Creature Generation using Genetic Algorithms and Auto-Rigging

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Abstract

This report covers the design and development of tools for Creature Generation and Development, considering a novel solution towards creature generation and auto rigging.

Three tools were developed, the first of which will generate a series of creatures based on variables the user provides and provides functionality to save and re-load designs as well as generating a bone rig and appropriate controls for any given creature. The second tool employs a Genetic Algorithm to breed creatures to create new generations and can be used to generate variations on a single design, creating a species. The final tool is a Procedural GUI system, written in wxPython and utilising wxGlade, that will generate a bespoke Control GUI for any given creature providing the user a GUI based control system alongside the visual controls that are generated with the rig.

The project represents a novel pipeline for fast creature development, bypassing concept drawings and potentially providing designs the user would never have previously considered, whilst also allowing automatic rigging solutions to any generated design. There are limitations to the extent of parts designed and number created, however the tools created are an excellent platform for future development in automated creature design and rigging.

Acknowledgements

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Chapter 1

Introduction

The purpose of the Masters Project is to perform a substantial piece of work in the field of Animation and Visual Effects. There were a number of areas of interest considered that could have resulted in interesting and useful projects; from among them it was decided to create a tool written in Houdini that would leverage the power of the Houdini Object Model (HOM) and its interface with the programming language Python to procedurally generate systems of nodes to achieve a given goal. This would provide a lot of knowledge of scripting in Python, and the use of the HOM to design and create tools within Houdini, both being excellent transferable skills.

The project decided upon was to build a suite of tools which would act as a Creature Generator program. The hope would be to design and build a set of tools in Houdini that would allow a user to generate a set of creatures based on some information provided by the user, the features and sizes of each being random within user set limits. The tools would then employ Genetic Algorithms to further allow the user to select which designs to take forward and use as the parents of the next generation until they arrived at a design (or designs) they were happy with.

The general idea was that such a program would be of use to anyone who wanted to quickly create a series of simple creatures that could be used for film, TV, games and art applications. The generated creatures would not themselves be of high enough fidelity to use directly, but could be used as proxy geometry, which could be exported and around which a proper mesh could be designed. The utility of the program would be in providing the user quickly with a large array of designs, many of which they may have never considered themselves. This is not the usual design processes for a creative task such as creature development, which would ordinarily begin with concept designs drawn up and re-designed before actual 3D creature modelling and later rigging takes place.

Out of this concept an additional idea quickly became apparent. In order to generate a creature, composed of different parts, the program must have a lot of information about the relative sizes and positions of all these components and if it has this information, due to the possibility of using the HOM to generate Houdinis bones and kinematic solvers, it might be possible to not only generate a creature, but to create a basic bone rig for it as well.

Successfully bringing these two functions together would mean that a user could quickly generate a series of creature designs, and evolve them through successive generations to arrive at designs that they wanted to use. They could then immediately generate a basic rig for a given creature with which they could begin animating right away - with the generated creature acting as a proxy character - whilst the proxy geometry was being used as the blueprint for creating a proper creature mesh elsewhere. That completed mesh could then be brought back into Houdini and tied to the animation that had already been done (additional weight painting would still be required to achieve the users desired final capture of the rig). This system, whilst somewhat unconventional, could save time for users and be used as both a creativity tool as well as a productivity tool.

1.1 Report Structure:

The report is split into the following sections:

Chapter 1 - Introduction

Chapter 2 Previous works

Chapter 3 Technical Background

Chapter 4 Design and implementation

Chapter 5 Examples

Chapter 2

Previous Work

The main influence of forming the initial idea for the project was Venter and Hardy's paper Generating plants with gene expression programming (Venter & Hardy 2007) which explores evolving L-Systems (for plant design) with a Genetic Algorithm, based on users aesthetic preferences. A Genetic Algorithm is a system that takes two individual items, selected for their fitness for a given purpose, and breeds them to produce offspring; this process will be further detailed in the next section of this report. This use of a Genetic Algorithm whose generations are influenced by the decisions of a user is a process often referred to as Aesthetic Evolutionary Design (AED).

Bentley described in his paper Aspects of Evolutionary Design by Computers (Bentley 1999) the four main types of Evolutionary Design as employed by computers, and how their overlapping has led to four new areas, one of which is Aesthetic Evolutionary Design, whereby a design is evolved purely on its aesthetics rather than anything else.

Rowland presented an excellent example of artist use of Genetic Algorithms in a system (Rowland & Biocca 2000) where a users aesthetic choices are used to breed new populations, in this case, virtual sculptures.

There are two interesting papers on generating simple characters, to be refined purely by the by the eye and aesthetic taste of the user. Ogura and Hagiwara presented a paper (Ogura & Hagiwara 2013) that used a Genetic Algorithm to generate and refine 3D faces whilst Ando and Hagiwara presented a paper (Ando

& Hagiwara 2009) dealing with entire characters. These systems employed an interesting function whereby they attempted to extract rules based on the user selection, in order to try and present solutions that the user is more likely to find aesthetically pleasing. This is a fascinating augmentation to the procedure and one that could be of interest in developing further the tools described by this report.

There are two prior works that are the closest in terms of prior art to the specifics of the program developed during this project. The first was a generalised Genetic Algorithm called Metavolve (Lewis et al. 2001), designed to be used in Houdini as a Genetic Algorithm that could be used for a number of purposes. One of the potential purposes that was shown as a work in progress was the evolution of humanoid body shapes, which is similar in principle to this project, however this project seeks to generate creatures with multiple limbs and form factors beyond humanoid.

The prior work that most resembles this project was the work of Yamamoto, Maki and Shirai in their project 'Skeleton-based diverse creature design tool for mass production' (Yamamoto et al. 2011), which was a tool written in Python and designed for Maya, explicitly aimed at creating a tool to quickly create many useful designs. Their program would allow a user to pick bone chains for sections of a creature based on body part templates and join them together as well as move and otherwise alter them. This would result in a controllable skeleton around which a creature could then be designed. They describe the results of one of their (at the time) most recent tests as "an artist who can create tarot [sic] 22 creatures in 20 days in sketch based workflow was able to create 10 base creatures in 3 days with skeletal structures and sketches". This statement suggests that a workflow based around creating a skeleton and then altering it to produce designs was highly advantageous in terms of time.

It is this observation that is the the backbone of the idea behind the tools developed in this project, that of creating tools that can speed up the work of artists and designers. The hope of this project is to result in a set of tools that allows rapid creature creation, alteration by genetic algorithm and automatic rigging to provide a robust pipeline to enhance both the creativity and speed of artists and designers.

Chapter 3

Technical Background

3.1 Genetic Algorithms

The following is a brief explanation of Genetic Algorithms (GAs), which are employed by this program. GAs are a form of Evolutionary Computing, whereby a program attempts to optimize a given problem. GAs were first developed by John Holland in the 1970's and published in his book 'Adaptation in natural and artificial systems' (Holland 1992).

GAs can be employed in any area where a population of individuals (or phenotypes) can be represented by sequences of genes that the genetic operations can be performed on. These individuals can be anything, from pictures to coded computer programs, as long as an appropriate representation of them can be made for the algorithm to work upon. The representation is as a series of 'genes' relating to aspects of the 'individual', these are often coded in binary, but other appropriate representations are possible, such as arrays or the use of Python dictionaries as used in this project. There are two main operations that are performed by a GA on the genes of its 'individuals', Crossover and Mutation, but dependant on the GA, other operations may also be used such as those used by Akbari and Ziarati, migration and re-grouping (Akbari & Ziarati 2011).

The specifics of GAs depend on the type of problem and the sort of entities that it is operating on, but all GAs have the same function, to narrow down the search space (containing all possible solutions, regardless of their quality) to find the optimal solution. To do this they generate an initial population of 'individuals' (potential solutions to the problem) and select parents for a new generation from these, based on their fitness to a given task or goal. For each new entity that needs to be generated, a pair of parents is randomly selected from the parents group. One parent is taken as the base code and then has half the genes of the second parent (chosen at random) swapped with its own comparative genes.

Following this procedure a new entity has been created which may then undergo mutation if desired. Mutation can be as simple as swapping the value of a single digit in a genome comprised from a binary representation, to more involved processes such as randomly generating a number for every gene and if that number is below a set Mutation Rate (or threshold) then causing that gene to mutate in a way specific to that program.

Fitness is usually calculated by the algorithm based on the attributes of an entity and designing this fitness function can be a very difficult job, depending on the problem area being faced. But the complexity is variable depending on what the entities are and their goal, for instance in Sims seminal paper Evolving Virtual Creatures (Sims 1994), which generated moving creatures from primitive blocks, fitness for jumping creatures was calculated by the highest point the creature reached during a set time period.

Fitness is considered differently however in the tool presented in this report. For the purposes of the GA employed in the tools for this project, the fitness is actually decided by the user, based on creature appearance alone, making the fitness function the users own aesthetic eye.

3.2 Houdini Object Model

The Houdini Object Model (HOM) is used extensively in this project. It is an Application Programming Interface (API), that allows the user to interact with the component nodes of Houdini to poll information from them, perform operations on them etc, through use of the Python programming language.

Chapter 4

Design and Development:

As it was decided to write the program as Python and HOM script, the process of writing the program for the project was split up into a number of Houdini shelf tools to perform different tasks and test small bits of code separately before integration. The original iteration of the program as presented at the mid-term critical presentations did not have a GUI and was implemented as code only. This was done for the sake of speed since the program was still expected to change and evolve further during development and so it was decided that creating a GUI should be done later in the timeline when the project features were more firmly fixed.

The initial two tools developed were the main Creature Generator and Genetic Algorithm tools, which will now be further detailed. Following on from there is an explanation of the GUIs designed to interface with the code and then the final tool, the procedural Control GUI for the creatures.

All these tools are available in the folder title Utilities accompanying this report. In order to run these tool successfully, the main folder Creature Generator should be placed in a users home directory, as the code works relative to that folder and the folders it contains. The code for each of the four tools should be placed into separate shelf tools in Houdini, the first three CreatureGen, GA, GUI were developed for this project and Fix contains a sample program by SideFX (the makers of Houdini), that whilst unrelated to this project, is present due to a bug with running the GUIs successfully that is detailed later in this report.

Early attempts at splitting various algorithms off into separate modules to then be imported to Houdini again by simpler main tools, were failures. This seemed to be due to an issue where Houdini wouldnt recognise the hou notation (necessary for node calls in HOM) if it was being imported from another file. Due to this, the tools are rather long, dense sequences of code; in the future it would aid the readability of the code correct to this bug and to split up the code across multiple files which might also reduce the code size due to shared algorithms or sections of algorithms appearing in the different tools. At the end of this project it was realised that this most likely had a simple fix that had not been considered earlier; in that it might be fixed by importing the 'hou' module at the start of every external module, however time did not remain to attempt this solution. It would be one of the first fixes in an update to the project.

It should be noted that the program was not written to be specifically made of high integrity or highly efficient code, but was designed to prove a potentially novel pipeline and the general concept, with the expectation that future iterations of the program would improve and optimise the code design and structure.

4.1 Creator Generator

The Creature Generator comprises three main parts, the actual Creature Generator itself, a Creature Builder and the Creature Rigger.

4.1.1 Creature Generator Tool:

The function of the Creature Generator is to take a number of user provided variables, which are maximums and minimums for both numbers of possible component parts and their sizes as well as the actual number of creatures that the user would like to generate. There are some limitations on this initial system for the number of component parts, in that only one or two pairs of legs and wings are supported.

The reason for the limitation was in order to reduce the complexity to a manageable level, the focus of the project on delivering a cohesive design, rather than attempting a fully comprehensive system and failing to deliver anything of note.

This system however proves the capability of these tools as part of a pipeline and a future iteration of the programs could remove these limits by extending and augmenting the current algorithms. The following sections present the algorithms as they are currently coded and where applicable, suggestions for appropriate future algorithms that if implemented would extend the capability of the system.

In order for the generated creatures to be able to work with the Genetic Algorithm tool, all sizes, rotations and positions of pieces are stored in a series of Python dictionaries (referred to henceforth as the creature's 'genome') which are saved to file via Pythons pickle command at the end of each creatures generation. The information stored in these is enough to recreate the model of the creature and to also generate the information necessary to auto-rig it using the rigging tool designed in this project.

The main algorithm randomly chooses between its provided variables to decide on what parts the creature being generated will be made from and then it randomly selects the size of each component based again on the user input. In theory the user can generate large numbers of creatures, but the design is optimised as a 5 x 5 grid, so 25 creatures is suggested per generation. The general algorithm is detailed in Algorithm 1.

For the purposes of this program, all creatures are considered to be symmetrical; the algorithms generate the left side limbs and mirror their parameters to the right side pieces appropriately. The genome for each creature still consists of both left and right side pieces, even though their genes are the same, so the program could be extended to deal with asymmetric individuals, however due to breeding the designs via the Genetic Algorithm program, asymmetric designs could quickly produce poor and undesirable aesthetics; however this could be an interesting subject for future research.

An algorithm could be written to allow a user to alter the proxy geometry and then save the changes to file, this may allow the rigging program to then rig the resultant creature and if the appropriate naming conventions were used as presented throughout the code, could allow additional parts to be added. This has not been implemented due to time constraints; however Algorithm 2 presents what would be an appropriate algorithm to run after changes have been made.

