Creating Order and Progress

Angelo Fraietta
University of New South Wales
Cnr. Oxford Street & Greens Road
Paddington NSW 2021, Australia
a.fraietta@unsw.edu.au

ABSTRACT

This paper details the mapping strategy of the work *Order and Progress: a sonic segue across A Auriverde*, a composition based upon the skyscape represented on the Flag of Brazil. This work uses the Stellarium planetarium software as a performance interface, blending the political symbology, scientific data and musical mapping of each star represented on the flag as a multimedia performance. The work is interfaced through the *Stellar Command* module, a Java based program that converts the visible field of view from the Stellarium planetarium interface to astronomical data through the VizieR database of astronomical catalogues, which is then mapped to musical parameters through the HappyBrackets Java based programming environment. I will discuss the strategies employed to create a work that was not only artistically novel, but also visually engaging and scientifically accurate.

Author Keywords

Indigenous Languages, Stellarium, Astronomy, Algorithmic Composition

CCS Concepts

•Applied computing → Astronomy; Sound and music computing; •Social and professional topics → *Race and ethnicity;*

1. INTRODUCTION

Perception of the cosmos has been an integral part of human civilisation from prehistoric time. Cosmology was included in the *Quadrivium* from antiquity alongside mathematics, geometry and music as a standard part of classical education up until the renaissance [26]. Moreover, stars have often been perceived as eternal or immutable entities and have often been used in flags and nationalistic or religious symbols [32, 23].

Many civilisations have created songs and dances based on astronomical data to mark seasons for planting or harvesting crops, when to hunt for a particular type of animal, times to trade, reproductive cycles, migration and religious or cultural practices [32, 9, 24]. Likewise, many composers in modern western civilization have composed works inspired by astronomical events [21].

NIME'19, June 3-6, 2019, Federal University of Rio Grande do Sul, Porto Alegre, Brazil.

Astronomy has become very popular [2] and the advancement of computing power has made the availability of planetarium software available on both desktop computers and mobile devices commonplace [3]. While planetarium software on a mobile phone enables a user to point their mobile phone to a celestial object to see what star or planet they are seeing, the ability to simulate a skyscape based on a date, time, and geographic location not only assists planning of viewing and astro-photography sessions, it also facilitates researchers in archaeoastronomy because they are able to digitally render archaeological landscapes complete with accurate views of the sky for that period [42, 43] coupled with accurate scientific information that can be displayed on screen [5]. Moreover, the availability of astronomical data from online catalogues, coupled with algorithmic mapping strategies, allows composers to abstract astronomical data from stars; such as colour, celestial position, magnitude and distance; to create musical works that correlate sound and outer-space [10, 39].

This paper presents a detailed analysis of the work *Order and Progress: a sonic segue across A Auriverde* (hereafter OAP)[1], a multimedia composition for planetarium, digital signal processor and percussion ensemble. The work primarily focuses upon the Flag of Brazil, which portrays the skyscape that would have been over the capital at the proclamation of the Republic of Brazil [11, 23]. The work uses the Stellarium planetarium software as a performance interface, blending the political symbology, scientific data and musical mapping of each star represented on the flag as a multimedia performance. The work is primarily driven by the *Stellar Command* module [19], a Java library developed by the author and detailed in another paper in these conference proceedings [18]. Stellar Command converts the visible field of view from the Stellarium planetarium interface to astronomical data through the VizieR database of astronomical catalogues. This data is then mapped to musical parameters through the HappyBrackets Java based programming environment. I will discuss the strategies employed to create a work that was artistically novel, visually engaging, ethnologically sympathetic and intellectually edifying.

2. BACKGROUND TO RESEARCH

2.1 Astronomy and ethnoastronomy

Astronomy and ethnoastronomy are completely different disciplines [33]. Astronomy is one of physical sciences and involves the systematic study of celestial objects and phenomena that originate outside the Earth's atmosphere. Astronomic data from various missions are recorded in catalogues for use within the scientific community.

