

PROCEDURAL ANIMATION ALGORITHM FOR SASANDU PLAYING PERFORMANCE IN 3D ANIMATED FILM "BAKO"

Chanel Maria Novela

Andrew Willis

Study Program of Animation, Universitas Multimedia Nusantara,
Jl. Scientia Boulevard, Gading, Serpong, Tangerang,
Banten 15227 – Indonesia, 021 – 54220808.

ABSTRACT

Many techniques can be implemented to create a 3D animation; one of them is procedural animation. Procedural animation is a type of animation in which all movements are created using programming languages or scripting. This technique is very effective to animate repetitive movements. Therefore, the motion created using procedural algorithms in "Bako" 3D animation short film is playing musical instruments. Python is used as the scripting language, with Sasandu as the musical instrument. Sasandu is a unique musical instrument of the island of Rote that is starting to go extinct. Playing the Sasandu is relatively difficult to animate manually, as we have to keep synchronizing it with the melody and tempo of the music. In the attempt of creating a fluid and believable animation of the finger striking, the rig should also be adjusted to mimics the structure of the hand and the human joints. Also, the logic of the algorithm created should be able to create a proper strumming movement with the tone and timing. This is to make sure that the resulting animated movements are correct according to the song's notations.

Keywords: Procedural animation, scripting, rigging, music, Sasandu

INTRODUCTION

Along with the development of the era, three-dimensional (3D) animation technology is increasingly experiencing rapid development. With various existing plug-in innovations and animation software, animators constantly attempt many ways to maximize their potential. In addition to the visual and technical elements, the role of the animator that makes the characters look alive and convincing is certainly no less important. However,

before animating a character, the rigging process must be carried out first. Rigging represents the process of constructing joints and controllers on characters to facilitate the animation process. According to Allen and Murdock (2008), the character rigging process is one of the most delicate stages in production. Therefore, scripting techniques can be used to accelerate this process.

Scripting can be used not only for rigging but also animating stage. According to Beane (2012), 3D animation movements are divided into three techniques: keyframed animation, motion-capture animation, and procedural animation. With procedural animation, the movement is generated using software calculation. Thus, animators don't need to move the controller manually. The animation can be produced using pre-determined computer calculations and algorithms. Procedural animation is very practical for measurable and repetitive movements (Beane, 2012). This technique can speed up the process of difficult animation instead of using conventional techniques like the keyframing method. Playing musical instrument is one of many great examples of complex movement to animate – especially when we cannot guarantee that all animators provide musical backgrounds.

The difference in playing one type of musical instrument and another will produce the need for a different animation script. This is because each musical instrument requires a different approach in analyzing and breaking down the way it plays into procedural steps. The musical instrument selected in this final project is Sasandu, a traditional version of Sasando - a stringed musical instrument from East Nusa Tenggara. We play the Sasandu using both hands by plucking the strings using fingers. We use the left hand to play the melody and bass notes, while the right hand is in charge of playing the accord (Noviyanto, 2011). According to Noviyanto, the younger generations of Rote are reluctant to play and preserve Sasando's existence. If Sasando - which is a more modern version of Sasandu - is almost extinct because nobody wants to be their successors, Sasandu's existence is unquestionably far more threatened.

Because of its uniqueness, not many people understand how to play Sasandu. This will cause the process of animating Sasandu's hand movements with the keyframe method more difficult. Animators have to synchronize the finger for each note according to the tempo and music. This will cause a low-level accuracy between the animation and the music. As a result, the animation will feel less tangible, especially for audiences who understand music. Therefore, the algorithm to create Sasandu playing procedural animation is needed to make realistic animation movements, as the Sasandu playing scene is one of the significant scenes in the 3D animated film "Bako."

RESEARCH METHODOLOGY

The method used in this research is through the study of literature on animation, scripting and algorithm, and music. In addition to literature studies, interview with Sasandu player is also conducted. This is to get information about the Sasandu's musical scales and learn how to play them from the video record for reference. Finally, the last method used is experimenting with the procedural animation scripts and music score codes.

ANIMATION AND 3D ANIMATION

Since ancient times, humans have always been interested in moving images. McClaren (as cited in Wells, 1998) outlined that animation is not an art of moving images, but an art of movement in the form of images. According to Thomas and Johnson (1981), there are 12 terminologies used by animators referring to special techniques in making moving images. These twelve terminologies then become the basic principles of animation, which are: squash and stretch, anticipation, staging, straight ahead and pose to pose, follow through and overlapping actions, slow in and slow out, arcs, secondary action, timing, exaggeration, solid drawing, and appeal.

The crew management process in the game can start with the planning step. This allows the players to do some preparation before going on an adventure by buying stuff, upgrading their vehicle (ship) and they do it with the destination in mind. After that, the implementation step is when the players are already on their way, for example, when there is a combat with another ship. The players have to reallocate their crews so the ship's combat ability can be at its peak. But the allocation of the crews to the weapon room can affect the other room abandoned, and this is where the players have to think fast and using their already prepared plan when this dire situation comes. The evaluation process is where the players learn from their mistakes. They will learn from their mistakes whether they arrived successfully on their destination or not. They will learn from what they lost, from what they should have prepared beforehand and the more efficient allocation of crews in a similar situation.

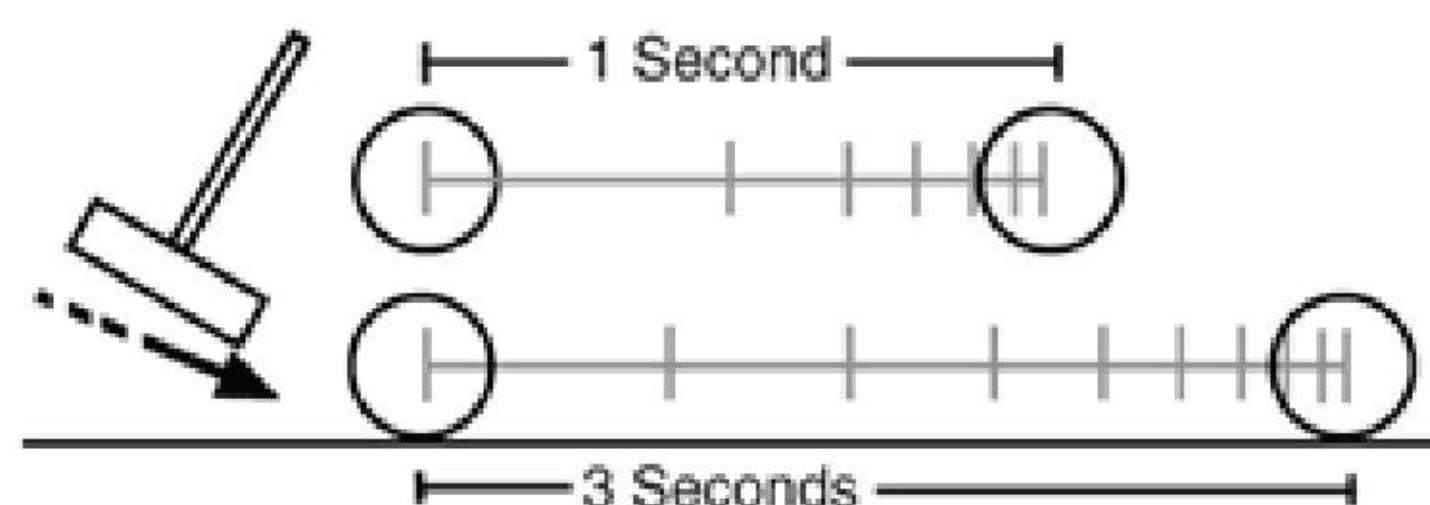


Figure 1. Frame Placement Comparison on 1 Second and 3 Second Movements
 (<https://www.evl.uic.edu/ralph/508S99/timing.html>)

Along with the development of technology, now animation is not only in the form of paper-drawn movements, clay manipulation, or manipulation of photographic frames as stated by McLaren (1998). In recent years, many 3D animations have been made by computers (Bib-liowicz, 2005). Beane (2012) argues that the need for 3D visual animation will continue to encourage computer technology in creating a variety of new techniques, to compensate for more rapid hardware development.