Algorithm 1 Main Algorithm

```
for each creature to be generated do
    Choose random number of legs, arms, sections in arms, fingers, sections in fingers, wings,
main sections in wings, subsections in wings, neck segments and tail segments within set limits
    Choose random sizes for head, ears and muzzle sections
    for every section in the body do
        Choose random size for each segment
    end for
    for each segment in Neck do
        Choose random size for segment
    end for
    for each segment in Tail do
        Choose random size for segment
    end for
    for each Arm do
        for each Arm segment do
            Choose random size for segment
            if multiple sets of arms present then
                Angle arm appropriately
            end if
        end for
        for each Finger do
            for each Finger segment do
                Choose random size for segment
                if multiple finger then
                    Angle fingers appropriately
                end if
            end for
        end for
    end for
    for each Leg do
        Choose Leg style:
        if Biped style then
            Create two segments with random sizes
        end if
        if Quadruped style then
            Create four segments with random sizes and appropriate rotations
        end if
    end for
    for each Wing do
        for each Main Wing segment do
            Choose random size and angle for segment
            for each Wing sub segment do
                for each Wing sub segment do
                    Choose random size angle for all segment
                    Chose random size for segment
                end for
            end for
        end for
    end for
end for
```

Algorithm 2 Algorithm for adding changes to the geometry to the creatures save file

```
for each node in creature geometry network do
    Calculate which entry in the genome corresponds to this node
    if match found then
        For each position value:
    end if
    if different then
        Update genome
    end if
    for each rotation value do
        if different then
            Update genome
        end if
        if no match found then
            Add new entry to genome
        end if
    end for
end for
```

Specifics of the algorithms used for each of the part types are detailed in the following sections. Each algorithm determines the parts position in world space, based on the positions of other relevant body parts and segments of itself and also adds this position information into the dictionary holding the genome information for the creature. Once all position information has been calculated, the main geometry node is collapsed inside of a subnet the reason for this was the hope of being able to later convert the creature into a Digital Asset, an operation which must be applied to a subnet.

4.1.2 Legs:

There are two leg types available for the program to employ. A simple Biped style, which is made from two segments like the shin and thigh of a human leg and a Quadruped style, based on a generalised animal leg model with four segments. The generalised animal the design is based on is taken from the book 'Animal Anatomy For Artists - The Elements of Form' (Goldfinger 2004), where the leg comprises Toes, Hind Foot, Lower Leg and Thigh. The algorithm to achieve these Leg types is presented in Algorithm 3.

The leg segments will later be moved along the X-axis so that they fall at the sides of body.

Algorithm 3 Leg Algorithm

```
for each Leg do
    if Leg is Biped style then
        Place first segment so that its base is at 0 Y in world space
        Calculate position of top of segment
        for each additional segment do
            Place base of next segment at position of top of prior segment
            Calculate position of top of segment
        end for
    end if
    if Leg is Quadruped style then
        Place first segment so that its base is at 0 Y in world space
        Calculate position of top of segment
        for each additional segment do
            Place base of next segment at position of top of prior segment
            Calculate position of top of segment
        end for
    end if
end for
```

A future extension to the project would be to allow additional segments to be added by the program into these leg types. Another extension would be to add further leg types, the most obvious of which would be crustacean/arachnid style legs. Such a leg type could be considered as made of two general sections, the first being a number of segments coming up from the ground, the second being a number of segments descending from the tip of the first section and meeting the body at the lowest point of the second section. The general algorithm to achieve this is shown in Algorithm 4.

4.1.3 Body:

The body is made up of 3 sections, each made up of three segments, based on a generalised body model of upper, mid and lower torso. The algorithm for this is detailed in Algorithm 5.

4.1.4 Arms:

The program can generate arms made up of any number of segments, at the end of which it can also place any number of fingers, also made up of any number of segments. The code currently restricts the models to having the same number

Algorithm 4 Crustacean/Arachnid Leg Algorithm

```
for each Leg do
    if Leg is Arachnid style then
        for first section do
            Place first segment so that its base is at 0 Y in world space
            Calculate position of top of segment
            for each additional segment do
                Place base of next segment at position of top of prior segment
                Calculate position of top of segment
            end for
        end for
        for second section do
            Place first segment so that its top is at the top of the first section
            Calculate position of bottom of segment
            for each additional segment do
                Place top of next segment at position of base of prior segment
                Calculate position of base of segment
            end for
        end for
    end if
end for
```

Algorithm 5 Body Algorithm

```
Position first central segment at the top of the leg segment
Position side segments to either side of the central segment
for each additional central segment do
    Place immediately above the highest point of the preceding section (either the top of the
central or side segments, whichever is higher)
    Position side segments to either side of the central segment
    if creature has more than one pair of legs then
        Shift this row of segments forward
    end if
    if central segment is the final segment and creature has more than one pair of legs then
        Adjust height of final row of segments to be at top of the front pair of legs
    end if
    for each Leg do
        Shift segments to be at the extents of the relevant side sections of the creature
    end for
end for
```

of fingers on each hand, but this could be changed to allow each hand to have a different number of fingers and segments. The general algorithm for the arms is shown in Algorithm 6.

Algorithm 6 Arm Algorithm

```
for each Arm do
    Place start of first segment at edge of body
    Calculate position of end of segment
    for each additional segment in Arm do
        Place start at position of end of previous segment
        Calculate position of end of segment
    end for
    for each Finger do
        Place start of first segment at end of arm segments
        Calculate position of end of segment
        for each additional segment in Finger do
            Place start at position of end of previous segment
            Calculate position of end of segment
        end for
    end for
end for
```

4.1.5 Neck and Tail:

The neck and tail can be made up of multiple segments; however no tail is required for a given creature, but the neck must be at least one segment in size. The algorithm for the Neck and Tail sections can be seen in Figure 7.

Algorithm 7 Neck and Tail Algorithms

```
Place first Neck segment at top of body
for each additional Neck segment do
    Place above previous segment
    Place first Tail segment behind the base of the body
    for each additional Tail segment do
        Place below and behind previous segment
    end for
end for
```

4.1.6 Wings:

Wings are divided into two sets of segments, the main segments which can be considered the top edge of the wing and the subsections which branch off of the main section, as shown in Figure 4.1.

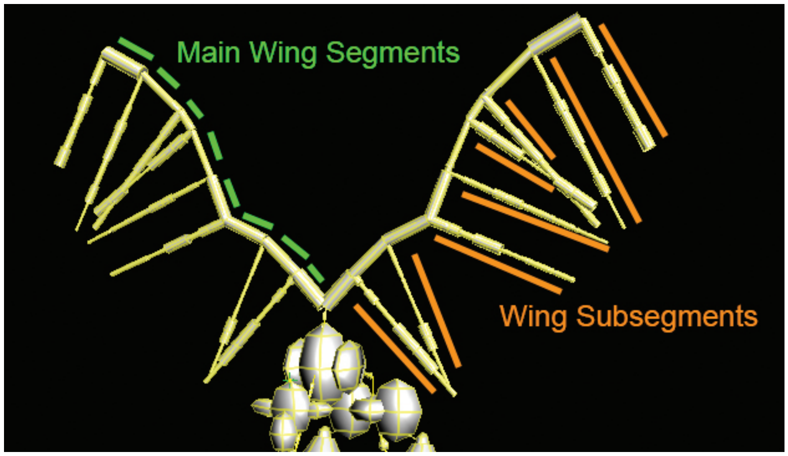


Figure 4.1: *Main and subsections of Wings*

The algorithm decides the sizes of each segment in each part of the wing and can be seen in Algorithm 8.

Algorithm 8 Wing Algorithm

```
for each Wing do
    Place start of first segment at a random distance behind centre of spine
    Calculate position of end of segment
    for each additional Main Wing segment do
        Place start at position of end of previous segment
        Calculate position of end of segment
    end for
    for each Wing sub-segment do
        Place start of first segment at end of a Main Wing segment
        Calculate position of end of segment
        for each additional segment in Wing sub-segment do
            Place start at position of end of previous segment
            Calculate position of end of segment
        end for
    end for
end for
```

4.2 Creature Builder:

This section of the program reads the genes of a creature and then builds and connects all the relevant Houdini nodes in order to visualise it. The program begins by creating a single surface Geo node and deletes the File SOP it contains. All the creatures geometry will then be placed inside of this node.

Since the positions of every part of the creature have already been calculated during the generation process, the code to visualise the parts is very simple. Each element of the creature is represented by either a primitive sphere or a tube, which can be easily generated in Houdini via HOM script. Depending on how the part is to be visualised, the algorithm will select a Tube or Sphere representation, change the size as per its genotype information and then place it in world space. In order to move it within the world space, the original sphere or Tube is appended first with a Group node to capture all of the pieces of that geometry and then an Edit node which allows for the position to be changed.

Once all pieces have been built, an algorithm then runs through the nodes, connecting them all into a single merge node. Two more nodes are added at this point. Firstly a convert node is used to convert all the geometry to mesh form, this is due to meshes being better captured by the rigging system. The second node is a switch node, which allows for the switching between the merger of the nodes generated within this Geo node and a File SOP which can read in external geometry. The reason for this feature is to allow the user to capture the generated geometry to their rigging structure and animate with it, but at a later time, switch out that proxy geometry for a proper model.

The display flag is then set to the switch node, this means that either all the pieces making up the creature will then be displayed or the imported creature mesh, depending on the status of the switch.

4.3 Creature Rigger:

Due to the amount of information that the Creature Generator part of the program generates, there is enough to procedurally set up a basic bone rig. Following Side FXs own suggestion for user made rigs, the program establishes a root for the creature, represented by a Null at the centre of the world space (and later moved appropriately if multiple creatures are being generated at once). All of the Bones and Nulls (used for controls) that will then be generated will link back to the root node, so that when that is moved, everything else will move with it.

There are many types and styles of rig that can be created, and these vary from situation to situation, character to character and the preferences of the rigger and/or animator. This project did not set out to create an all-encompassing rig, but demonstrates one particular style. If this code was generally disseminated, it is assumed a Technical Director would alter the current rigging algorithm to better suit their own style and needs, however the rig as presented should be fully usable.

There are generally 4 main styles used for rigging multiple bones, Forward Kinematics (FK), Inverse Kinematics (IK), a blend of the two and bones can also be set to follow a provided curve. Which style is used can depend on the part of the character or a given situation it is being used in. For this system, the legs, arms and fingers all use IK solvers and the neck, spine, tail and wings follow curves.

The program generates a series of Inverse Kinematic solvers for the relevant limbs and applies them to the appropriate bones as they are built, allowing for a simple, moveable skeleton right away.

This program does not offer a user the ability to blend between IK and FK, which is certainly a desirable capability. The reason for this comes down to mathematics and the way that Houdini handles connecting bones. To employ an FK/IK blended rig, the resting position of the rig in FK should match the position that IK would pull it to; however when connecting and parenting bones, Houdini resets the rotation values of each bone to zero, whilst pointing in the same direction as whatever its parent bone was.

In practise this isn't a problem if you are building a rig by hand, but doing so procedurally necessitates a lot of calculations to nullify the prior rotations before then calculating new ones based on positions of relevant body parts. It was not possible in the timeframe to fully sort this out and so a number of bones attached to IK solvers, would not be otherwise rotated correctly if that solver was not present, as in the case of FK control, rendering an appropriate blending scheme impossible. The very first improvement that would be made to the rigging system, would be to fix this issue and offer the capability of performing blends.

The following sections describe the algorithms used for generating the bones and rig controls for each set of parts making up the creature.

4.3.1 Spine/Neck/Tail:

It was decided to model the Spine, Neck and Tail as following a curve, with the control points of that curve then translating as control points to move the Spine, Neck and Tail. The positions of the Neck and Tail segments are known and it was decided that the spine would be made up of 7 parts, this was done for simplicity to match the 3 sections of the body (plus the base), but could be altered to be more procedural in the future.For the spine a point was calculated for the centre of the lowest central body section, the top of the two upper sections and then two additional points at the 'thirds' marks between these.

Tests with using Houdinis inbuilt Path node which generates a curve and control points did not a scheme that seemed suitable for reproducing procedurally so the simpler Curve node was used. The Curve node defines a curve by a series of points entered into it (in this case as the centres of Null nodes) and so a system was written to generate a Curve SOP and then procedurally locate the centre of each Neck and Tail segment as well as the positions calculated for the Spine and add them as controls to the curve.

A bone chain is generated from the base of the spine to the top of the neck segments and to one additional point at the top of the head, the size of each bone being calculated based on the positions of each point along the spine curve. A second bone chain is calculated for the tail. Ideally the tail and spine should have also been connected, but this led to some strange results and so they were separated. A future improvement would be to find the source of the problem of connecting them and to resolve the issue.

To be able to interact with these control points easily, a set of Nulls are generated at a distance behind the creature, as parents to the actual Nulls controlling the curve, and set to display as coloured boxes. An example of these controls can be seen in Figure 4.2.