[1] A video showing the composition can be viewed at `https://youtu.be/NhXRdd-MNoo`.

Ethnoastronomy is a social science belonging to the discipline of ethnology and examines the way astronomy is practised in the context of a particular culture [33]. Ethnoastronomers have observed that the indigenous people of Brazil were particularly systematic in their observation of the sky. Capuchin Claude d'Abbeville noted the stargazing practices of the Tupinambá people by stating "There are only a few of them that don't know the majority of the celestial bodies and stars of their hemisphere and that don't call them by the proper names that were invented and imposed upon each of them by their ancestors" [24, p. 947].

The Stellarium planetarium software can display constellations from several different cultures and has labels translated to more than 40 languages, making Stellarium both culturally aware and inclusive [5], and facilitates displaying both astronomic and ethnoastronomic information on the screen. VizieR is an online database of high quality astronomical catalogues collected by the Centre de Données astronomiques de Strasbourg (CDS), one of whose main goals "is to promote the usage of the reliable astronomical catalogues to the astronomical community" [29, p. 25]. Astronomic data from VizieR was used as input to the sound generating algorithms in the composition

2.2 Flags containing stars

Flags are often symbols or totems that signify a shared identity [14]. Some national flags contain symbols that declare identity with a religion; including Muslim, Christian, Buddhist, Taoist and Jews; or idealistic philosphy or political affiliation such as communism. Muslim nations often contain a flag with a "crescent moon, often accompanied by a star" [23;, 40, p. 71]. Likewise many Christian nations "use crosses in their flags"[23, p. 71]. There are many national flags that have depictions of stars [41]. Some flags display stars without astronomical correlation and are used only as symbols, while others display an asterism or constellation that indicates the geographic location of the nation. The first use of stars on a national flag was that of the United States of America, and used stars to symbolise a "new constellation"[23, p. 78]. The flag, often known as the *Stars and Stripes*, contains fifty stars that represent the fifty states that make up the republic. Although the original flag had only thirteen stars, more were added as states were added to the republic, with the statehood of Hawaii bringing the number of stars to the current number of fifty in 1960. There is no correlation between any particular star on the flag with a specific state [23]–only the *number* of stars has iconic political or national significance. Other nations with the number of stars that represent their states or provinces include the Federated States of Micronesia, Venezuela and Syria.

Nations that use a constellation on their flags include Australia, New Zealand, Samoa and Papua New Guinea, which all have the Southern Cross prominent, announcing that their geographic location in the southern hemisphere is of national significance and identification [23].

Some flags have a combination of both astronomical and numeric symbology. For example, the Australian flag has the Southern Cross signifying its geographic location, coupled with the seven pointed Commonwealth star. Similarly, the Brazilian flag is a combination of both the political framework in that the number of stars on the flag correlate to the number states and territories that make up the Republic of Brazil. The Flag of Brazil, however, is unique in that displays twenty-seven stars from nine constellations as they would have appeared at a chronological point in time, with each star representing a different state [11, 22]. The creators of the republican flag intended to represent the stars in the sky of Rio de Janeiro at 8:30 a.m. on November 15, 1889, at which point the greater arm of the Southern Cross was vertical and coincident with the meridian of Rio de Janeiro [11].

Unlike the other flags, which display the Southern Cross viewed from the ground, the stars on the Brazilian flag are displayed as though viewed by a cosmic observer looking down on the Earth, and consequently, displayed as a mirror image [11, 23]. Figure 1 displays the sky viewed from Earth, showing Scorpius on left, Canis major on the right and the Southern Cross in the centre with the smallest star to the right of the long arm, whereas the Flag of Brazil in Figure 2 shows these constellations mirrored. Furthermore, the stars on the flag would not have been visible at the time because of the atmospheric daylight.