PROCEDURAL ANIMATION

Procedural animation is an animation technique where each move is generated from computer algorithm calculations using script codes. Using this technique, the program creates a set of rules, and the character will move according to the rules that have been made (Beane, 2012). According to Wong and Thung (2011), the line between procedural and non-procedural method is difficult to define. Almost all animations contain a certain procedural element in them. Good animation usually has both procedural and non-procedural elements, because procedural techniques can achieve results that cannot be achieved using non-procedural techniques and vice versa. Wong and Thung (2011) think that a non-procedural approach requires more skill in craftsmanship than planning. Meanwhile, in the procedural approach, it is necessary to do planning before the stages of the production. We have to figure out the elements of input and output first, and all of this has to be determined in the design stage. Procedural approaches require logical thinking, careful planning, and sometimes a mathematical calculation.



Figure 2. Comparison of Non-Procedural and Procedural Work Process
(Wong dan Thung, 2011)

MAYA SCRIPTING

Scripting is a form of programming that generally does not have the requirements to be compiled directly (Stack Overflow, n.d.). The script is written in the form of a scripting language. In 3D animation, scripting is one of the features provided by 3D animation

software that allows users to add plug-ins or customizable tools (Beane, 2012). With this feature, users can increase productivity in 3D animation production by creating tools that can help to do repetitive work. According to the Autodesk Knowledge Network (2017a), we can write Maya scripts using three types of programming languages, namely C++, MEL, and Python.

PYTHON

Python is a high-level programming language that can be applied to various fields, including web programming, scripting, scientific calculations, and artificial intelligence. We can use Python script to handle many tasks in Maya software; from running simple commands to develop plug-ins (Autodesk Maya, 2017). Python command elements include variables, lists, functions, loops, conditional statements, and modules.

ALGORITHM

The algorithm is a computational procedure that uses several values as inputs and produces other sets of values as outputs. We can also see an algorithm as a tool to calculate specific computational problem (Cormen, Leiserson, Rivest, & Stein, 2009). According to Tutorials Point (2016), an algorithm is a procedural step that defines an instruction to run in a certain order to get the desired output. The concept of algorithms usually stands independently in several programming languages.

MUSIC AND MUSICAL SCORE

According to Merriam-Webster (2018), music is an art that regulates tones or sounds in combination to produce a composition that has unity and continuity. Fundamentally, music consists of seven basic elements, namely rhythm, dynamic, melody, harmony, tone (timbre), texture, and form (Jacobson, 2006). Rhythm is an aspect of time in music. It is influenced by several important aspects, namely duration, tempo, and meter. Melody is a series of pitches arranged horizontally. Harmony is the verticalization of the tone - often seen as the art of combining chords into chords. Chords are some notes that are played together as a block.



Figure 4. Chord dan Chord Progression
(Jacobson, 2006, hal. 3)

Music notation is the art of recording music in written form (Rush, 2016). This is because audio recording technology hasn't been found yet in the early era (Hollis B., & Gilloti, 2004). According to Hollis, Bankson, and Gilloti (2004), 15 components compose the notation system in a musical score. They are the staff, clefs, grand staff, measures, notes, ledger lines, note durations, dotted notes, rests, accidentals, ties and slurs, articulation, dynamics, repeats, and time signatures. Staff is where notes are placed. It consists of five lines and four spaces. Clef is a runny symbol found on the leftmost end of the staff. Musical notes are symbolized as a small oval circle located right in the middle of a line or space on the staff.



Figure 5. Examples of Musical Scores and Their Elements
 (https://www.music-scores.com/midi.php?sheetmusic=Beethoven_5th_easy)

CORRELATION BETWEEN MUSIC AND ANIMATION

According to Maestri (2002), to create a believable movement, we have to let the tempo of the music to encourage the animation. Engländer (2011) argues that we must know the rhythm of the music. The rhythm data obtained should be quite precise. If not, after a few seconds the animation will look out of sync - although initially, it looks appropriate. If the music score does not include information about the tempo, there are several ways to find the right beat. According to Maestri (2002, p. 112-113), simply count the number of beats for six seconds, then multiply the number of beats by 10 to get several beats in 60 seconds (one minute). After getting the number of beats per minute or BPM, we can determine how many frames are needed in one beat. For example, if a song has a tempo of 50 BPM, the calculation becomes:

$$25 \text{ fps} \times 60 \text{ second} = 1500 \text{ frame per minute (fpm)}$$

$$1500 \text{ fpm} : 50 \text{ BPM} = 30 \text{ frame per beat (fpb)}$$

BEAT every

YOUR FRAME RATE

	30	25	24
9	200	166,67	160
10	180	150	144
11	163,64	136,36	130,91
12	150	125	120
13	138,46	115,38	110,77
14	128,57	107,14	102,86
15	120	100	96
16	112,5	93,75	90
17	105,88	88,24	84,71
18	100	83,33	80
19	94,74	78,95	75,79
20	90	75	72
21	85,71	71,43	68,57
22	81,82	68,18	65,45
23	78,26	65,22	62,61
24	75	62,5	60
25	72	60	57,6
26	69,23	57,69	55,38
27	66,67	55,56	53,33
28	64,29	53,57	51,43
29	62,07	51,72	49,66
30	60	50	48

FRAMES

BPM

Figure 6. List of Beats per Frames for Various BPM on Different Frame Rates
 (<https://www.animatorisland.com/animating-to-music/?v=b718adec73e0>)

ANALYSIS

Two songs in 3D animated film "Bako" are using this Sasandu procedural animation, which is the Harvest song and the War song. When creating the script, the author refers to the scales and Sasandu playing techniques based on the reference video from the interview. The results of the observation will be combined with other procedural animation scripts.

1.) Script Reference

When designing procedural animation algorithms for the Sasandu play movement, the author refers to the piano animation script based on the midi file created by Lagnaheet Pradhan (2012). The script uses the Python programming language in Maya 3D software. The script works by importing the midi parser module, so we have to enter the midiparser.py file into the Python folder in Maya in Program files so that it can be read automatically when the script is run.



