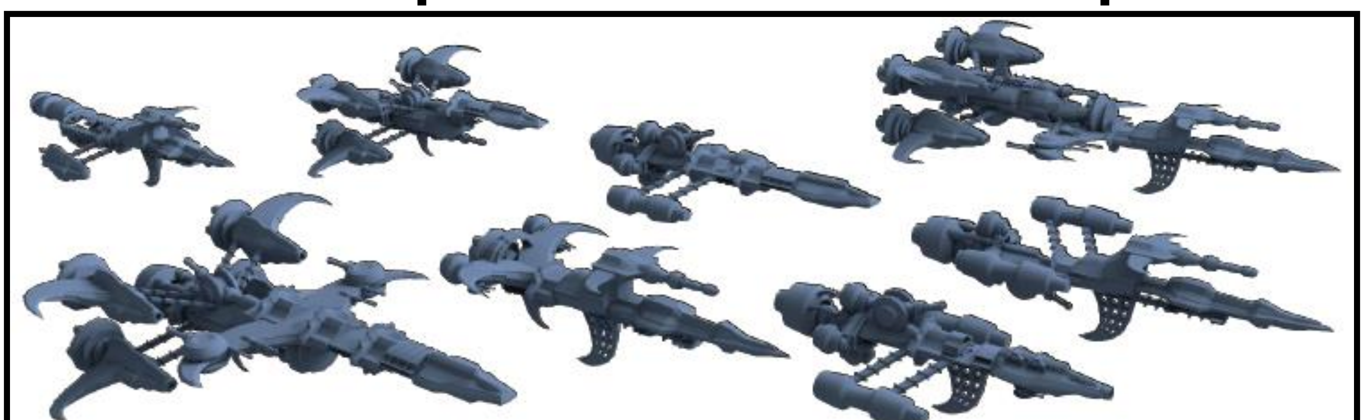
**The Terminal Shapes**



**The Training Examples**



**The Computer Generated Examples**



J. Talton, L. Yang, R. Kumar, et al. Learning Design Patterns with Bayesian Grammar Induction. *ACM Symposium on User Interface Software and Technology* 2012.

# RESEARCH OBJECTIVES

# Shape Grammar Induction Goals

- Most important goal is *accessibility*
  - Intended for artists and designers
- Inducing from scratch is not very accessible
- Assume the grammar *G* exists, and we would like to improve *G*'s parameters
  - How would we measure improvement?

# Induction Algorithm Overview

We are given a grammar, *G*, and want to optimize it based on a designer's **criteria**.

- We choose to hold $i$ **rounds** of optimization
- In each round, we will generate $j$ **grammar variants**- copies of the original grammar with the rule probabilities altered
- For each grammar variant, we will generate $k$ **exemplar designs** (AKA **exemplars**)

# Induction Algorithm (cont.)

- Exemplars are scored based on how well they achieve the designer’s criteria
- At the end of each round, the next round of variants is generated
  - The new variants are derived from the most optimal grammar(s)
- The variants will ideally converge on an overall optimal grammar