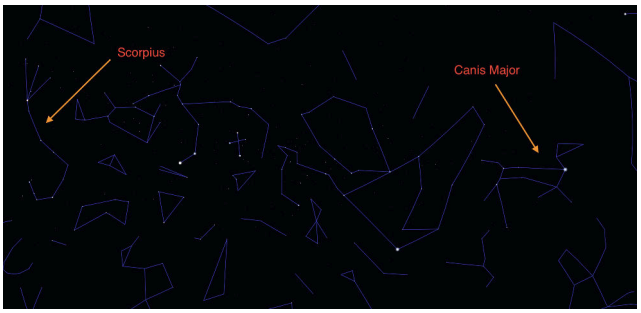

Figure 1: View of skyscape from Earth.

Figure 2: Flag of Brazil

3. RELATED WORK

Many composers have used the cosmos as inspiration or stimulus to their works, with many using scientific observations or data as input [21, 17]. For example, Stockhausen composed the works *Ylem* (1972) for nineteen musicians based on the theoretical material of the oscillating universe into the realm of music; and *Tierkreis* (in74-75), twelve melodies for the "zodiac of human types" [30, p. 98-99]. Ruff and Rogers's describe their work *The Harmony of the World* (1979) by stating: "Three and a half centuries after their conception, Kepler's data plotting the harmonic movement of the planets have been realized in sound with the help of modern astronomical knowledge and a computer-sound synthesizer" [31, p. 286]. The work is based on the planetary relationships within the solar system rather than stellar data.

The concept of composing an audio visual musical tour of the sky was inspired by the author's unrealised compositions, where sonically mapped astronomical data coupled with a laser pointer and binoculars provided a musical tour of the Southern Cross [17, p. 51], which is a major feature on the Australian flag [41]. When considering a method to demonstrate mapping astronomical data with music, the challenge was to compose a work that not only demonstrated the possibilities and capabilities of Stellar Command as a composition and performance interface, but to compose a work whose subject celebrated the conference theme and location.

4. METHODOLOGY

Stellarium was used in this composition to display the sky on the morning of November 1889 by hiding the atmospheric daylight that would have hidden the stars from a terrestrial viewer. The audience is escorted to each star, symbolic of travelling to that state in Brazil. Scientific information coupled with the name of the state the star represents on the flag is presented to the viewer. Each change in position triggers a new astronomical data acquisition, resulting in a musical change. The audio synthesis and musical control was realised using the Happy Brackets creative coding toolkit, which enabled complex digital audio synthesis using the Java programming language using the Beads realtime audio library [16, 6, 20].

4.1 Mapping Pitch and Time

Although Right Ascension (RA) and Declination (Dec.) could be mapped to pitch and time [17], this does not necessarily correlate to the position of the stars from left to right. For example, Figure 3 shows the Dec. values decrease as stars are displayed from left to right and the RA decreases from bottom to top. Figure 4, however, shows RA decreases as stars are displayed left to right and declination increases from bottom to top. Consequently, stars were mapped using the azimuth as time and altitude for pitch, similar in a sense to how one might view notes on the stave. Altitude and azimuth, commonly referred to as AltAz, must be calculated using the geographical location of the observer and the absolute time at GMT [12]. The display was treated

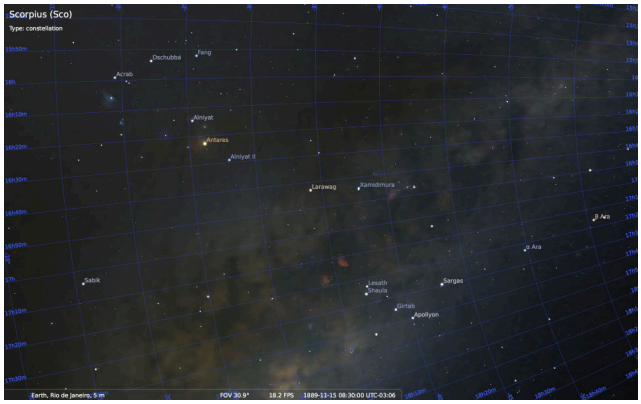

Figure 3: Scorpius with equatorial grid.