Figure 7. MIDI-Based Procedural Animation in Maya by Lagnaheet Pradhan
 (https://www.youtube.com/watch?v=9Cpn2_n3qoQ)

Based on this script, the authors conclude that Python can read song data in Midi by parsing data with the text output. Therefore, the author was inspired to use the same concepts and techniques: creating a python script to lock the keyframe on the finger controller based on music score data. However, the stage of parsing the reference script is done manually by the author. The author will read the musical notes on the scores and convert the data notations into frame units with the final results of the data structure that can be read by the script.

2.) Sasandu

Based on the interview with Sasandu and Sasando players - Ganzer Lana - Sasando is a musical instrument originating from Rote Island, East Nusa Tenggara. The name "Sasando" itself was born from the Kupang dialect which likes to abbreviate words and replace the letters "u" to "o." Therefore, the Indonesian people are more familiar with Sasandu with the pronunciation of O, which is to become "Sasando." According to Lana, there are two types of Sasando known in East Nusa Tenggara, namely Sasando Gong and Sasando Biola. Sasando Gong is a more traditional type of Sasando. Usually, Sasando Gong is referred to as Sasandu with the pronunciation of the Rote people, while Sasando Biola –which is more modern- is called using the Kupang pronunciation, Sasando. The difference between Sasandu and Sasando is that Sasandu has fewer strings (around 7-12 strings) with pentatonic scales. Also, the part of the lontar leaf hood on Sasandu cannot be folded because it is made of one intact whole palm leaf.



Figure 8. Twelve-Stringed Sasandu

3.) How to Play Sasandu

Based on interviews conducted with Ganzer Lana, the way to play Sasandu is a little different from how to play other melodic instruments. If we compare it with piano playing techniques, Sasandu techniques apply the opposite. When playing the Sasandu, the

the right hand plays the rhythm while the left hand plays the melody. Therefore, the reach of the left hand is more extensive than the right hand because it is responsible for playing the main melody.

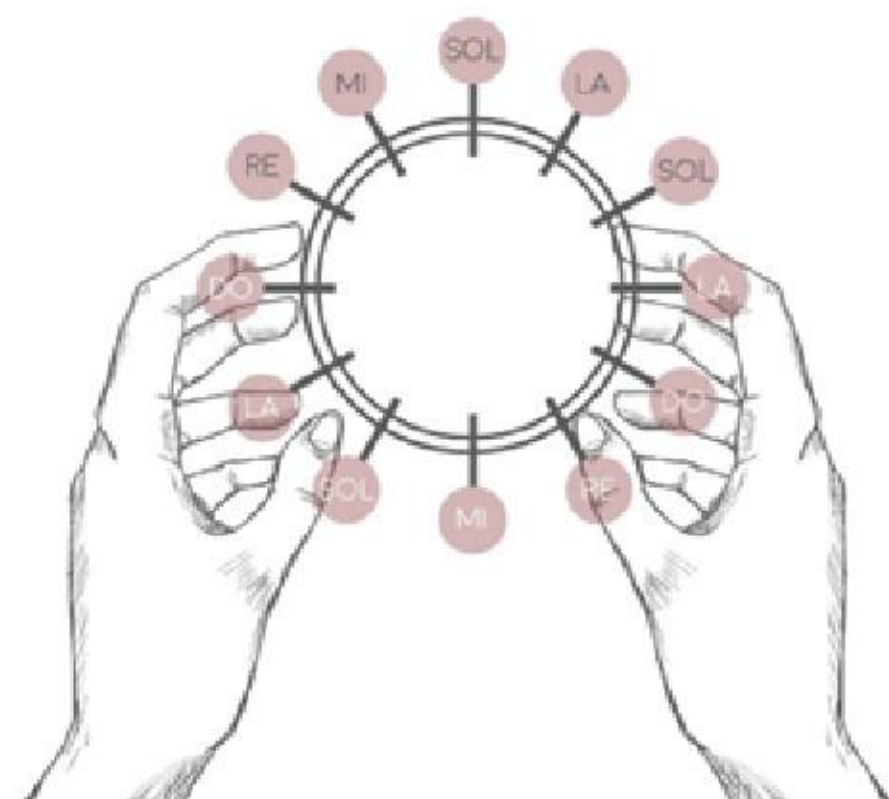


Figure 9. How to Hold a Twelve-Stringed Sasandu

4.) Sasandu Scales

The Sasandu instrument used in the Bako film was inspired by Ganzer Lana's Sasandu Gong which consisted of 12 strings and had a minor pentatonic tone. Minor pentatonic tones are musical scales consisting of 5 notes, namely (la-do-re-mi-sol). In the karawitan musical instrument system (like the Javanese gamelan), the tone ladder is referred to as the pentatonic slendro scales. The Sasandu as the reference for the author has the following sequence of tones: la (A2) - sol (G3) - la (A3) - do (C4) - re (D4) - mi (E4) - sol (G4) - la (A4) - do (C5) - re (D5) - mi (E5) - sol (G5). The first tone (A2) functions as bass. The pattern above is calculated from the pitch of the front part of the right arm in a clockwise direction so that the string on the front-middle part has mi (E4) pitch.