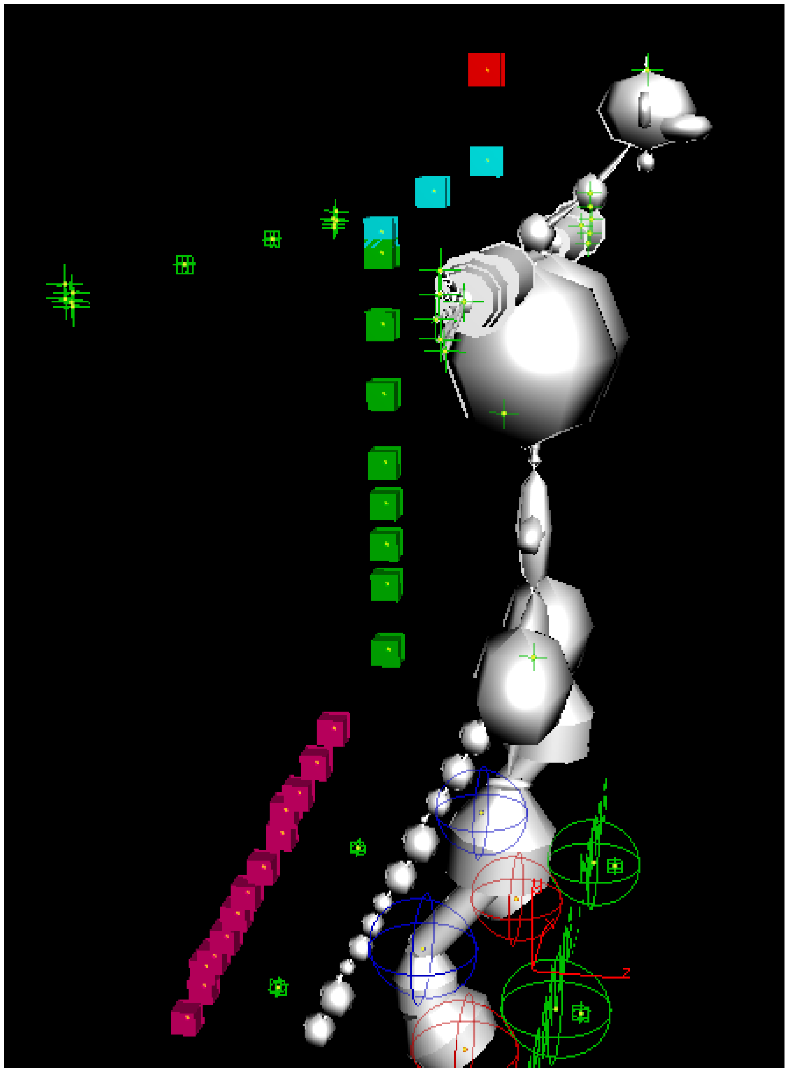


Figure 4.2: *Spine, Neck and Tail Controls*

4.3.2 Arms:

Bones are calculated for the arms based on the end points of the arm segments. There is also an additional bone connecting the top of the spine to the beginning of the arm chain, generated based on the relative positions of the spine and beginning of the arm. Bones are also appended from the end of the arm, out to the tips of the fingers, where again bone length is set by calculating the distance between the segments.

Control points are set for the arm as a Null at the wrist and at the end of each fingertip to control position as well as appropriate Nulls placed away from the character controlling the twist of the IK chains in the arms and fingers. An example of these controls can be seen in Figure 4.3.

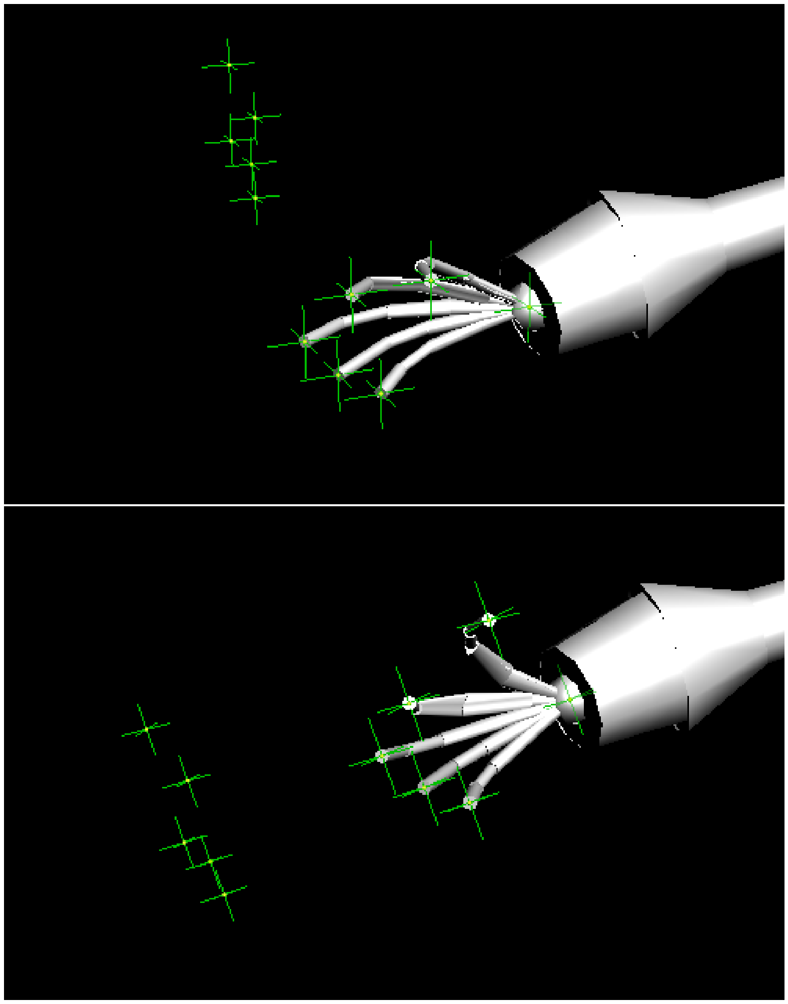


Figure 4.3: *Arm and Finger Controls*

4.3.3 Legs:

Bones are calculated from the top of the leg down, two for Biped style legs and four for Quadruped style ones, again with an additional bone built from the base of the spine to the top of the leg chain.

For Biped style Legs there are two controls, one at the base of the leg and another set away from the body controlling the IK twist. For Quadruped style legs, the Leg is divided into two sections, upper and lower, each with their own solver and so a control is placed at the end of each chain and another set away from the body to control twist. There is also an additional control that both the other translation controls are parented to, allowing the user to easily move the whole leg as one. Examples of these controls can be seen in Figure 4.4.

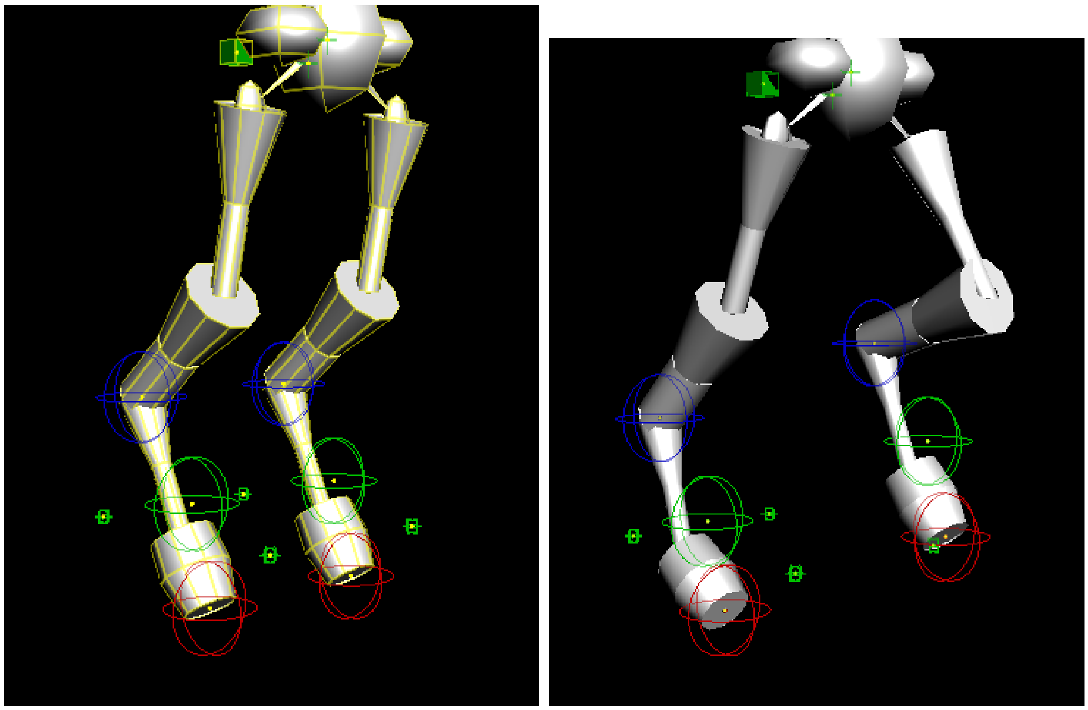


Figure 4.4: *Leg Controls*

4.3.4 Wings:

Bones are calculated for the wings in much the same way that Spine by creating curves for IK solvers to follow. A null is placed at the end of each Main and Sub wing segment, and an appropriate bone chain calculated in the same way as the Arms and Fingers were, with the exception unlike the Fingers, the Subsections come from the end of each Main segment, rather than all from the end of the final one.

Again like the Spine, control Nulls are generated away from the body to move the actual Null points and presented as coloured boxes, these can be seen in Figure 4.5.

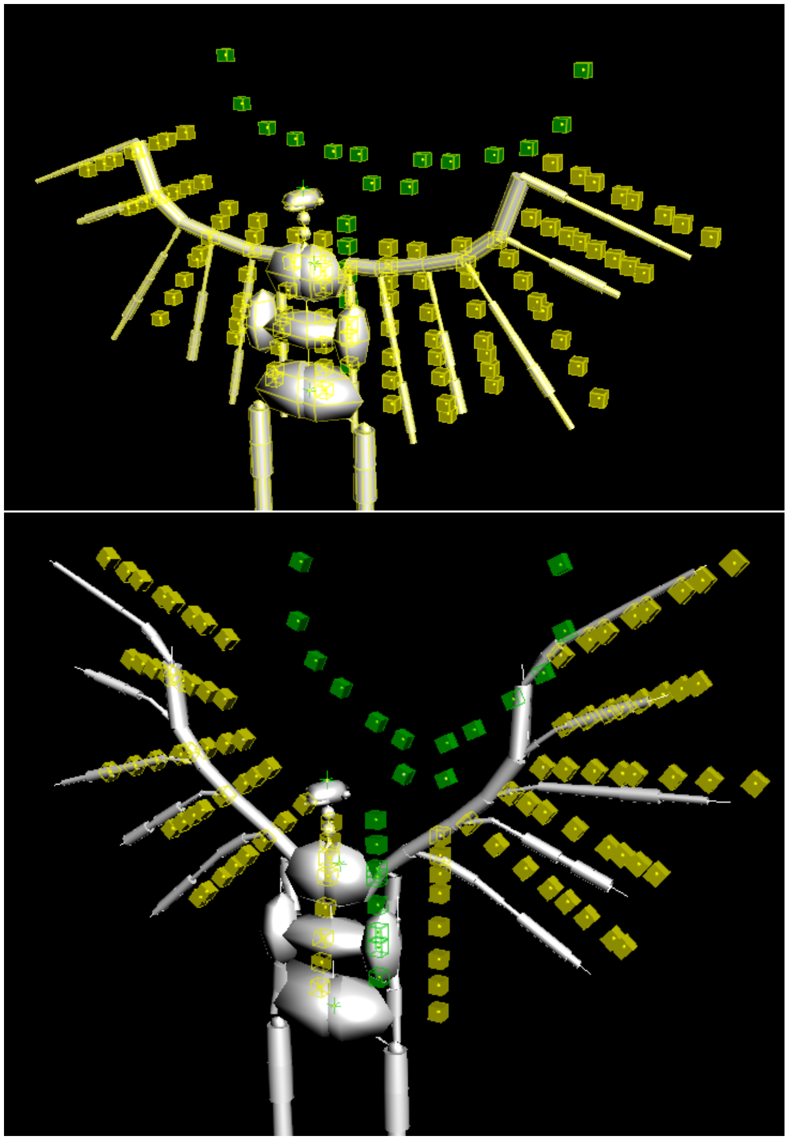


Figure 4.5: *Wing Controls*

4.3.5 Bone Capture Buckets:

There is an area around each bone, referred to as the capture area, zone or bucket, geometry within which can be tied to the movement of that bone. The rigging tool automatically calculates and sets capture zones around every bone that it generates, their extents decided upon based on the size of the particular segments of the model the bone is within. This means that when the rig is attached to the generated proxy geometry, the user will already have a good capture set up for them so that all generated geometry should be captured correctly. A few minor issues have been seen with edges of segments being captured by multiple buckets which are too close but not from the same part of the creature i.e. the arm buckets deliberately overlap slightly at their ends, but it is possible that a wing bucket might intersect with the body or part of the arm, and this would need to be rectified by the user.

4.3.6 Attaching the Rig to the Creature:

Although these tools are capable of generating creature geometry and an appropriate rig, they cannot currently automatically capture the geometry to the rig, the user must still do this manually. The process is simple, but due to how the appropriate tool is implemented in Houdini, has to be done by hand. The user must double click on the subnet containing the nodes representing the creature, from here they must select the node title Creature_name where name is the creatures name beyond Generated_Creature_ e.g if its name is Generated_Creature_Bob, then the node the user needs to find is Creature_Bob.

If a user presses l to auto layout the nodes, the appropriate one will be found in the small cluster at the top right of the rest of the nodes. The user must next press the Capture Geometry tool button in the Character shelf and then find the root node of the creature rig, this will be the top most node with a vast array of nodes as children beneath it. Once they have selected this node, they must place their mouse over the viewer section of Houdini and press the Enter key. This process should capture the geometry to the bones. It is hoped that in the future a way to do the capture in this way automatically, will be found.