as a loop, in the same way someone would treat a repeat section. For example, in Figure 3, *Sabik* would be played at a lower pitch first, followed by *Acrab* with a higher pitch, then *Dschubba* higher again, and so forth, until *Sargas*, at which time the section would start again to *Sabik*. The pitches and rhythmic position of the resultant calculations

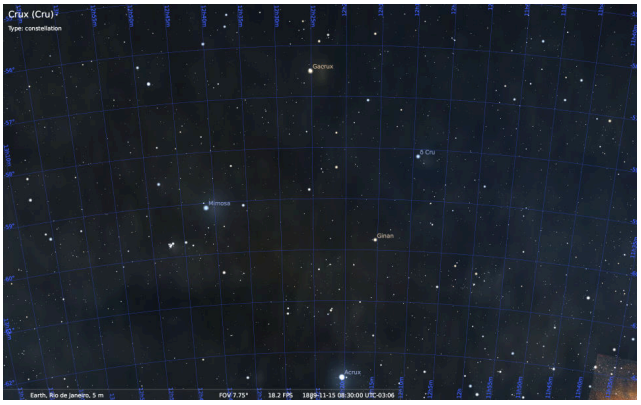

Figure 4: Crux with equatorial grid.

were quantised in accordance with the required musical aesthetic.

All astronomical data from VizieR was saved to file using the centre stellar object name as a key to map sample names, tables and scripts. For example, the data for the star *Graffias* was saved to a file called *Graffias.txt*, the sample containing the indigenous language dialog called *Graffias.wav*, and the call to focus Stellarium onto the object Graffias.

5. COMPOSITIONAL STRUCTURE

The work is constructed in three distinct movements. The first movement, *Amerindia*, primarily uses granular synthesis. Audio samples were obtained from ethnomusicological recordings of the indigenous peoples of Brazil, coupled with spoken voices in indigenous languages sounded when each star is played. This not only symbolises the important contribution and cultural diversity the indigenous peoples provide Brazil, but also highlights the plight of vanishing indigenous languages [35]. The stars' names, Brazilian state, and language usage are listed in the order they appear in the piece in Table 1.

The second movement, *Cães Celestes*, translated *Celestial Dogs*, provides a harmonic transition from chaos to order by progressive quantisation of astronomic stellar data sonified through sine wave oscillators. The title was chosen because *Canis Minor* and *Canis Major* are the main constellations featured in the movement.

The third movement, *Celestial Samba*, is a suite of Brazilian dances performed by a percussion ensemble. In *Celestial Samba*, the ensemble leads the entire cosmos in joyful dance in celebration of Brazil. This movement is a showcase of artistic possibilities available in the Stellarium software through a planetarium cadenza improvised for performance with the Samba Ensemble.

5.1 Amerindia

The first movement starts with an observation of a time-lapsed sun rise on the dawn of November 15, 1889 with the sound of the Brazilian rainforest in the background. The Tukano sky lore was used to highlight indigenous Brazillian astronomy[3], with whispering talk in Xavánte[37][4] heard as

[3]The Tukano people, who are indigenous people of the northwestern Amazon region of Brazil, correlate their constellations to mark the period of river level in the area they live [7].

[4]The Xaványte are indigenous peoples located in cerrado regions of the Brazilian Central Plateau, east of Mato Grosso[34].

Table 1: Star names, states and languages used.