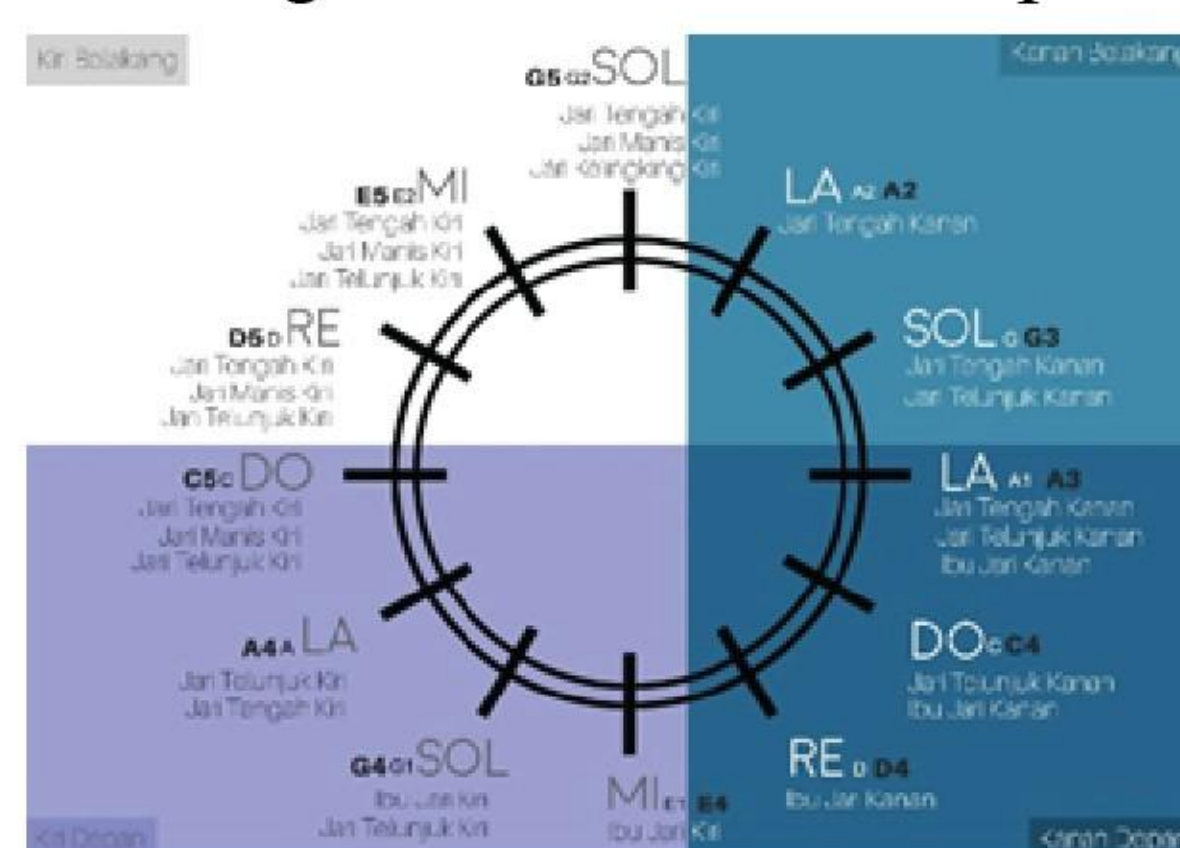


Figure 10. Musical Scale of 12 Stringed Sasandu

5.) Rig Test Experiment

The author makes a temporary rig to test procedural animation logic. This experimental rig consists of a hand model, hand joints, and the controllers. In addition to hand rigs, the author also made a simple Sasandu model that has 12 strings. This temporary rig is made from the author's Narrative Animation Production rig. The author observes the movements of strumming on each Sasandu string. This observation aims to find out the timing when making the string plucking animations. Next, the author starts designing procedural animation scripts. When composing the script, the author conducted several

experiments to create a button script. This experiment aims to improve the script so that the writing is brief and effective. The final result of the experiment is using the Python command list and function. The use of buttons is only to simplify the process of checking the animation movements. For the final script, the author will not use the button but calling the animated pas-sages using the music score data code.



Figure 11. Rig Test Using Kyla Character Model

```
#WRIST, IDLE
#frame 0
rotDet(wrist, [{"x": 10.393, "y": -0.115, "z": -1.535}])
rotDet(bottom, [{"x": -6.787, "y": -24.652, "z": -5.3}])
rotDet(middle, [{"x": -4.351, "y": 20.341, "z": 9.89}])
rotDet(idle_thumbsUp, [{"x": -8.05, "y": -5.918, "z": 19.668}])
rotDet(idle_thumbsDown, [{"x": -14.889, "y": 28.911, "z": -12.627}])
rotDet(idle_bottomInf4, [{"x": 6.818, "y": -2.556, "z": 10.354}])

rotDet(idle_ideBottom, [{"x": -39.841, "y": -11.462, "z": -23.656}])
rotDet(idle_ideMidUp, [{"x": 30.277, "y": -21.687, "z": 11.634}])
rotDet(idle_ideUpIn, [{"x": -21.047, "y": 16.618, "z": -18.347}])
rotDet(idle_ringBottom, [{"x": -3.364, "y": -37.23, "z": 9.736}])
rotDet(idle_ringMidUp, [{"x": -21.381, "y": 8.946, "z": 2.94}])
rotDet(idle_ringUpIn, [{"x": 26.296, "y": 62.997, "z": 17.637}])

rotDet(idle_pinkBottom, [{"x": -8.372, "y": -37.136, "z": -1.099}])
rotDet(idle_pinkMidUp, [{"x": -8.146, "y": 7.852, "z": -6.192}])
rotDet(idle_pinkUpIn, [{"x": 10.281, "y": 33.33, "z": 2.954}])
cmds.setKeyframe(wrist, bottom, middle,
  idle_thumbsUp, idle_thumbsDown, idle_bottomInf4, idle_ideBottom,
  idle_ideMidUp, idle_ideUpIn, idle_ringBottom, idle_ringMidUp,
  idle_ringUpIn, idle_pinkBottom, idle_pinkMidUp, idle_pinkUpIn)

currentTime = cmds.currentTime(q=1)
nextTime = currentTime + 1
cmds.currentTime(nextTime)
```

Figure 12. Button Script Using Maya Python

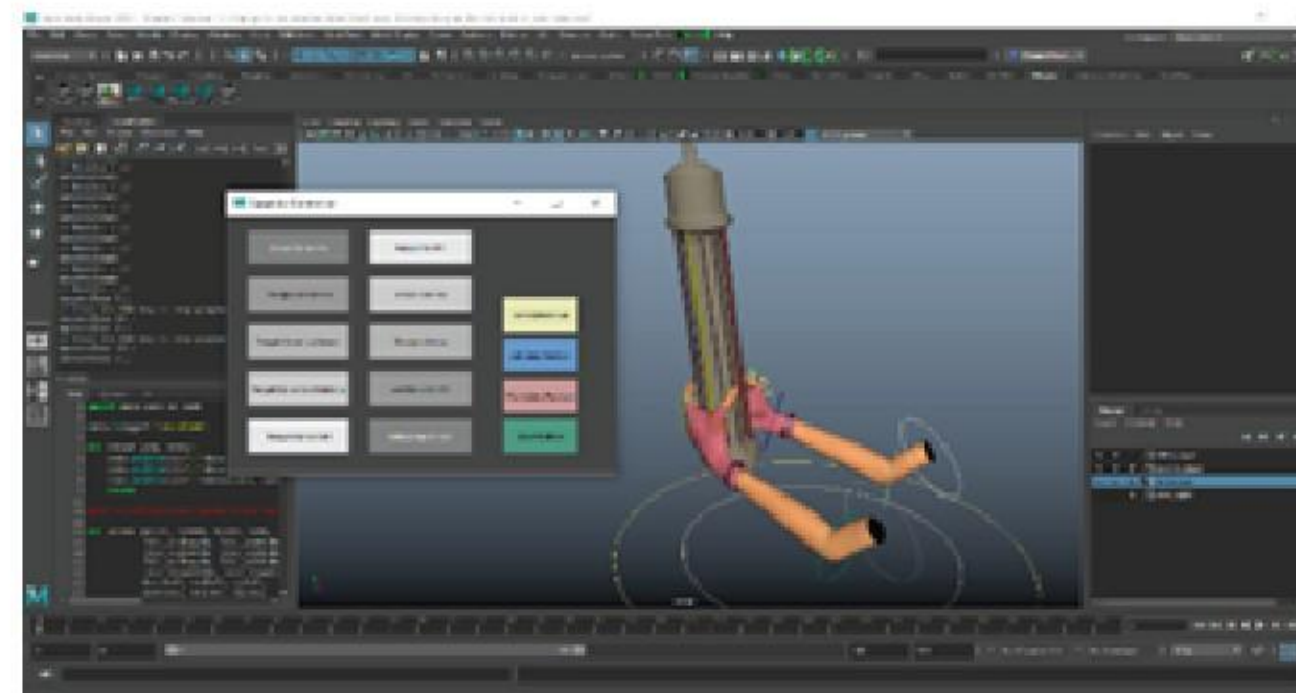


Figure 13. Button Layout Script of Sasandu Notes

To code the music score data, the writer must analyze the songs. The author analyzes which tones are played on the left and right hand, as well as the tempo of the song. Next, the author converts the results of the score analysis into a data structure. The data needed are the tones, fingers, and how many beats are in every certain number of frames. In addition, the author must equalize the tempo units of music with the frame rate of animation. This is because music uses units of a beat per minute, while animation uses units of frames per second. Furthermore, the data on the score code will be read by procedural animation logic as an instruction to determine which animation rotation data should be played in a particular frame. The trick is to use the Py-thon conditional statements command, namely...if else.