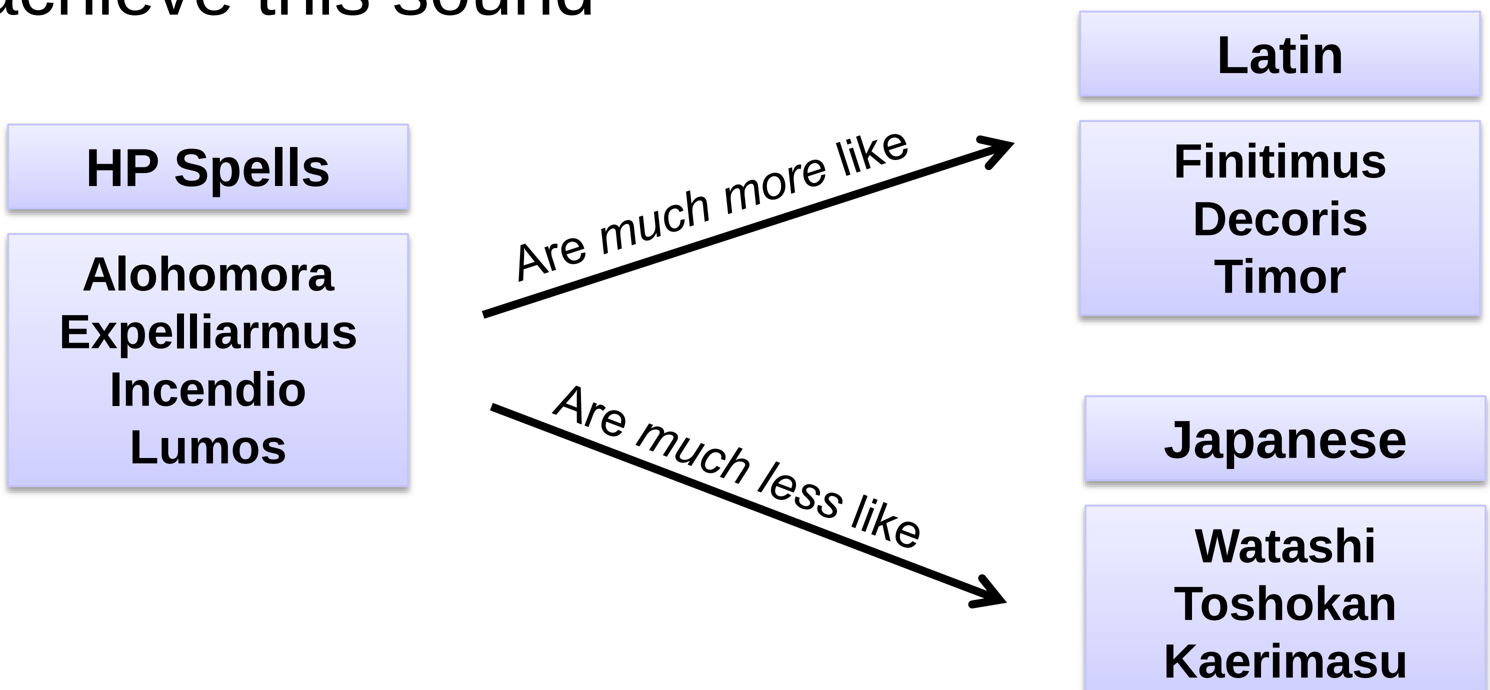
# Prototype: Harry Potter Grammar

- Using a text grammar for simplicity
- Recruited people I knew for evaluation
- To test this induction system, we need a criteria that is:
  - Easily determined by human evaluators
  - Something many people are familiar with
- Chosen criteria:

**How fitting would the word be as a spell or incantation from Harry Potter?**

# Harry Potter (Deconstructed)

- Most spells are derived from Latin and have their own unique sound
- Goal: find the right balance of parameters to achieve this sound



# Prototype- Methods

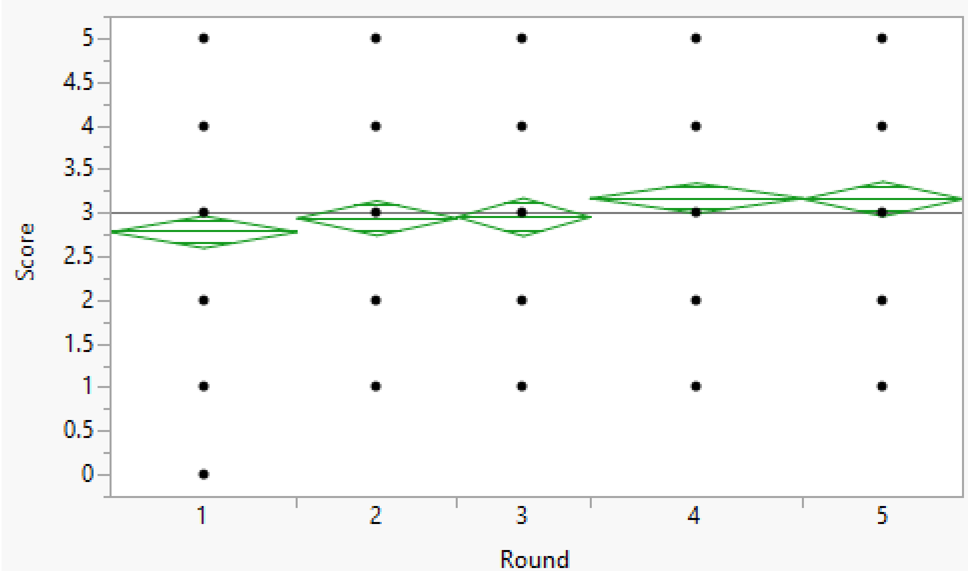
- Ran 5 optimization rounds, each with 5-8 variants, each with 25 words
  - 800 words total
- Words evaluated on a 1-5 scale

| Round 1 | Round 3 | Round 5 |
|---|---|---|
| Dumio | Conesio | Sermonio |
| Mhaete | Riurus | Karceros |
| Movsu | Vardoros | Avas |
| Pceetio | Padri | Noros |

# Prototype-Results

- Used One-way ANOVA and Tukey's Procedure
- Means: Rounds 4,5 were significantly higher than Round 1 ($p < .05$)
- Significant upward trend in mean score ($p < .01$)

**Oneway Analysis of Score By Round**




**Analysis of Variance**

| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| Round | 4 | 18.6162 | 4.65405 | 3.0396 | 0.0168* |
| Error | 795 | 1217.2588 | 1.53114 | | |
| C. Total | 799 | 1235.8750 | | | |

**Connecting Letters Report**

| Level | | | Mean |
|---|---|---|---|
| 4 | A | | 3.1750000 |
| 5 | A | | 3.1666667 |
| 3 | A | B | 2.9600000 |
| 2 | A | B | 2.9466667 |
| 1 | | B | 2.7885714 |

# Future Work

- 2D shape grammars
- 3D shape grammars
- More complex optimizations
  - Modifying other parameters
  - Generating new rules

# Acknowledgments

- Dr. Dylan Shell, Faculty Mentor
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Thanks!

Questions?