Star	State	Language
Graffias	Maranhão	Awá Guajá
Antares	Piauí	Guajajara
Larawag	Ceará	Fulnio
Xamidimura	Pernambuco	Fulnio
Sargas	Alagoas	Kayapo[† 2]
HIP87073	Sergipe	Tocantins[†]
HIP86670	Paraíba	Kadiweu[†]
Shaula	Rio Grande do Norte	Fulnio
Atria	Rio Grande do Sul	Kaingang
HIP77952	Santa Catarina	Kaingang
HIP74946	Paraná	Guarani, Mbya
Acrux	São Paulo	Kaingang
Mimosa	Rio de Janeiro	Maxakali
Gacrux	Bahia	Asurini Do Tocantins
HIP59747	Minas Gerais	Maxakali
Ginan	Espírito Santo	Guarani, Mbya
Procyon	Amazonas	
Mirzam	Amapá	
Sirius	Mato Grosso	
Muliphein	Rondônia	
Wezen	Roraima	
Adhara	Tocantins	
Canopus	Goiás	
Alphard	Mato Grosso do Sul	
HIP64962	Acre	
HIP104382	Distrito Federal	
Spica	Pará	

the sun rises, representing the voice of the indigenous people. At precisely 8:30, the time of the proclamation of the republic, the ground becomes invisible and the atmosphere is removed, allowing the stars to display even though the sun is in view. Indigenous *travel music*[36] is processed through a granular synthesiser and pitch shifted up to simulate travelling into the stars as they become lost. Astronomic tables are loaded each time the display moves to a different star, which maps indigenous samples of music from Iwalapetí[37][5], Kayabí[6] Animal and Bird Imitations[37] and Fiesta dance music from the Upper Amazon[36].

The magnitude of each star is sonically mapped to the duration and gain of the sample, while the azimuth and pitch are mapped to rhythmic position, panning and pitch. Each time a star was selected, a virtual granular synthesis instrument bank of sixteen stars mapped a unique star with an instrument. If a new table was loaded but the instrument had already been created from a different table, the existing instrument was used. The stars had to meet a magnitude threshold, and if sixteen met the criteria, the entire bank was filled creating a $\frac{16}{16}$ cycle. In the constellation of *Scorpius*, the bank was always full. If the table did not have sixteen stars that met the threshold, a different cyclical pattern was created. Some stars in the *Crux* constellation had eleven or five stars, producing $\frac{11}{16}$ and $\frac{5}{16}$ patterns.

The movement makes extensive use of different indigenous languages of Brazil. Although recorded languages have been used for research into the study of rhythmic analysis of phonetics [13], these were used to highlight the contribution indigenous peoples of Brazil have made, and continue to make, in the nation. The United Nations Educational, Scientific and Cultural Organization (UNESCO) have stated: "Languages play a crucial role in the daily lives of people, not only as a tool for communication, education, social integration and development, but also as a repository for each person's unique identity, cultural history, traditions and memory. But despite their immense value, languages around the world continue to disappear at an alarming rate. With this in mind, the UNESCO declared 2019 The Year of Indigenous Languages (IY2019) in order to raise awareness of them, not only to benefit the people who speak these languages, but also for others to appreciate the important contribution they make to our world's rich cultural diversity" [35]. The movement concludes by returning the viewer back to earth, however, to a metropolis rather than the rainforest.

[5]The Iwalapetí peoples are from Northern Mato Grosso, Brazil [28].

[6]The Kayabí are indigenous peoples of Mato Grasso [8]

5.2 Cães Celestes

The title of the second movement, translated *Celestial Dogs*, is so titled because the majority of the work is in the constellations of Canis Minor and Canis Major. The movement is sonified by sixty-four continuously sounding sine wave oscillators that vary in frequency and amplitude throughout the movement, with a ceiling and floor of 34.64 Hz (C#0) and 2637 Hz (E6) with all pitches scaled between these two values. The work commences with equally distributed random frequencies in daylight facing the sun, symbolising background cosmic radiation and atmospheric light hiding the starlight. When the atmospheric light is removed, the oscillators commence playing in sequence. When the first star is selected, the first table is loaded with sixty-four of the brightest stars within the displayed field of view. Each star altitude is mapped to a frequency by scaling the maximum and minimum altitude of the all the stars in the selected table, and quantising the frequency so it fits the nearest note that matches its harmonic set for the central celestial object shown in Figure 5. The oscillators are played in four part harmony, by sounding four oscillators at a time. A note is played by increasing the oscillator's amplitude envelope for 50 ms. Every time the display changes focus, a new table is loaded and new pitches are calculated. The harmonic progression of the movement is shown in Figure 5.

