# Background components that a reader needs to understand

# Intro.

# Digital Music

# What is it? (Personal Insight / Definition)

# Digital music is either human created or algorithmically created music.

# The music can be composed, arranged, or played with the assistance of digital devices such as computers

# The music can combine both human and algorithmic means to achieve the intended effect of creating pleasing music

# What are current types

# Human Generated music

# Humans compose the music manually using their own ideas, motifs, and feelings.

# May inherently involve a “process” but largely doesn’t automate the music

# Algorithmic music

# Seeks to automate the process of music creation by following to a variety of algorithms

# The algorithm used can greatly determine the outcome of the music

# Generated sheet music

# This is similar to algorithmic music, except the output is sheet music instead of musical notes.

# This allows humans to have oversight into the product and make changes easily

# Two Main Components of music

# Pitches & Notes

# Notes are the sounds of music

# Exist completely outside of time

# Instruct the musician or device to play a certain frequency

# Details on the theory of notes and how the octave interval breaks down

# Western music divides an octave into 12 pitches – Bell 100

# C, C#, D, D#, E, F, F#, G, G#, A, A#, B

# Neighboring notes are 1 half step away from each other

# Melody is a horizontal sequence of notes arranged one after another

# Rhythm

# Rhythm is the movement of music in time

# Does not have any “sound”

# Instruct the musician or device of when to play a corresponding note

# Important thing here is that notes and rhythm can be mutually exclusive and still form valid music

# I can have a collection of notes which do not have or depend on timing. They have movement vertically on a staff but the horizontal movements are unknown

# I can have a collection of beats in time which do not depend on any corresponding note. They have movement horizontally on a staff but the vertical movements are unknown

# Desirable Characteristics of Music

# Pitch

# Pitch mod 12

# Variety

# Dissonant Intervals

# Contour Direction

# Contour Stability

# Rhythmic Variety

# Rhythmic Range

# Duration of Notes

# Melodic Intervals

# Harmonic intervals

# “Two different notes do not always sound pleasant when played together” – Beer 2

# Different ratios of notes sound more pleasant when played together (1:2, 2:3, 3:4, 4:5, 5:6, 8:9) – Beer 2

# Harmonic bigrams (Manaris 1&2)

# 

# Music Formats

# Sheet music

# This is where the result is viewed visually instead of through auditory means.

# Patterns can be much simpler to see when the result is viewed this way, so there are benefits

# WAV

# A pure audio waveform file is the uncompressed audio

# Usually digital generation does not produce this type of audio as it requires recording or generation at a level much higher than MIDI

# MIDI

# MIDI is a format which allows for musical events to be encoded

# Tracks, events, and velocity can be recorded which all effect the output

# This is the defacto standard for papers who create audio output due to the ease of use and the packages out there that make it easy to use

# Digital Music Automated Generation Techniques & How is each used?

# Human Generated

# [This should be mentioned somewhat, but I don’t want to focus on it at all because I want to focus on the automated techniques]

# This will be important to mention as one of the current GA fitness functions used

# Rule Based / Expert System

# “A big part of composition is ‘hard work’ and inherently algorithmic whereas only a small part is considered to be ‘genius’” – Rehberger: 4.4

# This means that a rule based system is capable of producing a largely pleasant sounding music but not music that is particularly “genius” sounding.

# Genius sounding melodies is the important/difficult aspect of generated music then.

# “These composers are following a set of rules and, despite their possible complexity, these rules can be followed by a computer to automate the composition process.” – Bell 99

# Markov Chains

# Chip Bell

# Bell uses Markov chains in his paper in order to select the next pitch. He analyzes a set of Markov chains uses GA to determine what is most pleasing for the next note

# Bell uses a 144 entry (12x12) Markov chain where a given entry consists of “If the current note will be X, then the next note has a probability of being Y”. He also incorporate possible chord states leading to 5184 entry chains

# Genetic Algorithms

# “GAs are based on the modern evolutionary theory…making use of the same processes which nature uses to select the individual fittest to its environment: natural selection and sexual reproduction” – Rehberger: section 4.4