A user can now use the GUI or directly manipulate the controls to animate the character, and the geometry should now move with the rig. Once the user is at this stage they can animate with the creature however they wish, and later tie a proper mesh to the rig via the previously described File node within Creature_name.

4.3.7 Building a proper Creature Mesh:

A user could now use Houdinis modelling controls to create a proper mesh for the creature, but a lot of users will want to model in another program. To do this, they will want to export out the creatures geometry to use as a general guide whilst modelling and to do so they must go to the Creature_name node and enter it. From the right-click menu on the Convert node, they can then choose Save geometry and save out the geometry as a .obj file wherever they wish.

The .obj file can then be imported to another program and used as a guide with the knowledge that the automatically set up capture buckets for the bones are slightly larger than the proxy geo itself. Completed models can be imported back into Houdini via the File SOP found inside the creatures Creature_name node and switched to be active via the Switch node.

Any animation that has been done with the rig should now work with the proper creature mesh, however the user may need to refine the capture zones in appropriately and perform weight painting to achieve a high fidelity capture of the mesh to the rig. It is hoped in the future that an automated process for weight painting could be incorporated to make the process easier for the user.

An example of a creature generated by these tools and a quickly made basic mesh for it can be seen in Figure 4.6.

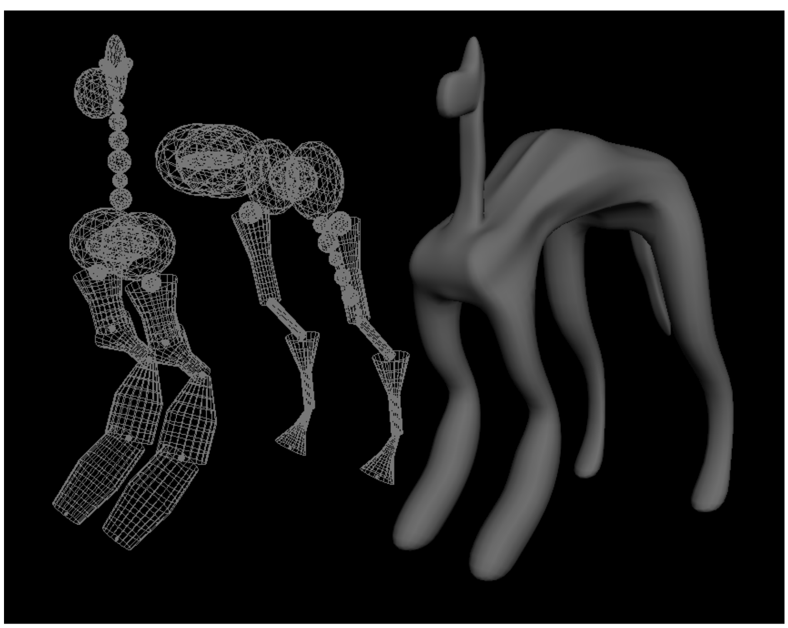


Figure 4.6: *Proxy Geometry and Mesh made in Maya for a creature*

Chapter 5

Genetic Algorithm

The Genetic Algorithm part of the program follows the standard GA processes Crossover and Mutation as previously described in the report.

5.1 Crossover:

The algorithm picks a pair out of the possible parents in the parent pool (that the user will have filled from the pool of creatures they have already generated) and swaps over half of their genes to create an offspring. The gene swap may not be possible in cases where the limb or segment numbers do not match between the parents.

If the limb number doesn't match (i.e. a gene from the third pair of arms of one creature is selected to be applied to a creature with only two pairs of arms), then the algorithm is able to generate new arms (and legs or wings) and then apply the requested change to the required part. If the segment still does not exist (or the limb already existed but the relevant segment did not) the program will currently ignore this and move on. In the code the user will find a series of partially coded algorithms that attempted to allow the tool to add in new segments, but unresolved errors have prevented them from being accessible by the main algorithm. In the future these would be completed in order to allow the GA to provide a more complete solution. The reason these were not completed was due to a changed focus to enhancing the rigging system and the associated additional work this required for the relevant GUI and the required alterations and completions would be a minor task during a future update.

5.2 Mutation:

The mutation algorithm is straightforward. The algorithm runs through the list of parts in the genome and for each one randomly generates a number, if that is lower than the mutation rate as provided by the user in the GA GUI, then it will randomise the size value of that part - within the creatures Max and Min sizes for the part in question. The algorithm runs through the list of parts three times in order to account for potentially changing the size of a part in each of the X, Y and Z dimensions as each should be considered a separate gene.

5.3 Use for Creature Variation:

There is also a secondary function of the GA, that can be of great use to the user. If they choose only a single parent for the parent pool, the algorithm cannot perform crossover (since they have exactly the same genes), however it can still apply mutation. In this way, it is of use to a user who generates a creature, either through the Creature Generator or as a result of use of the GA, that they find very interesting but not quite right for their purposes.

By setting up the parent pool to consist of that creature only, and setting the Mutation Rate appropriately, they will receive a generation of creatures that are variations of the original. This in effect produces a number of individuals of the species archetype of the original parent. The level of variation can be controlled via the mutation rate.

Using the GA in this way, the user can either arrive at a variation they wish to use, or else an entire population of similar creatures to rig and use as a species in a project. An example of this process can be seen with a single parent seen in Figure 5.1 and a generation of its progeny through mutation alone in Figure 5.2.

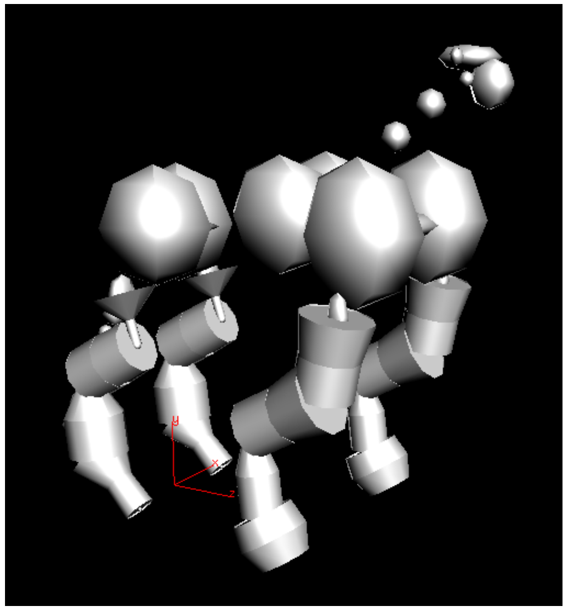


Figure 5.1: *A Single Parent Creature*

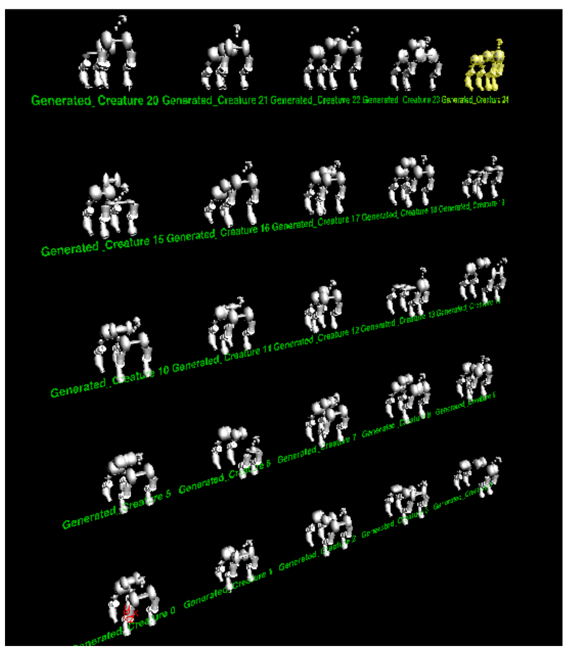


Figure 5.2: *Children generated for the single Parent seen in Figure 5.1*

Chapter 6

GUIs and Tool Controls

As previously stated, the program began life without any GUI, meaning that a user would have to open up the shelf tool and directly edit the code to affect changes in program behaviour. Once the features of the creature creation system were more firmly defined and an understanding of the control and rigging scheme was developed, it became possible to start to define a series of GUIs that could interface with the Python and HOM script and give the user full, simple interactive control over the program capabilities. There would be three necessary GUIs, one for the main Creature Generation controls, one dealing with Genetic Algorithm and breeding creatures and then some form of GUI for the generated creatures.

The initial idea was to package rigged creatures as Houdini Digital Assets so that they could be easily shared; however creating Digital Assets through code is severely lacking in example material. SideFXs page on HOM commands that deals with Digital Asset creation (SideFX Houdini 11.0) provides the command to turn a subnet into a Digital asset but it was not readily apparent how it would be possible to programmatically make Houdini build an appropriate GUI for a user, without attempting to work with Houdini code deeper than the HOM. Due to the lack of coverage on such an ability and time constraints, it was decided to create an external GUI to provide these controls to the user. At the end of the project, rereading again Houdinis commands in relation to Digital Asset creation, it seemed that it might be possible to promote the controls of the creature to a single DA GUI via the 'addParmFolder' and 'addParmTuple' commands, but it would require a lot of work to find out if these commands were usable in this way and to establish a usable procedural method to do this if they were. At that stage no time remained to properly explore this possibility, so the rest of this section will detail the design and development of the external GUI system. Fully exploring this idea would be a high priority for an update to the program.

Three separate GUI systems were built, the first developed was a static (i.e. non-procedural GUI) that would present the user with all the options associated with generating a creature or creatures. The second was also static and dealt with GA control. The third was designed as procedural system for the control of creatures generated by the first or second GUIs associated tools. It was procedural in that the creature generation system can produce a wide variety of creatures with many different combinations of limbs, leg designs, wings etc. and so when activated for a given creature it would procedurally build a GUI containing all the controls relevant for that particular creature.

There are two main supported methods for creating external GUIs in Houdini, these are PyQT and wxPython. Houdini provides example code for running either, including the necessary code to run the GUI in a separate thread (avoiding Houdini being locked up otherwise when the GUI is activated) and opinion seems to be divided as the which is the better to build with. wxPython was chosen to implement the GUI for this project due to a good example of it being used with Houdini being available online via the 'Python and Houdini' webpage (Pate 2008) and due to issues with getting PyQt set up on the computer the project was originally built on.

The example showed how a simple user interface employing wxPython can be built with a simple GUI designer called wxGlade (wxGlade 2013), which was installed and used for this purpose. wxGlade allows a user to drag and drop GUI components onto a window, position these components correctly and bind event calls to buttons, control boxes, etc. All three GUIs were created in wxGlade which generated the relevant wxPython code to create them when called. For the Creature GUI examples of all the things that would need to be procedurally generated were made and then the resulting code was altered to allow the program to automatically build the relevant controls needed for a specific creature based on the information contained within its genome.

6.1 GUI Threading Bugs:

There are several recurrent bugs that have been encountered with wxPython GUIs and Houdini. Firstly an issue where GUIs will load, but not actually affect Houdini when used. When closed they present an error about C++ objects no longer existing. A proper fix for this bug has not been found, but a work around has been made. By first invoking another tool, this error can be bypassed the tool in question is a simple script provided in SideFXs examples (SideFX Houdini 10.0), which simply generates a test tool that alters fonts. For some unknown reason if this tool is activated and the resultant window closed first, the GUIs developed for this project will usually run without encountering the C++ error, however it can still occur intermittently, so whilst tedious it is best practice to run the Houdini example tool before every use of a project tool. Future work would involve fixing this bug which is most likely an issue to do with threading and until then the code for SideFXs tool is provided in the file named Fix within the project folder Utilities and should be added to a shelf tool along with the project specific ones.

6.2 Creature Generator GUI:

This GUI was designed to provide the user with easy access to all the variables for numbers of components and the maximum and minimums of the sizes for those components. It is structured into four tabs, Number of Parts, Body Sizes, Limb Sizes and Rig/Save/Load as well as an always present bar at the base with the button for generating the creatures and a box allowing you to alter how many are made. The parameter fields that the user can alter are linked to the creature generating code via events bound to those fields. Each time the user changes a value, an event is generated that will lead to an update of the relevant parameter in the main code itself.

6.2.1 Functions:

The front page, displaying the various options, can be seen in Figure 6.1.