5.3 Celestial Samba

In the first two movements, the planetarium led and dictated what sounds would be made and how long a section of music would play. In the last movement, a celebration of Brazil would have been incomplete without a traditional music band to lead the final celebration.

Brazil is well known for samba, described as the "national rhythm" [4, p. 58] and "commonly recognized as the most 'pure' representative of Brazilian nationalist expression" [25, p. 1]. By virtue of Brazil's diversity of cultures from their different regions, "other musics can also be argued to represent 'the nation' to a wide audience of Brazilians" [25, p. 1]. This cultural wealth is based on its indigenous ethnic groups and of immigrants from Europe, Africa, and Asia in the last five centuries. Each region of the country has its own characteristics and these regions are very distinct from each other, according to the human concentration that settled there. Subsequently, although the title implies that it is a samba, it is actually a suite of nine short Brazilian dances. The dances were selected in the following order to facilitate choreography for the planetarium performer: *maxixe, partido alto, carimbó, fandango, dança dos facões, coco de roda, catira, forró* and *xaxado*.

Miller describes the maxixe as a "combination of the sensuous movements ... that was so provocative that maxixes were banned from being performed ... and were looked upon

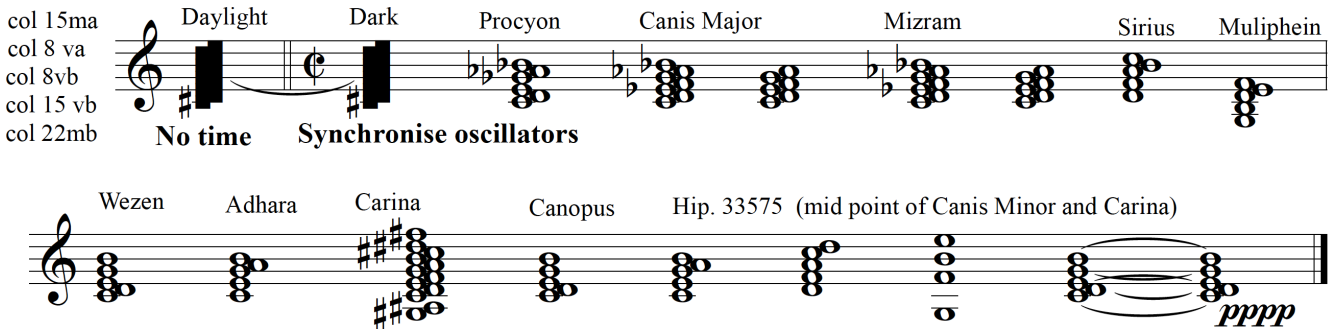

Figure 5: Harmonic progression of Cães Celestes

with moral outrage by the elite of the society" [27, p. 20]. Maxixe is used as an introduction while planetarium provides a field of view that displays the whole skyscape as presented on the flag.

Pardito alto is West African based $\frac{2}{4}$ rhythm with asymmetrical phrasing; however, the pardito alto rhythm is often embellished or improvised during the performance [38]. This section is a cadenza for the planetarium in that the performer uses the opportunity to improvise on many of the possibilities available in Stellarium, including landscapes, sky lore, planet tracking and scientific information display.

Carimbó is a circle dance from the North of Brazil [4]. The planetarium uses this opportunity to display the stars for the states of Mato Grosso do Sul, Acre and stopping on Distrito Federal.

Fandango is a European based rhythm from southern Brazil [4]. The planetarium zooms into *Polaris Australis* and back out again. A magnitude limitation is applied to mask higher magnitude stars, which is not apparent until the next dance.