# “GAs provide a powerful technique for searching large, often ill-behaved problem spaces…it seems natural to apply GAs to musical tasks” – Biles 1

# Each iteration improves on the previous but it can take a long time to converge on an acceptable state

# Matic 163

# Aspects to a GA

# Chromosome

# Representation (usually string) of a problem solution instance

# Each chromosome is a single solution to the problem and must be evaluated to determine how good it is

# Fitness function

# Measures how well a particular chromosome “performs” inside of the problem environment

# An unfit chromosome is less desirable than a fit chromosome

# “Because [chromosomes] are not all identical, some may be more likely to survive than others” – Rehberger; 4.4

# This is the “natural select” aspect

# “Since a Genetic Algorithm can only produce melodies as good as the knowledge encoded in its fitness function, the design of the fitness function is a critical part in the process of developing a GA for Music Composition” – Rehberger: 4.4

# Mutation

# A chromosome can be randomly mutated at a fixed percentage chance to change an aspect of it in a random way

# This rate should be low and consistently random (treat all chromosomes fairly)

# Crossover

# This is the “sexual reproduction” aspect

# Takes two deemed fit chromosomes and combines them to form a new chromosome

# Several techniques exist to perform crossover

# [What can I put here?]

# The resultant chromosomes become the next iteration and hopefully wholly improve over time

# “GAs don’t rely on a particular problem structure or problem specific knowledge” – Horner&Goldberg 1

# Current implementations

# Chromosome

# Biles 2-3

# A Phrase consists of an integer fitness as well as pointers to measure chromosomes

# A measure consists of a fitness function as well as notes (0-15)

# The fitness of a measure does not affect the fitness of the phrase (mutually exclusive)

# The size of the measure population should be a power of two to get maximum efficiency

# De Frietas 419

# A chromosome consists of MIDI information in the form of a binary string of bits which can easily be converted into a MIDI file by extracting the MIDI information

# Papadopoulos 1

# Uses a symbolic representation of structures and data in order to provide more meaningful operations in the context of domain knowledge

# Ralley

# Use a header body system where the header contains the starting pitch

# The body contains the offset from the previous note to a position in the chromosome (first is 0)

# This allows for quick transposition and mutations which can either affect a slight piece of the chromosome (mutation in body) or the entire chromosome (starting pitch)

# Fitness Function

# Biles 2-3

# Uses human mentor powered fitness functions where an operator must say “g” or “b” for each measure and the sum of the “g”s and “b”s at the end of the melody is the fitness

# This utilizes the power of humans, who can very quickly determine whether a melody sounds good or bad, which is not an easy task

# The downside is that this is not a fully automated fitness function and would take a large amount of time

# De Frietas 419

# “Fitness computation in most evolutionary-based systems for art and music requires aesthetic judgements, which are not easy to model and implement in the form of an algorithm”

# It becomes beneficial for this reason to use human powered GA for “genius” pieces

# Horowitz 1

# Uses human powered fitness functions

# Several objective fitness functions are also used which use global statistics of the rhythm to evolve the population

# Objective fitness is similar to my idea

# Jensen 1

# Zipf’s Law

# Describes the “scaling properties of many natural phenomena”

# “The frequency of an event is inversely proportional to its statistical rank” f = r-a, where f is the frequency of occurrence of some event, r is its statistical rank and a is close to 1.

# Used to explore metrics such as: rank-frequency distribution of pitches, chromatic tones, note durations, pitch durations, chromatic tone durations, time between repetition, melodic intervals.