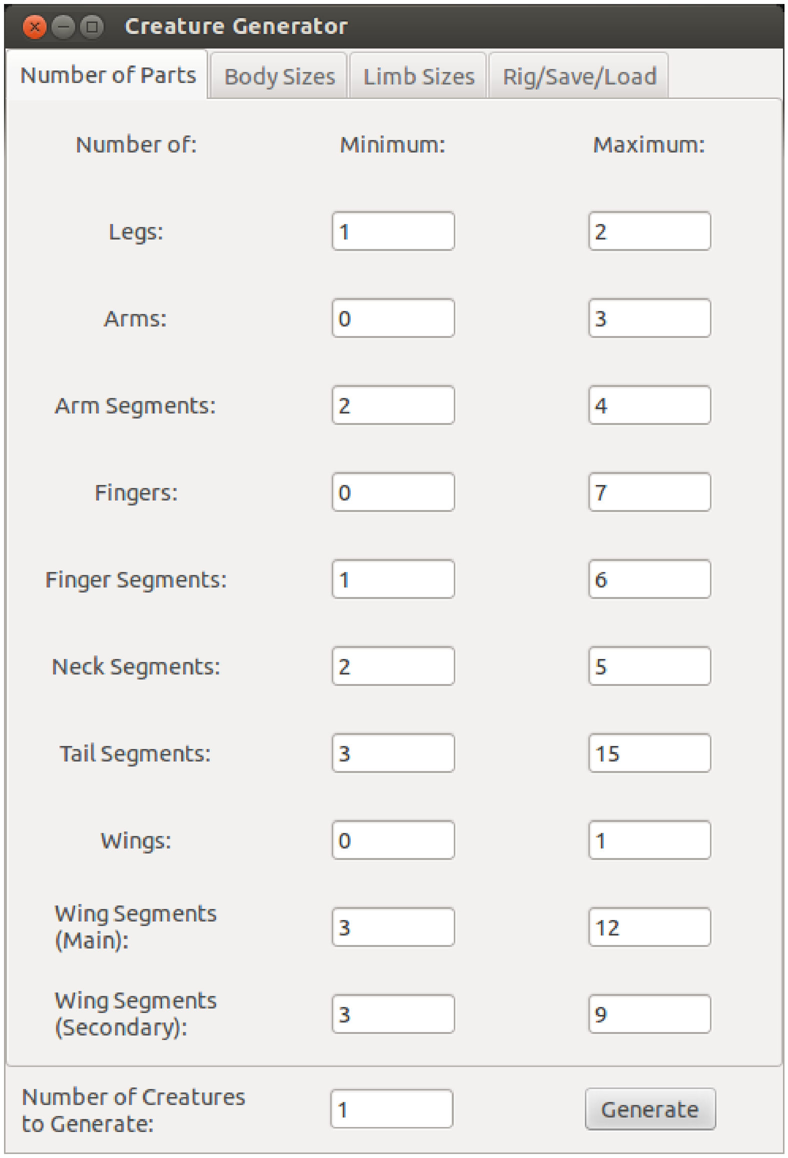


Figure 6.1: *Creature Generator GUI Main Page*

As previously indicated, there are some limits that must currently be observed by the user, no more than two pairs of legs or one pair of wings.

The next two pages of the GUI, seen in Figure 6.2, allow the user to set size ranges for all the component parts that will be generated in order to comprise the creature.

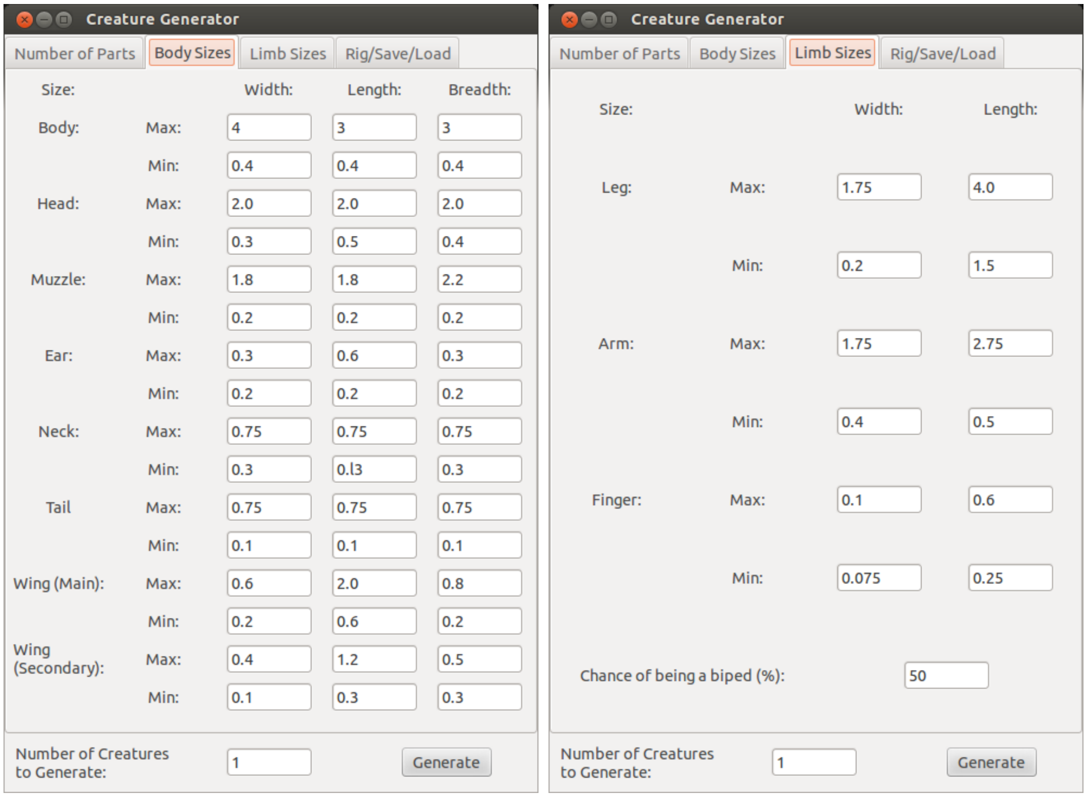


Figure 6.2: *Creature Generator GUI Second and Third Pages*

The final tab presents a number of useful controls to the user and can be seen in Figure 6.3.

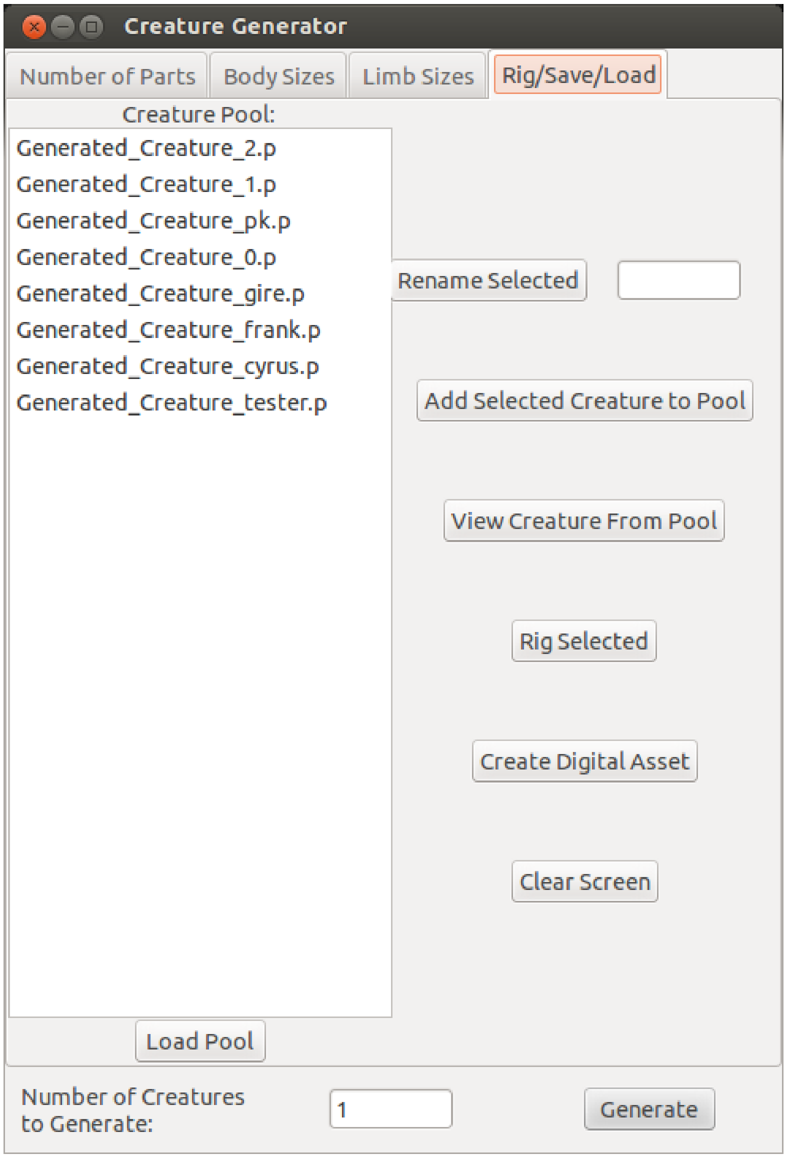


Figure 6.3: *Creature Generator GUI Final Page*

A list box provides a list of all the creatures currently saved in the Creature Pool, which represents the contents of the Saved Creatures folder in the project file structure. In the context of this GUI, selected means that a user has selected the appropriate subnet for a given creature in Houdinis Node view.

When a creature is selected, pressing Rename Selected will rename the creature and its save file to Generated_Creature_ + whatever they have entered into the text box. Pressing Add Selected Creature to Pool will copy the creatures file to the Saved Creatures folder and Rig Selected will invoke the Rigging algorithm on that creature. Pressing Clear Screen will delete all current nodes.

If a user wishes to look at a previously saved creature, they can select it in the list box and press View Creature From Pool, which will read the creatures file from the Saved Creatures folder and rebuild it, centred at the world origin. A creature loaded in such a way can then have its node selected and be subject to the above operations.

6.2.2 Creating Digital Assets:

A user can also select a creature and press Create Digital Asset, which will automatically create a Digital Asset (DA) for the creature, named with the same name that the creature had. This was only implemented at the end of the project and whilst successfully creating a DA out of a creature, does have some issues. Firstly to create the DA, the code is set to suppress warnings about relative references, which due to the way the code has been written, there are examples of a lack of. The solvers reference to full file strings from the /obj level, and in theory could be broken when the DA was invoked elsewhere. This problem was not actually encountered during brief testing, but could theoretically appear.

Another issue is that each time you create an instance of the Asset, it is locked, which is standard practice for DAs, but means that the rig is frozen as it is contained within the Asset and so is locked. To get around this issue, if a user tries to use the GUI tool while selecting a creature that is a DA, it will check its status as a DA and upon finding it is one, unlock it, allowing the GUI controls to properly interact with the rig. The problem with that approach is that any updates made to master version of the DA, would never flow into the DA instance to match it to the update.

The final problem with using the creatures as DAs is that when you call an instance of one, its Rig will be initially broken, as the DA appends its own name with a number, which results in the Rig looking for parts that do not exist. This can be remedied by removing the number appended to the DAs name; however that prevents having multiple instances of the same creature, as they would all need the same name in order for the rigs to work, and multiple nodes with the same name cannot coexist (at the same level) within a single Houdini file. One way around this is to keep renaming and re-saving the same creature multiple times. Future work would involve finding solutions to these problems that are more practical.

6.2.3 Creature Generator vs Creature Designer:

Although the GUI is primarily organised to help the user set up a variety of creatures to be created, the user can also narrow the variables and restrict them to a large extent, thus allowing them to create a highly specific type of creature. Although this is not a true Creature Designer it is an approximation and shows how the program could be extended to allow full Creature Designer capability to be incorporated into it, or as a standalone tool. The idea was considered during the development process, however it was decided to keep the code generalised as a Creature Generator and allow the user to narrow the fields such that it has designer like capability, without being a designer solely. The expansion of the code to allow true designer functionality would be relatively minimal, requiring a new specific GUI and potentially some additional functionality.

6.3 Genetic Algorithm GUI:

The Genetic Algorithm GUI needed to allow the user a good interface into the GA algorithm, with simple, clear controls. The resultant GUI can be seen in Figure 6.4.

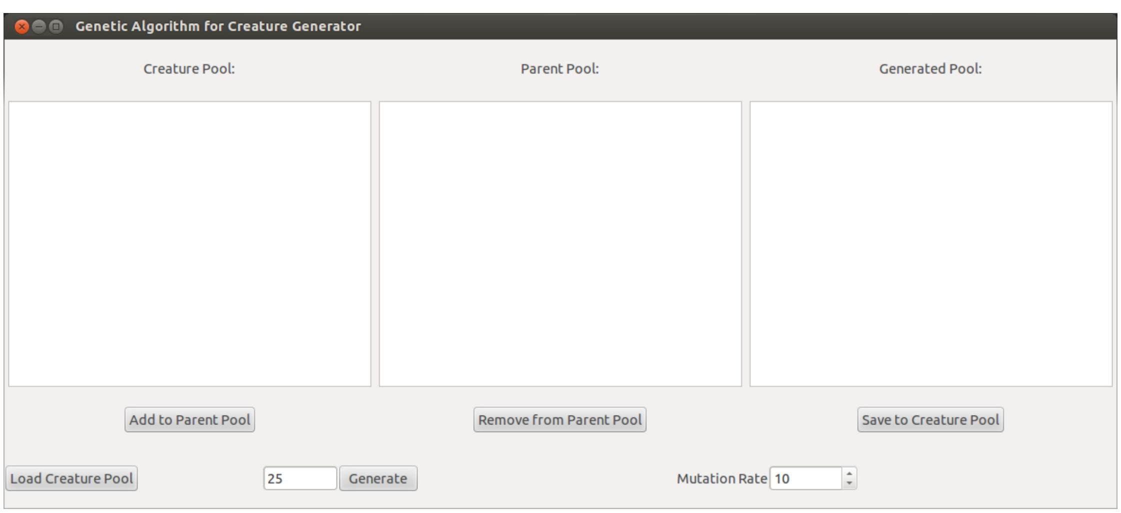


Figure 6.4: *Genetic Algorithm for Creature Creature GUI*

The user is presented with three list boxes, one containing all the creatures that have so far been saved, one containing the parents to be used for the next generation of creatures and one displaying the creatures that have been generated. There are also controls for selecting the number of creatures and generating them and for setting the Mutation Rate. The Mutation Rate is in terms of the percentage chance that any given part will mutate during the breeding process, usually these are set quite low, but if there are only two parents then a higher rate of mutation might be desirable in order to get a better variety of creatures during the next generation.