APPLICATION

After observing and conducting experiments, the resulting procedural information algorithm is produced as follows:

1.) Application of Final Score Codes

In Sasandu song scores, the top row (G key or treble clef) is played with the left hand, while the bottom row (F key or bass clef) with the right hand. After analyzing the harvest song, the au-thor found that both in harvest songs and war songs, the left hand played a harmonic tone and the right hand only played a melody.

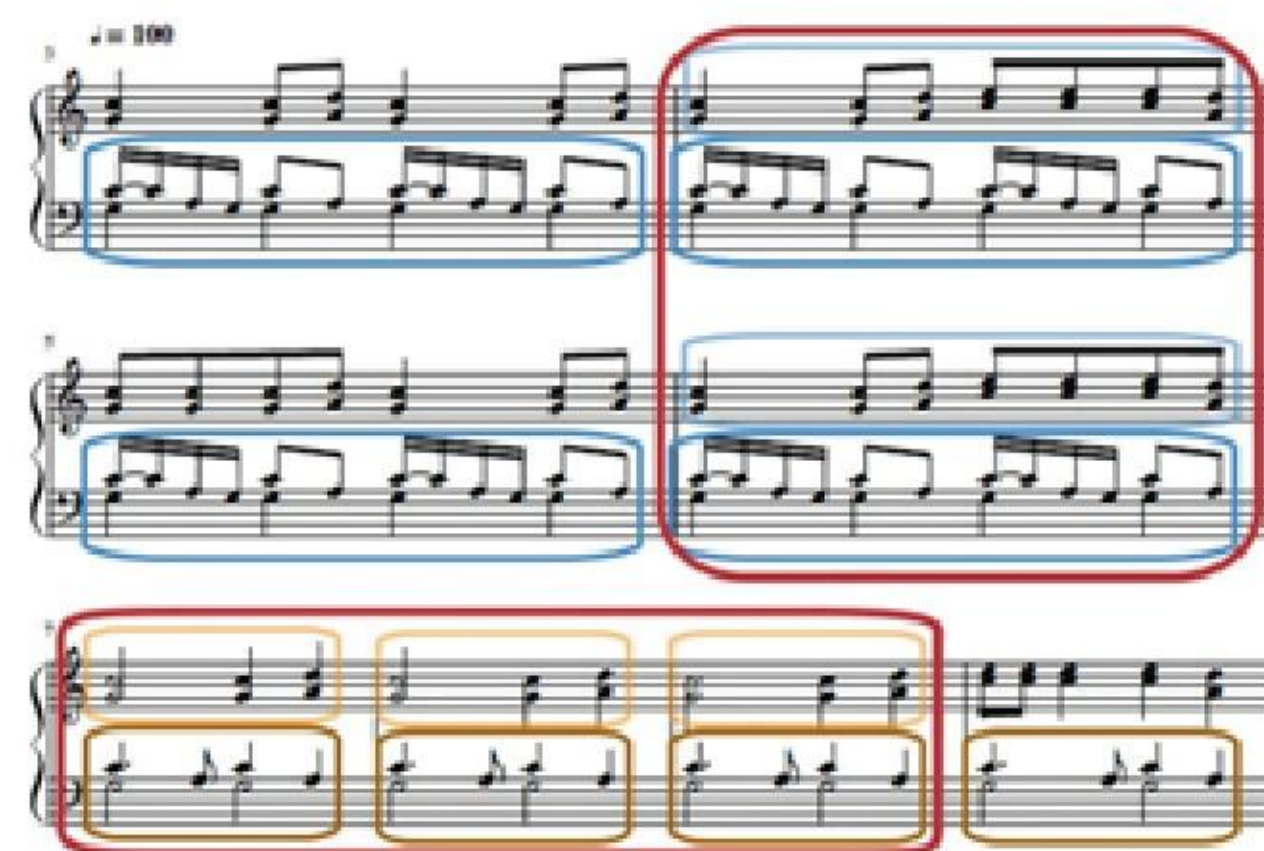


Figure 14. Repetition on War Song's Musical Notes

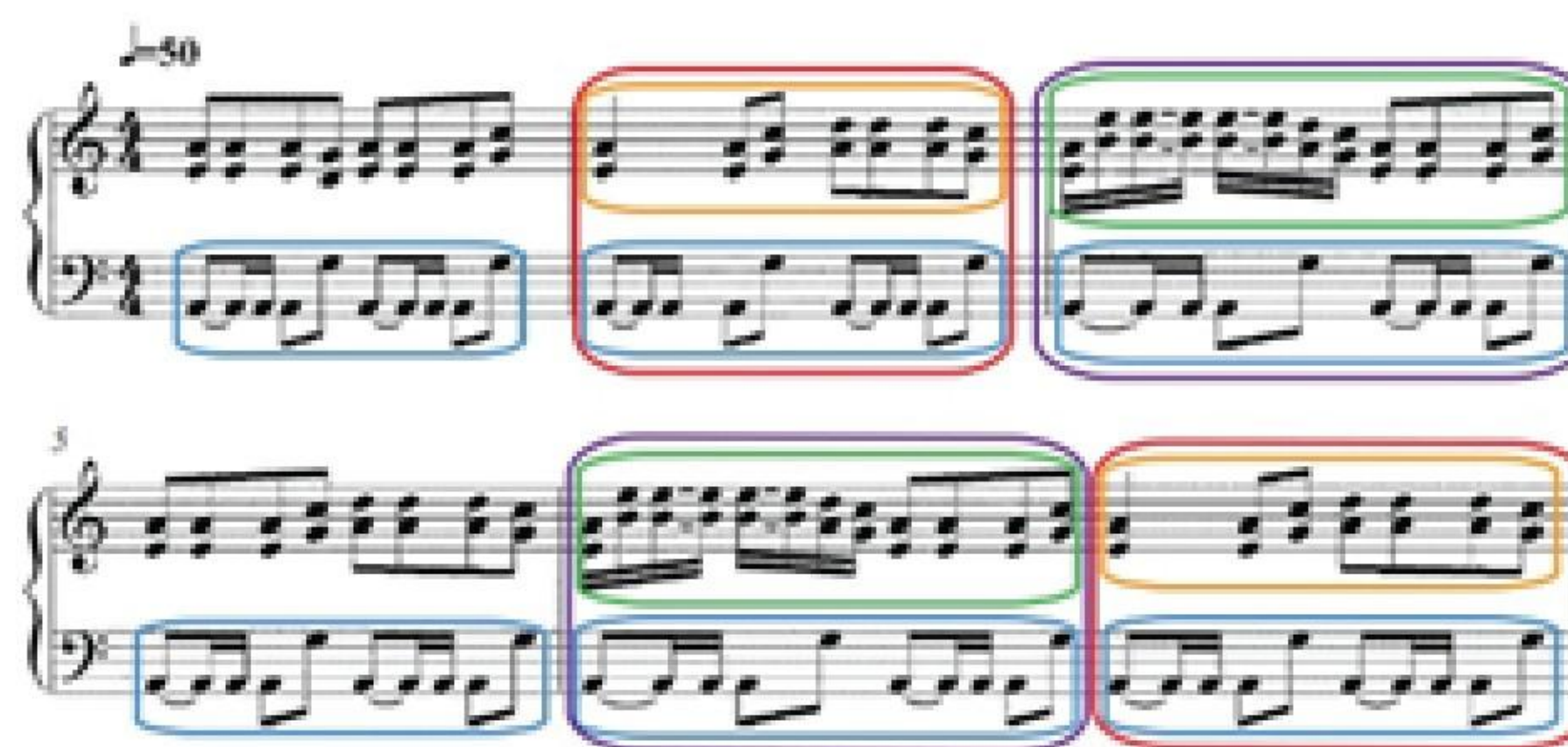


Figure 15. Repetition on War Song's Musical Notes

From the results of musical score data analysis and observations of the Sasandu videos, the au-thors concluded that most of the tones played were in the form of harmony. Therefore, the au-thor decided to animate the movements of two fingers at once in one Maya file. Moreover, there are many repetitions of song phrases, both on harvest songs and war songs. The author decided to marks the repetition of tones that occur with codes A, B, C, D, etc.

Table 1. Naming Format Table of Harvest Song's Finger Strike Animation

Code	File Name	Finger	Hand	Note
A	AHL	TMB IDX	Left	G4
B	BHL			C5