Dança dos facões, translated machete dance, is a popular dance in Rio Grande do Sul and traditionally danced by two men, both armed with a machete in each hand [1]. With each clash of swords, more stars are displayed by causing Stellarium to incrementally relax the magnitude limitation imposed from the previous dance.

Coco is a circle dance where the participants sing and play percussion instruments and is closely related to samba [4]. The planetarium cycles out of its stationary position, displays the final star on the flag, and stops on a view of Saturn.

The catira is dance that combines hand clapping and tap dancing [15]. Stellarium shows its moons dancing around it at a moderate tempo.

Megwen Loveless, in describing forró states: "Sweet accordion riffs, the steady twang of the triangle, and the offbeat pounding of the *zabumba* drum make *forró* music a favorite for all Brazilians. The infectious tunes and syncopated beats have been described as "a mixture of ska with polka in overdrive," and with its hard-hitting beat and memorable hooks, it is a quintessentially Brazilian music." [25, p. 1]. The moons on Saturn move into overdrive as they dance around their planet with full gusto, with a final crash onto the surface of the planet in preparation for the audience's return to Earth.

Xaxado is traditionally from the interior of the Northeast [4] made made popular by cangaceiro (bandits) in Lampião's gang [25]. This is the finale where the display zooms from the surface of Saturn toward Earth. The Earth is seen continually spinning and stops when the band stops. Bandeira do Brasil then displays showing the Earth with its motto and stars as though viewed from space.

6. CONCLUSIONS

This paper detailed that although many nations display stars on their flags, the Flag of Brazil is distinctive in that it displays a chronological moment in time as a series of constellations. Though the composition and Stellarium software, the audience were taken on an astronomical tour of the sky as it would have been at that moment, and using astronomical data, mapped that to sound. Not only were the political states and scientific data presented to the audience, but the language, music and culture of the Brazilian people captured in the composition.

7. ACKNOWLEDGMENTS

I would like to acknowledge the support of Georg Zotti and Alexander Wolf from the Stellarium development team for their advice and guidance in using Stellarium. Samples sourced from the albums Indian Music of the Upper Amazon and Music from Mato Grosso, courtesy of Smithsonian Folkways Recordings. I would also like to thank Global Recordings Network International for allowing the use of language samples from the indigenous peoples of Brazil. The *5fish* mobile phone application for Android and IOS can be used to access audio recordings in your language. Helena de Souza Nunes and Natanael de Souza Ourives provided the dances for the third movement.

8. REFERENCES

[1] Machete dance. `https://dancasfolcloricas.blogspot.com/2011/05/danca-dos-facoes.html`, 2011. Accessed: 2019-01-27.

[2] J. P. Adams and T. F. Slater. Astronomy in the national science education standards. *Journal of Geoscience Education*, 48(1):39–45, 2000.

[3] J. Ashley. Computers and computer programs. In *Astrophotography on the Go*, pages 151–161. Springer, 2015.

[4] J. A. P. Azoubel. *Frevo and the Contemporary Dance Scene in Pernambuco, Brazil: Staging 100 Years of Tradition.* PhD thesis, University of Florida, 2007.

[5] K. Berglund. Using free, open source Stellarium software for iya2009. In *Preparing for the 2009 International Year of Astronomy: A Hands-On Symposium*, volume 400, page 483, 2008.

[6] O. Bown, M. Young, and S. Johnson. A Java-based remote live coding system for controlling multiple Raspberry Pi units. In *ICMC*, 2013.

[7] W. T. Cardoso. Constellations and natural cycles within Tukano's people. In *IHPST Thirteenth Biennial International Conference Rio de Janeiro July 22-25*. IHPST, 2015.

[8] S. F. de Athayde. *Weaving power: Displacement, territory and indigenous knowledge systems across three Kaiabi groups in the Brazilian Amazon*. University of Florida, 2010.