Buttons are also provided to add creatures from the Creature Pool to the Parent Pool, to remove them from the Parent Pool and to save a generated creature, these functions will move the creature files appropriately in the file structure (creatures placed into the parent pool are copied rather than moved). A user could later load a generated creature via the Creature Generator tool and rename/rig it as they wished. This can also be done directly to any of the creatures that have been created and are currently displayed in the window, however it is essential to shut down the GA window first before calling the Creature Generator Tool, as there is currently a bug that if more than one GUI is active at the same time, it will cause Houdini to either lock-up or crash.

In Figure 6.5 several creatures are shown as the parents for a new generation and Figure 6.6 shows a generation of creatures made from them.

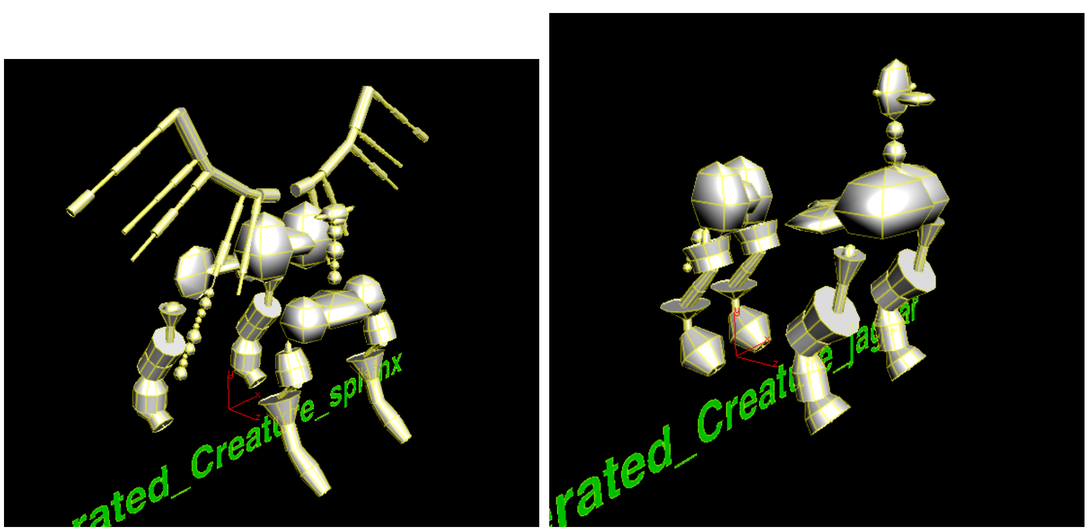


Figure 6.5: *Parent Creatures*

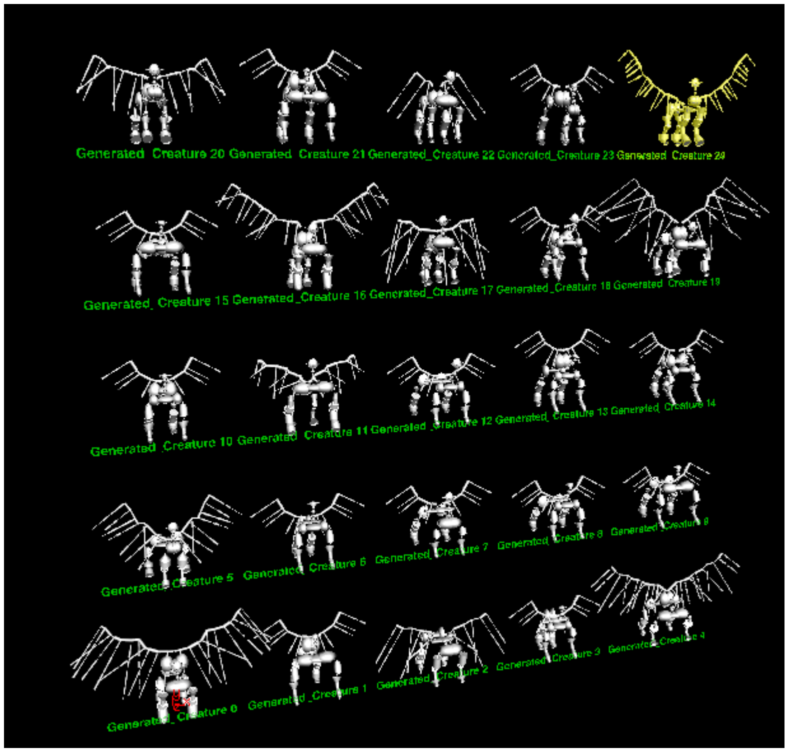


Figure 6.6: *Child Creatures generated from Parent Creatures in Figure 6.5*

6.4 Procedural Creature Rig Control GUI:

When setting up the rigging code it was ensured that along with the bones and solvers created, all the relevant control points would also be visualised for the user. This would allow for them to see the controls in the main window and to select and manipulate them as they wished in order to move the rig. This can be an effective control scheme, but it does not allow for easy fine tuning and if many controls are visualised at the same time, it can be confusing. Due to this there was a desire to create a GUI for the controls, much like the one Houdini creates for its own Auto Rigs.

As has already been shown in the prior section, it is entirely possible to generate an external GUI that can interoperate with Houdini successfully; however there are a number of issues that are raised in producing an auto rig style control GUI for a project such as this. The Creature Generator program can create a wide array of creature types with differing limb numbers and types, so creating a single all-encompassing GUI would not be the best solution, as it would either present redundant controls to the user for parts a given creature doesnt have, or else it wouldnt provide controls for parts that the creature does in fact have.

The best solution is a procedural approach whereby the GUI automatically builds appropriate sections within itself to present only the controls required by a given creature. The general algorithm for designing such a GUI is shown in Figure 9.

This sort of functionality is not widely discussed in terms of wxPython, and in order to let the program build as much as it needs, its labels must all be dynamic. The best way it was found to achieve this was by making them Python dictionaries, allowing easy iteration over them during 'For' loops.

The resulting program can be slow to generate the GUI as it has to work out what to actually generate for the GUI, every time it is run, taking 15 seconds or so for particularly complex creatures, but usually less than 5 seconds for simpler creatures. Due to the number of controls generated for them, creatures with large wing structures are particularly susceptible to taking a longer time to build a GUI for. As such, whilst this is an effective stopgap until a TD has written a full DA interface, its slow speed to load likely makes it impractical for long term use. Future work would focus on ways to build the GUI within Houdini, either as part of a Digital Asset or through some other method. The resultant procedural GUI can be seen in Figure 6.7.

Algorithm 9 Procedural Creature GUI Algorithm

```
for Each Leg do
    if Biped style then
        Create Leg Translate Control
        Create Leg Twist Control
    end if
    if Quadruped style then
        Create Full Leg Translate Control
        Create Upper Leg Translate Control
        Create Upper Leg Twist Control
        Create Lower Leg Translate Control
        Create Lower Leg Twist Control
    end if
end for
for  Each Arm do
    Create Arm Translate Control
    Create Arm Twist Control
    for Each Hand do
        Create Hand Rotation Control
        for Each Finger do
            Create Finger Translate Control
            Create Finger Twist Control
        end for
    end for
end for
for Each Wing do
    Create Wing Translate Control
    Create Wing Rotate Control
end for
for Each Main Wing Segment do
    Create Segment Translate Control
    Create Segment Rotate Control
end for
for Each Sub Wing Segment do
    Create Sub Segment Translate Control
    Create Sub Segment Rotate Control
end forHead Translate
for Each Neck Segment do
    Create Neck Segment Translate Control
end for
for Each Spine Segment do
    Create Spine Translate Control
end for
for Each Tail Segment do
    Create Tail Translate Control
end for
```

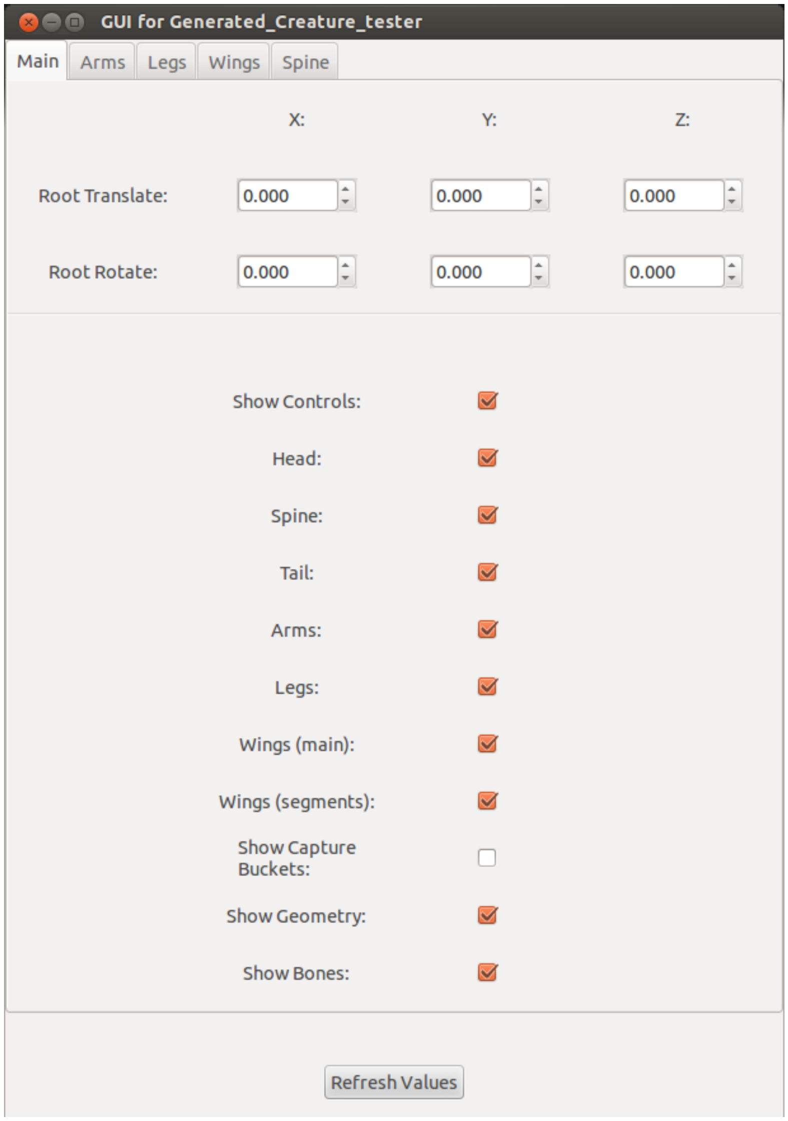
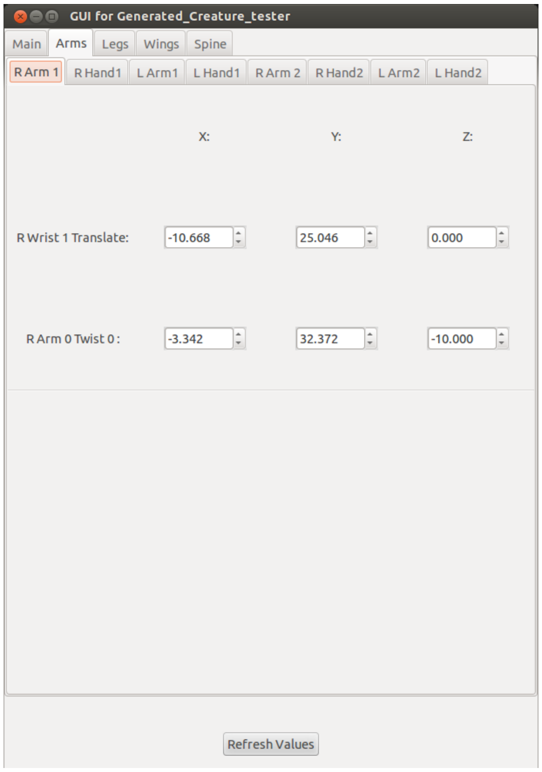


Figure 6.7: *Creature GUI - Main Tab*

The first page of the GUI allows the user to translate and rotate the creature as a whole by manipulating its root. A set of check boxes are also provided in order to alter which sets of controls are shown for the creature. A user can also set whether or not to show the geometry of the creature and the bone rig and can also display the capture areas for the bones.

The Arms tab provides separate sub tabs for each arm and hand, with associated controls for the translation and twist of the arms and fingers displayed appropriately. This can be seen in Figure 6.8.



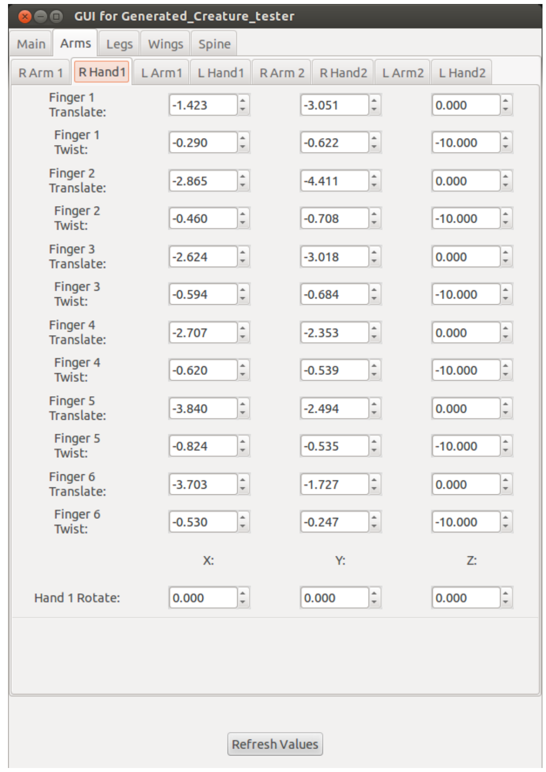


Figure 6.8: *Creature GUI - Arm Tab*

The Legs tab shows two different control lay outs depending on whether the given leg is of a Biped or Quadruped style. For a Quadruped type leg, the user can separately control the upper and lower parts of the leg (each having its own IK solver) or move them in unison via the Full Translate option. The Full Twist option is currently not attached to any control in the creature as time constraints meant what would have been the applicable controls, were never coded in the Creature Generator tool. Examples of these tabs can be seen in Figure 6.9.