C	CHL			A4
A	AHR	TMB MID	Right	D5
B	BHR	IDX		C5
C	CHR	MID		E5

Table 2. Naming Format Table of War Song's Finger Strike Animation

Code	File Name	Finger	Hand	Note
A	AWL	TMB IDX	Left	E4
B	BWL	TMB MID		A4
C	CWL	TMB MID		G4
D	DWL	TMB IDX		C5
E	EWL	TMB MID		A4
A	AWR	MID	Right	D5
B	BWR	IDX		D4

Therefore, the naming format for the data structure of the party codes begins with the number of frames, the information on the tone played, which finger to pick it, and finally the right or left hand. The code is separated using a colon (:). A colon is used because the readability is better when compared to using other signs such as dots or commas. The script will recognize the data in the code after parsing the data using a colon (:) and recognizing it as data in the list, so that the data frame will be recognized as data [0], tone code data will be recognized as data [1], data the song will be recognized as data [2], and hand data will be recognized as data [3].

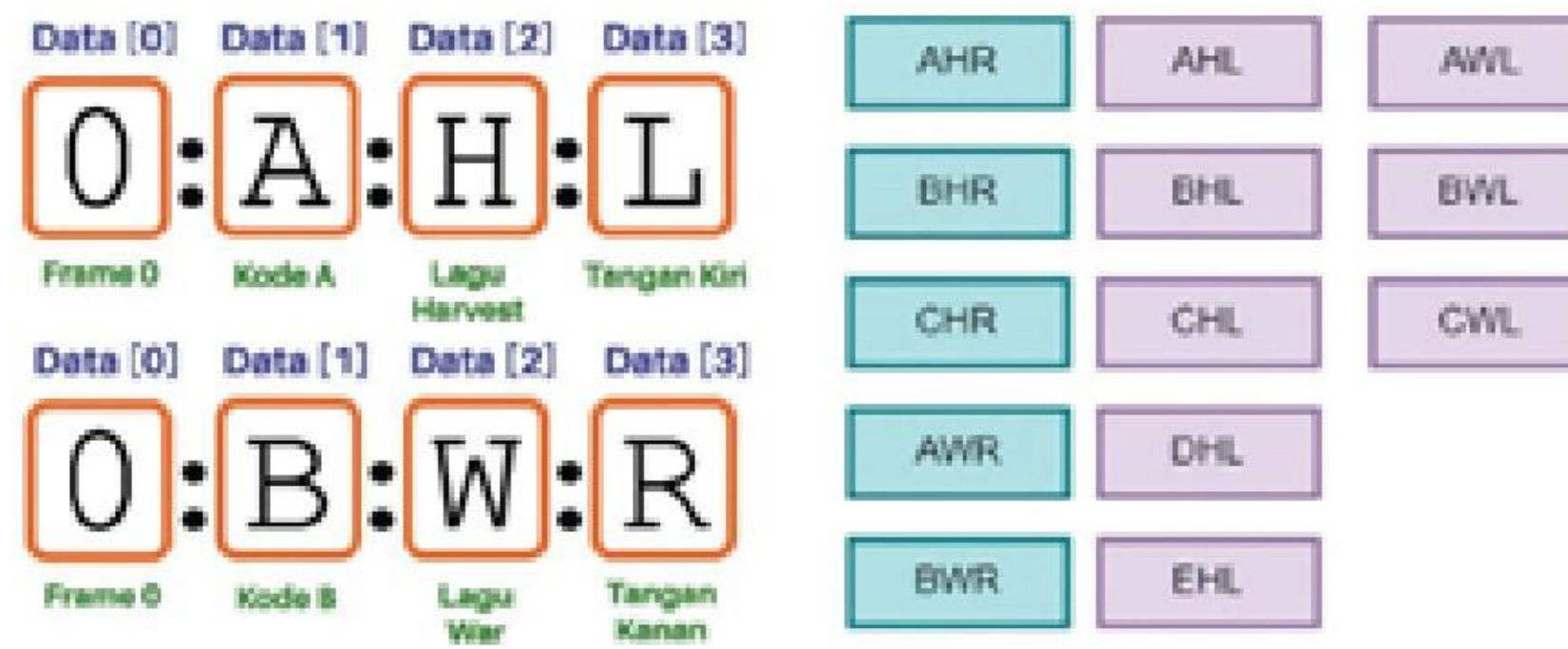


Figure 16. List of Def Variables for Harvest and War Song

Based on the def function variable data, which consists of 13 data for harvest songs and war songs (left and right hand), the resulting if ...else logic with workflow in figure 14 is generated.