# Fitness score is calculated as a distance to the target vector of the linear regression slopes that are pre-defined

# Zipf metrics determined to be a working but poor technique for generating music

# Khalifa 1873

# Uses intervals to determine whether notes are relatively acceptable to each other

# 1-4 half steps are acceptable. 5-7 steps are acceptable if the third note resolves, 8+ are never acceptable

# Papadopouulos 1

# An algorithmic fitness function will not be correct or universal, but it must be consistent in how it evaluates results

# Largest permitted intervals

# Pattern matching in pitch fragments

# Downbeat notes – certain pitches work best in the downbeat and need to be optimized

# Chord Note(10), rest(10), non-chord scale note(-10), non-scale note(-20)

# 3rd beat notes – same as downbeat but reduced values (5,5,-5,-20)

# Speed of the piece

# Mutation

# Biles 5

# None, Reverse Measure, Rotate measure right, Invert (15 – value),Sort Ascending, Sort Descending, Transpose Notes (Shift pitch up constantly)

# De Frietas 422

# Transpose a single note up, Reverse measure, Reverse pulse in measure, Exchange pulses in measure

# 

# Papadoupolos 4

# The genetic operators should not be “weak” and instead be focused to operate on the specific domain of music search space

# This leads to a more effective operator

# Random chromosome fragment of random length mutation such as transposition, permutation, sorting, reversing, changing pitches, shuffle durations while maintaining pitches, one note mutations

# Crossover

# De Frietas 421

# A random crossover point is sufficient for exploring the potential of a population in less artistic musical tasks

# If fitness function is free, a musically advantageous crossover should be used

# This can be done by analyzing the pulse of the chromosome and crossing over in locations that should not be broken.

# This assumes that notes and rhythm are represented by the same chromosome

# Papadoupolos 1

# One point and two point crossover were used

# More focus is put on the mutations

# Multi-stage GA

# Several GA use multiple stages to populate an initial set of measures and then later combine those again intso phrases

# Khalifa 1873 uses this technique to generate a population of motifs and then transposing those to form music phrases based on well known patterns

# GA Setup by Oliwa

# “abc” musical description language defines an eighth note as (1) and goes up to a whole note(8)

# Can be encoded as integer values and then decoded back into a distinct symbol string used for MIDI format

# One issue from tournament selection is that the best chromosomes can be lost. Ralley implemented a caching mechanism to help prevent this

# http://minuet.dance.ohio-state.edu/ralley2/icmc/icmc4.GIF

# Memetic Algorithm Variation

# A memetic algorithm is a GA that can always fix something known to be bad in the chromosome. This single fix will help the GA speed up in converging on a good solution

# The algorithm is the same as a GA except there is a localized search which finds chromosomes to improve and then an improvement mechanism

# Wells uses this by finding the first note which does not belong in a given key and then shifting it up or down to the nearest note that does belong in the given key

# Over many iterations, the pitches are quickly fixed and made to fit into the desired key of the piece or measure

# Drawbacks to Digital Music Generation / Current Limitation Results

# Limitations in Representation

# Many papers choose to thin out the possibilities for rhythms or notes. In order to retain interest, however, slower tunes need more complex rhythms. Thus, it is best to have tunes in the range of 120-180 BPM – Biles 6

# The sheer possibility of notes leads to an extremely large search space if all octaves are allowed. Typically, in a musical score, notes for a single melody are kept relatively close in octave to other notes (maybe a 2 octave variance at max). This assumption lowers search space at the cost of placing limits on the product

# Lack of Genius?

# It is hit in several papers that cited above that a certain “genius” plays into the composition of music. This genius is very difficult to turn into an algorithm and is thus considered not possible to encode against a search space.

# A GA is the most likely to hit this genius, if it is not able to be classified as a set of rules, because both Markov chains and rule-based systems look at rules much more heavily than GAs do

# Benefits to Digital Music Generation / Current “victories”

# Lack of Genius but lots of mediocrity

# Mediocrity is never something to strive for in results, but it is better than complete failure.

# Music can and has been created which is considered “normal” or “mediocre”. While lacking genius it may be a victory to not be awful.

# Java tools which exist to help out

# JFugue

# Great algorithmic package which can encode music based on string and play it back

# MIDI plugins may prove useful

# JGAP

# This library provides a relatively simple and stable GA package where the chromosomes, fitness, mutation, and crossover are defined and the rest just happens.