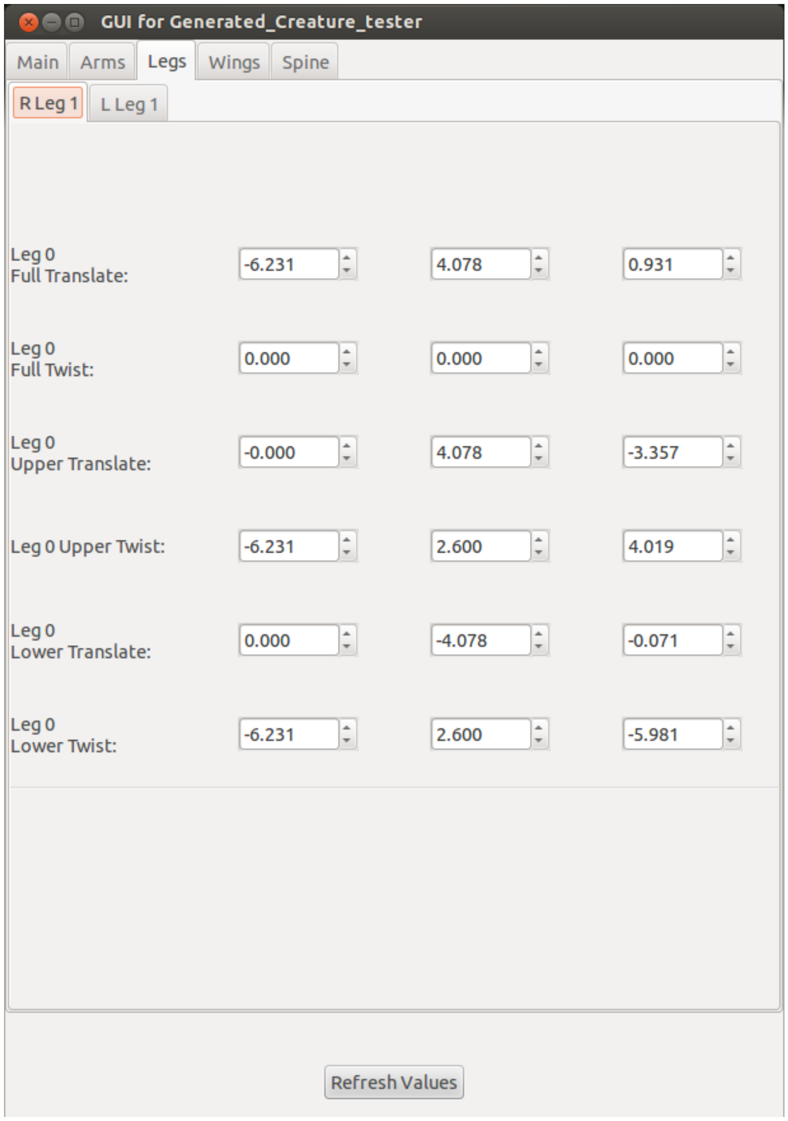


Figure 6.9: *Creature GUI - Leg Tab*

Like the Arms tab, the Wings tab generates multiple sub tabs to separately control the main sections of the wing and the subsection trailing from the main ones. These controls can be seen in Figure 6.10.

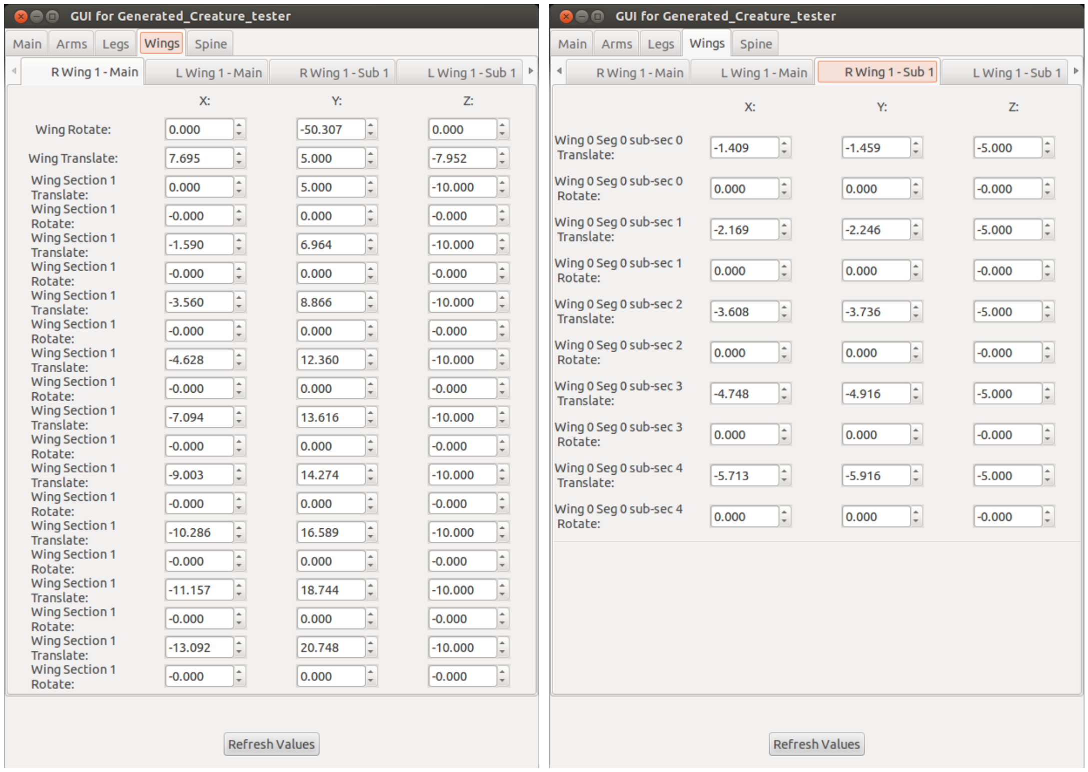


Figure 6.10: *Creature GUI - Wing Tab*

The Spine tab separates into three sub tabs, one for the actual spine part itself, one for the neck and head and one for the tail. There are only a set number of spine controls, so these are consistent across GUIs, but the Neck and Tail tabs will procedurally create as many controls as are required for the given creature. An example of these controls can be seen in Figures 6.11 and 6.12.

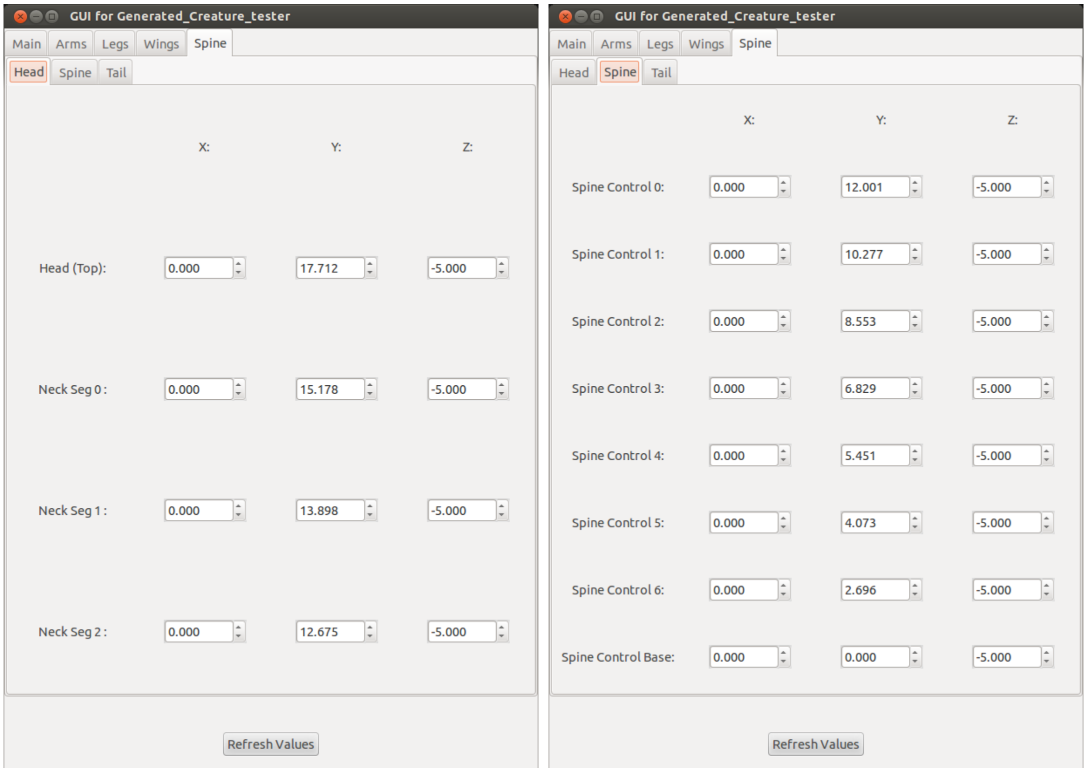


Figure 6.11: *Creature GUI - Neck and Spine Tabs*

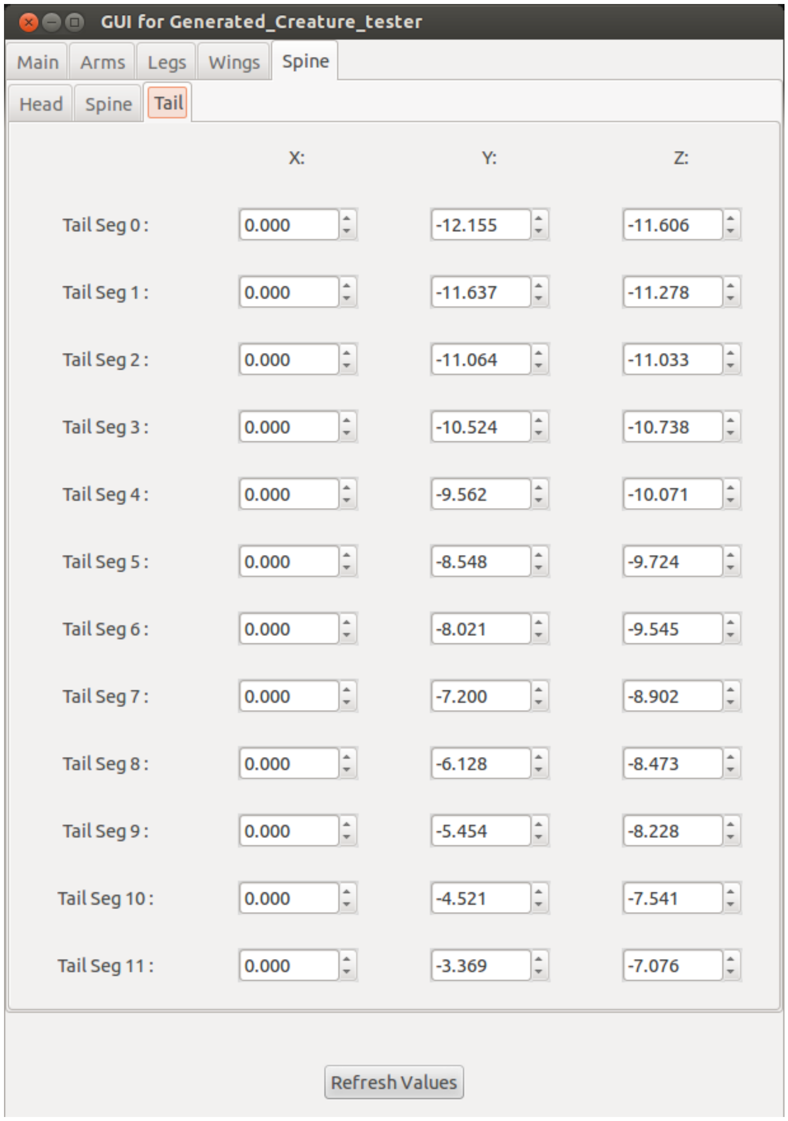


Figure 6.12: *Creature GUI - Tail Tab*

Chapter 7

Examples:

This report has already shown a number of examples of creatures generated by the projects tools, this section shows a few more. Figure 7.1 shows a generation of creatures.