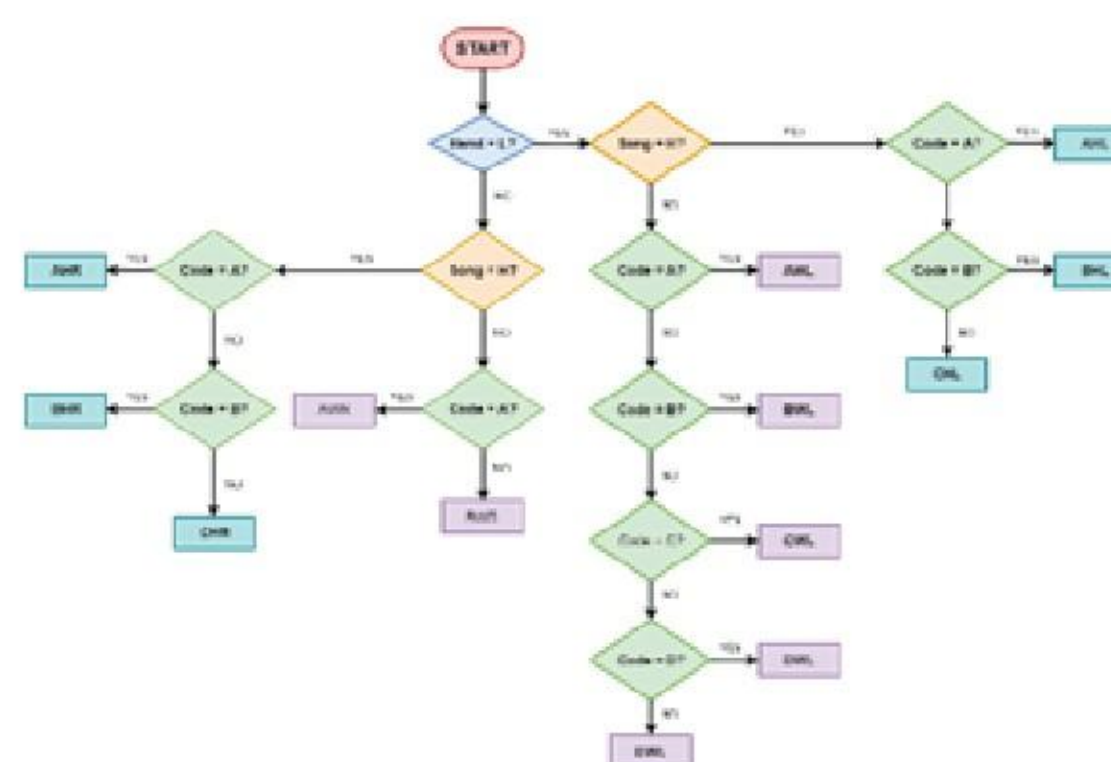


Figure 17. Sasandu Procedural Animation Script Logic



Figure 18. Logic Application of Sasandu Procedural Animation Script

2.) Harvest Song Animation Results

When the script is executed, the author marks that the procedural animation for harvest songs (480 frames) took around five minutes to process. The left thumb procedural animation for the harvest song is too fast and extreme. This is because the three-movement codes used in the left hand (codes A, B, and C) are all using the thumb and index finger. The animations seemed overlapping with each other because the keyframes are spaced only one frame away with a massive difference in rotation. Meanwhile, the distorted movement of the index finger happens on the right hand, at the mid and up parts. Even so, the overall animation is considerably im-proved by the rotation of the wrist that has been in sync with the song, so it doesn't look as dis-organized as the movement of the thumb.

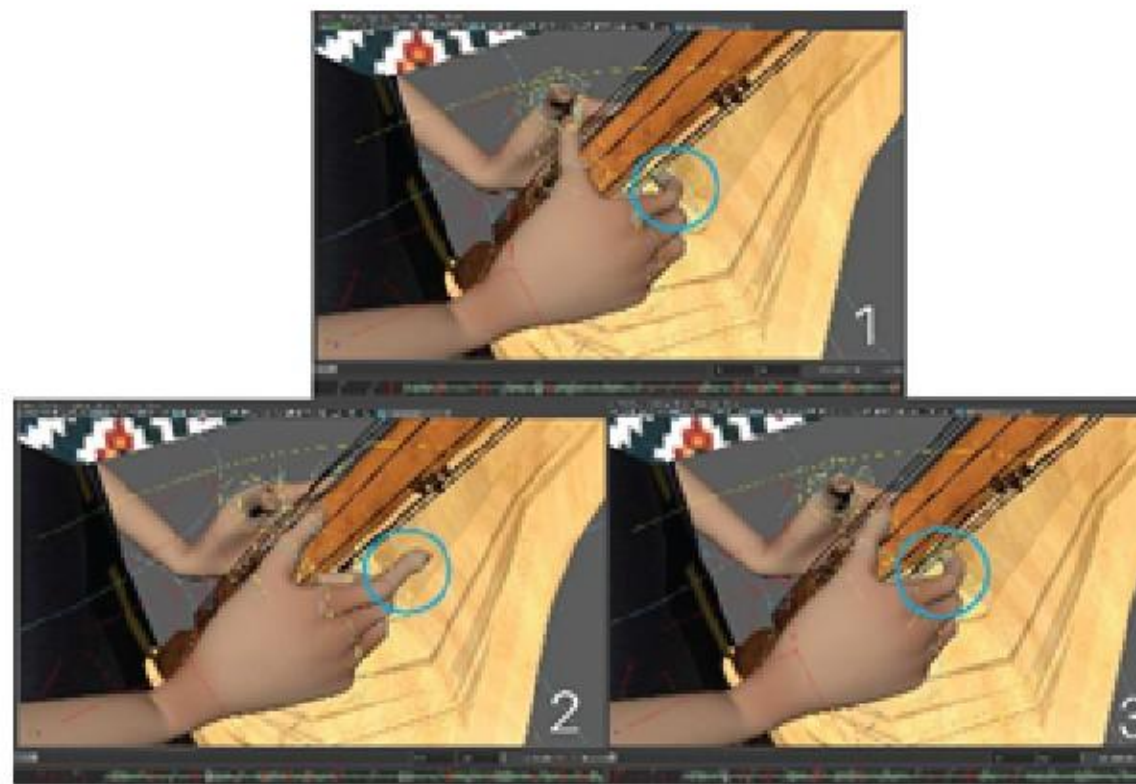


Figure 19. Harvest Song's Right Index Finger Problem

3.) War Song Animation Result

The process of animating the Sasandu performance for war song (720 frames) takes around seven minutes. Overall, the procedural animation results for the war song is better and more accurate compared to the results of the harvest song. This is because the war song's tempo is slower (50 bpm) and the right hand only plays one repeated phrase over the entire duration. In the harvest song, the right hand has two repeated phrases. The main problem of procedural animations for the war song is when doing BWL code animation. Based on the reference from the video, when playing the BWL animation, the index finger, ring finger, and little finger also moves slightly. However, when applied in the song, the silhouette generated from the animation source does not look good because the distance between the BWL code and the next code is very short.