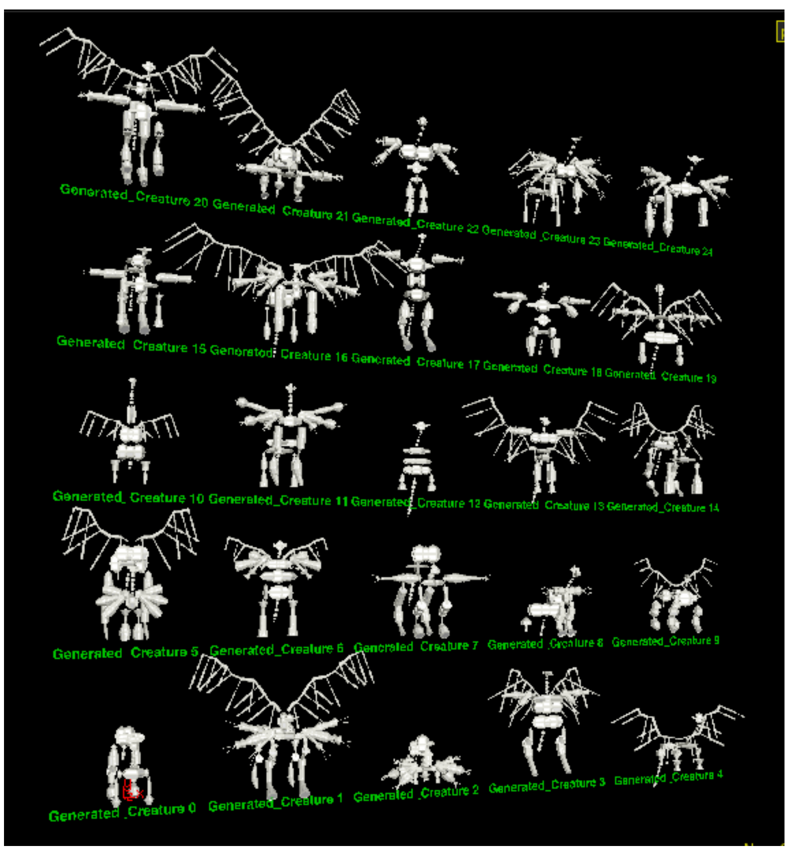


Figure 7.1: *A Generation of Creatures*

Figure 7.2 shows creatures generated during the videos submitted with this project.

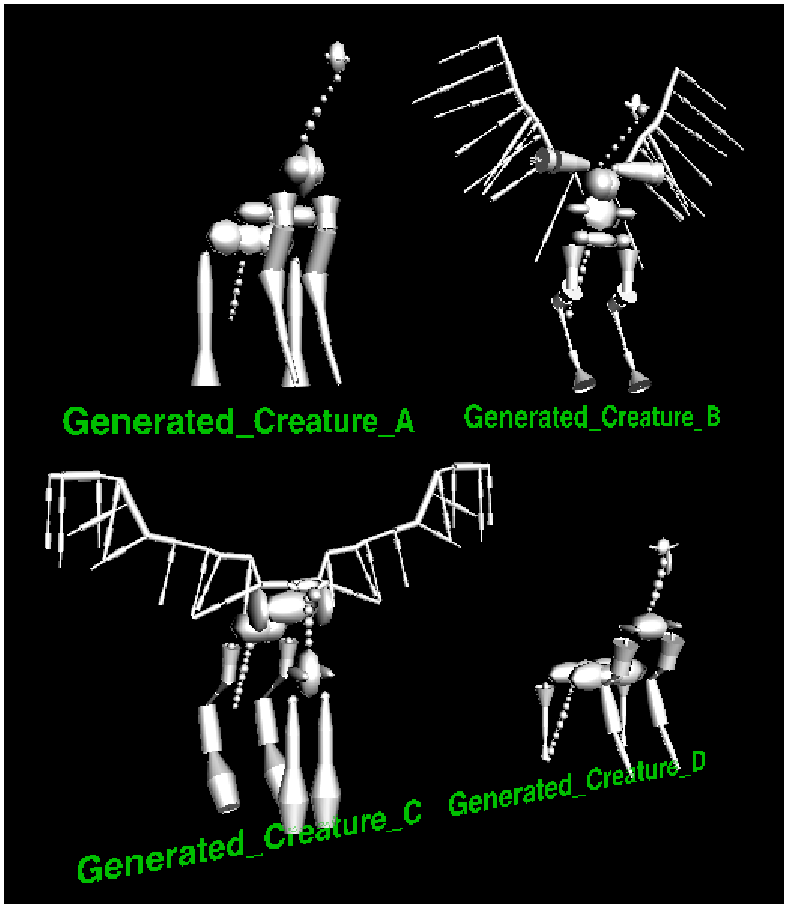


Figure 7.2: *Four Creatures seen generated in project videos*

Figure 7.3 shows a child generated from the Genetic Algorithm operating on the creatures of Figure 7.2. Next to this creature (on the right) is a creature generated by using the creature on the left as a lone parent with high mutation, to arrive at a variant.

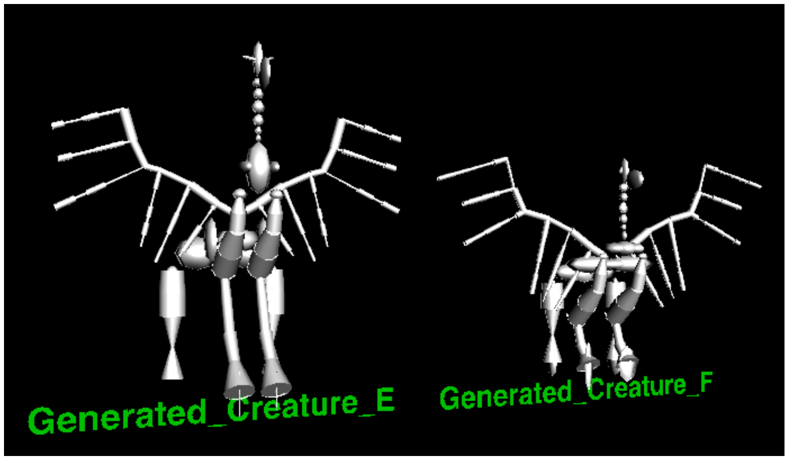


Figure 7.3: *Parent (Left) generated as child of Figure 7.2 and its Child (right) generated via Mutation of Parent alone*

Figure 7.4 shows an example of an arm that has been manipulated via the controls generated by these tools, as its underlying bones, the proxy geometry originally generated and a mesh modelled in Maya and read into the creatures geometry.

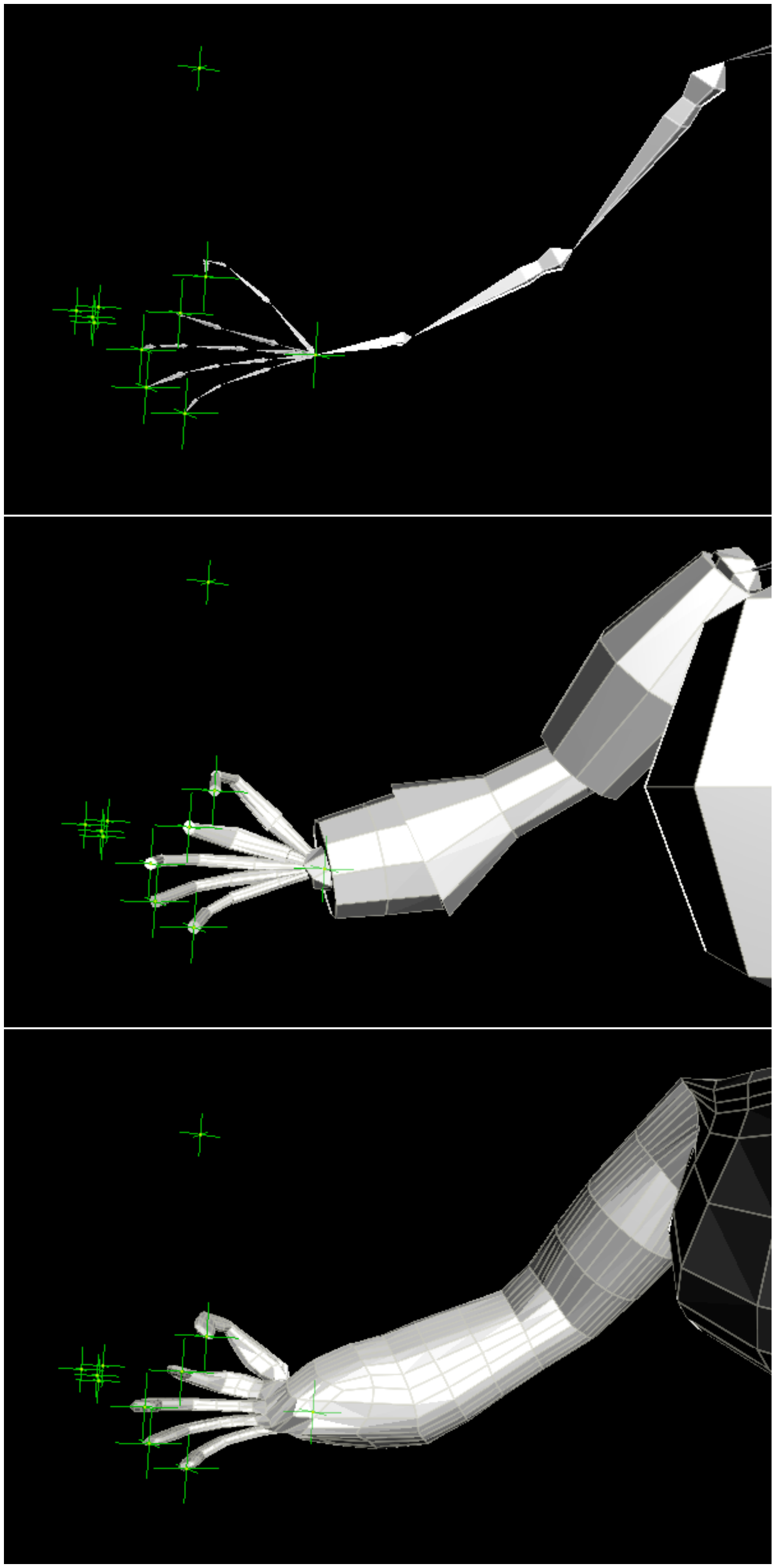


Figure 7.4: *Bone, Proxy Geometry and Mesh of a Creature Arm*

Chapter 8

Conclusion

Through undertaking this project a great deal has been learnt about both scripting with Python and tool writing in Houdini. Three tools have been created, the first to both generate and rig creatures, the second to breed creatures together to create new designs and the last to generate practical, procedural GUIs for these creatures.

The Creator Generator tool provides a lot of scope for user interaction in defining the creature types generated and allows the user to save, load and generate rigs for any creature produced. Extending this to allow even more user control would be beneficial in the future.

The Genetic Algorithm tool allows the breeding of multiple selected parents to produce offspring via Crossover and Mutation functions and has the added benefit of allowing a single parent to be used to generate variations on that parent leading to a refined creature of interest, or a species of individuals sharing the same form factor, or creature archetype.

The Procedural Creature GUI tool is a single program that can generate a bespoke GUI for any creature created by the other two tools. It will procedurally build itself to have the controls required for any given creature.

The tools were never designed to be entirely comprehensive, as has been noted throughout this report, but it is believed they show the power that a system like this has. Taking the project forward it could be further developed with the suggestions made earlier in the report, or used as the basis for a more complete Creature Designer and Auto Rigger, with more precise controls and fewer limitations on part numbers and types.

The Genetic Algorithm is an interesting part of the tools, but it is understood that different users would find it of differing levels of usefulness. It is believed that updates to the Creature Generator code, removing the current limitations would lend greater strength and utility to the Genetic Algorithm tool.

All the Python code is fully transferable to other software packages such as Maya, so the general algorithms could be employed in other programs, with the HOM commands swapped out for relevant commands in another package.

The project stands as a proof of concept that a system such as this is possible and could be a useful tool for any TD or animator. The pipeline for creature creation is different to the standard one for creating creatures from concept art onwards, but could provide time savings and potentially come up with designs that a user wishes to use but might not have otherwise considered themselves. The ability to both generate and rig a character automatically has been shown and this capability could be very useful, providing time savings in rig creation.

8.1 Future Work:

Commentary on specific avenues of future work have been made throughout this report, largely in regards to detailing limitations to remove, capabilities to extend and bugs to remove. The following is a brief list of the most important areas for future work:

- Fix the GUI threading issues
- Extend the parts the generator can create and remove current part number limitations
- Extend the Genetic Algorithm to be capable of adding additional segments
- Improve code by extracting relevant shared algorithms to call as modules
- Explore additional control schemes for the auto rig function
- Explore further how to create useful DAs from the creatures with Houdini based (rather than external) GUIs

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M. Lewis, et al. (2001). 'Aesthetic Evolutionary Design with Data Flow Networks' For a little over a decade, software has been created which allows for the design of visual content by aesthetic evolutionary design (AED). The great majority of these AED systems involve custom software intended for breeding entities within one fairly narrow problem domain, e.g., certain classes of buildings, cars, images, etc. Only a very few generic AED systems have been attempted, and extending them to a new design problem domain can require a significant amount of custom software development. High-end computer graphics software packages have in recent years become sufficiently robust to allow for flexible specification and construction of high-level procedural models. These packages also provide extensibility, allowing for the creation of new software tools. One component of these systems that enables rapid development of new generative models and tools is the visual data flow network. One of the first CG packages to employ this paradigm was Houdini. A system constructed within Houdini that allows for very fast generic specification of evolvable parametric prototypes is described. The real-time nature of the software, when combined with the interlocking data networks, allows not only for vertical ancestor/child populations within the design space to be explored, but also allows for fast horizontal exploration of the potential population surface. Several example problem domains will be presented and discussed. 1.

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