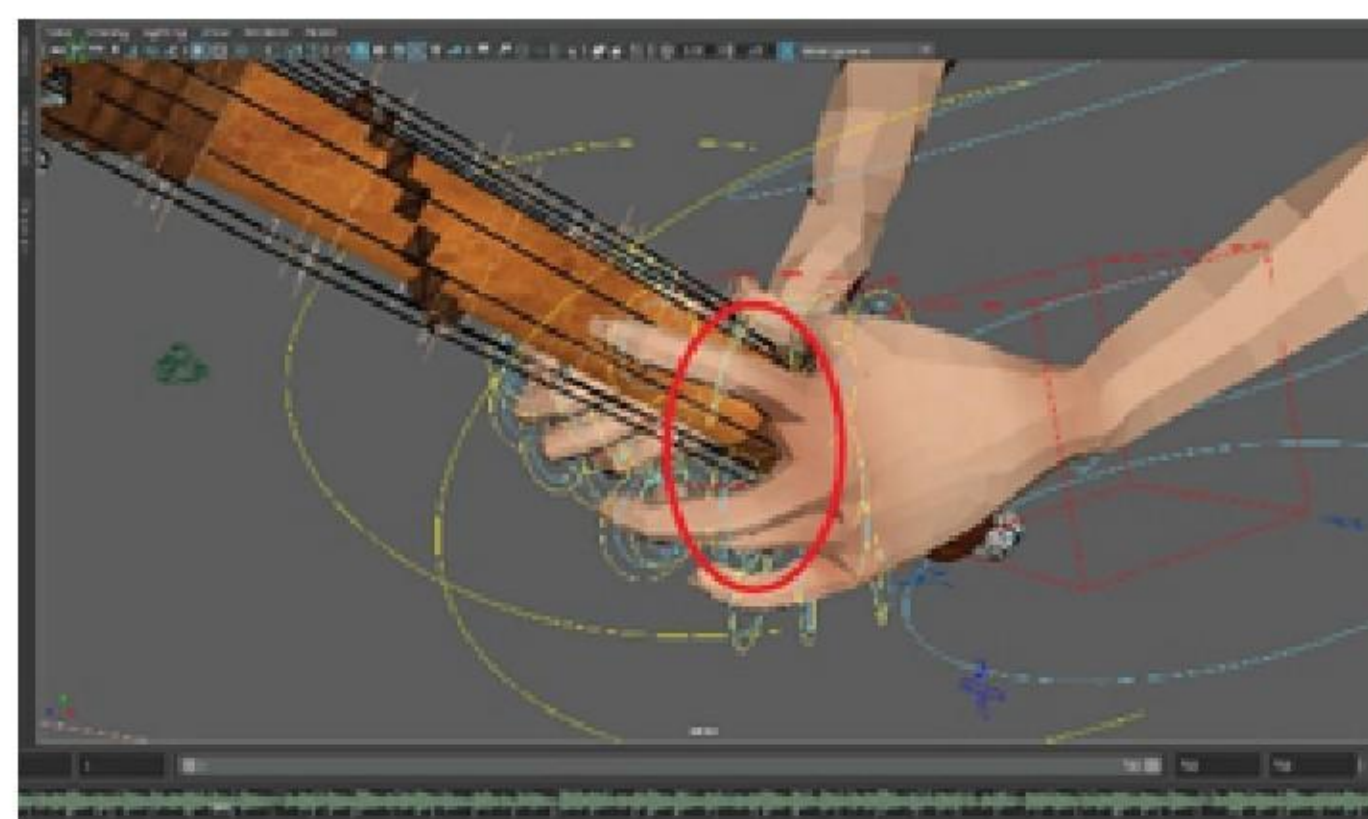


Figure 20. BWL Finger Silhouette

CONCLUSION

"Bako", a 3D animated film, is using procedural techniques to animate the movement of play-ing Sasandu songs. There are two songs, a harvest song on shot 13 with 18 seconds duration and a war song on shot 66 with 28 seconds duration. The author makes a script that has two main functions. The first function is to import rotation data scripts to move the finger controller. The second function is to read which controller data must be moved on which particular frame. This is done using logic data parsing.

Procedural animation script for the Sasandu play performance works by reading parsed data according to the frame, just like a tablature. The data contains various pieces of information such as the frame, code, song, and hand data. It also contains information about the tone and which fingers are going to move. Thus, the script can determine what tone is played on which frame, according to the music score. The results of procedural animations are not 100% accurate, so they need to be cleaned up manually by the animator.

However, the use of procedural animations is far more effective because the elements of timing, tempo, and other confusing things are arranged by the instruction and logic of the script. Although this technique still requires further animation clean up, the comparison of the process will still be much faster by using the script, because animators only need to fix the existing animation, instead of creating it from scratch. The procedurally generated animation is 80% accurate to the song, so animators only need to fix 20% of the total animation.

BIBLIOGRAPHY

Allen. E, & Murdock, K. L. (2008). *Body Language Advanced 3D Character Rigging*. Indiana Polis, Indiana: Wiley Publishing.

Autodesk Knowledge Network. (2017a). *Autodesk Maya 2017 Help: Maya API Introduction*. Didapat dari <https://knowledge.autodesk.com/support/maya/learnexplore/caas/CloudHelp/cloudhelp/2017/ENU/Maya-SDK/files/API-Introduction-htm.html>

Autodesk Knowledge Network. (2017b). *Autodesk Maya 2017 Help: Python in Maya*. Didapat dari <https://help.autodesk.com/view/MAYAUL/2017/ENU/?guid=GUID-C0F27A50-3DD6-454C-A4D1-9E3C44B3C990>

Beane, A. (2012). *3D Animation Essentials*. Indiana Polis, Indiana: John Wiley & Sons.

Bibliowicz, J. (2005). *An Automated Rigging System For Facial Animation*. (Master's Thesis, The Graduate School of Cornell University, Itacha, New York, USA). Didapat dari <https://www.autodeskresearch.com/pdf/mastersSelect.pdf>

- Cormen, T.H, Leiserson, C.E., Rivest, L. D. & Stein, C. (2009). *Introduction to Algorithms* (3rd ed.). Didapat dari <https://labs.xjtudlc.com/labs/wldmt/reading%20list/books/\Agrithms%20and%20optimization/Introduction%20to%20Algorithms.pdf>
- Engländer, F. (2011). *Animation Secret: Animating to Music*. Didapat dari <https://www.animatorisland.com/animating-to-music/?v=b718adec73e0>
- Hollis, B., Bankson K., & Gilloti C. (2004) *Basic Musical Notation*. Didapat dari <https://method-behind-the-music.com/theory/notation/>
- Jacobson, D. (2006). *The Elements of Music*. Didapat dari <https://bit.ly/2tm8reG>
- Maestri, G. (2002). *Digital Character Animation 2, Volume II: Advanced Techniques*. United States of America: New Riders Publishing
- Merriam-Webster. (2018). Didapat dari <https://www.merriam-webster.com/dictionary/music>
- Noviyanto (Ed.). (2001). *Di Indonesia, Cuma Ada 8 Orang Mahir Sasandu Rote*. Didapat dari <https://www.lensaindonesia.com/2011/09/07/di-indonesia-cuma-ada-8-orang-mahir-Sasandu-rote.html>
- Rush, T. (2016). *Music Theory for Musicians and Normal People*. Didapat dari <http://tobyrrush.com/theorypages/index.html>
- Stack Overflow (n.d.). *About Scripting*. Didapat dari <https://stackoverflow.com/tags/scripting/info>
- Thomas, F., & Johnston, O. (1981). *The Illusions of Life Disney Animation*. New York. NY: Hyperion.
- Tutorials Point. (2016) *Data Structures and Algorithms*. Didapat dari https://www.tutorialspoint.com/data_structures_algorithms/data_structures_algorithms_tutorial.pdf
- Wells, P. (1998). *Understanding Animation*. New York: Routledge.
- Wong, K., Thung, D. (2011). *Procedural Animation*. School of Creative Media, City University of Hong Kong. Didapat dari <http://sweb.cityu.edu.hk/ktdthung/sm4123/lec01.pdf>