[9] F. C. de Mello. *Astronomy and Cosmology of the Guarani of Southern Brazil*, pages 975–980. Springer New York, New York, NY, 2015.

[10] R. T. Dean and A. McLean. *The Oxford Handbook of Algorithmic Music*. Oxford University Press, 2018.

[11] P. A. Duarte. Astronomia na Bandeira Brasileira. `https://web.archive.org/web/20080502120005/http://www.cfh.ufsc.br/~planetar/textos/astroban.htm`, 2010. Accessed: 2018-12-21.

[12] P. Duffett-Smith and J. Zwart. Practical astronomy with your calculator or spreadsheet. *Cambridge University Press,*, 2011.

[13] S. Easterday, J. Timm, and I. Maddieson. The effects of phonological structure on the acoustic correlates of rhythm. *ICPhS XVII*, pages 623–626, 2011.

[14] T. H. Eriksen and R. Jenkins. *Flag, nation and symbolism in Europe and America*. Routledge, 2007.

[15] J. C. Faustino. Composing conventions: The first universal aspect of moda-de-viola. 2017.

[16] S. Ferguson and O. Bown. Creative coding for the Raspberry Pi using the HappyBrackets platform. In *Proceedings of the 2017 ACM SIGCHI Conference on Creativity and Cognition*, pages 551–553. ACM, 2017.

[17] A. Fraietta. Musical composition with naked eye and binocular astronomy. In *Australasian Computer Music Conference 2014*, pages 47–52. Victorian College of the Arts, 2014.

[18] A. Fraietta. Stellar command: a planetarium based cosmic performance interface. In *International Conference on New Interfaces for Musical Expression (NIME-2019)*. Federal University of Rio Grande do Sul, 2019.

[19] A. Fraietta. Stellar command software module. `https://github.com/angelofraietta/StellarCommand`, 2019. Accessed: 2019-02-02.

[20] A. Fraietta and O. Bown. Creating a sonified spacecraft game using HappyBrackets and Stellarium. In *Procedings of the 17th Linux Audio Conference (LAC-19)*, pages 1–7. CCRMA, Stanford University, USA, 2019.

[21] A. Fraknoi. Music inspired by astronomy: A selected listing for the international year of astronomy. In *Preparing for the 2009 International Year of Astronomy: A Hands-On Symposium*, volume 400, page 514, 2008.

[22] D. Kindersley. Complete flags of the world. *Londres: Dorling Kindersley*, 2005.

[23] S. A. Knowlton. Applying sebeok's typology of signs to the study of flags. *Raven: A Journal of Vexillology*, 19:57–97, 2012.

[24] F. P. Lima. *Astronomy in Brazilian Ethnohistory*, pages 945–951. Springer New York, New York, NY, 2015.

[25] M. M. Loveless. *The invented tradition of forró: A 'routes' ethnography of Brazilian musical 'roots'*. Harvard University, 2010.

[26] M. Lundy, J. Martineau, M. Lundy, D. Sutton, A. Ashton, and J. Martineau. *Quadrivium: The four classical liberal arts of number, geometry, music, & cosmology*. Walker & Company, 2010.

[27] B. McCann and R. Miller. African rhythms in Brazilian popular music tango brasileiro, maxixe and choro. *Luso-Brazilian Review*, 48(1):6–35, 2011.

[28] K. Oberg. *Indian Tribes of Northern Mato Grosso, Brazil*, volume 15. US Government Printing Office, 1953.

[29] F. Ochsenbein, P. Bauer, and J. Marcout. The VizieR database of astronomical catalogues. *Astronomy and Astrophysics Supplement Series*, 143(1):23–32, 2000.

[30] G. Peters and M. Schreiber. "... How creation is composed": Spirituality in the music of Karlheinz Stockhausen. *Perspectives of New Music*, pages 97–131, 1999.

[31] J. Rodgers and W. Ruff. Kepler's harmony of the world: A realization for the ear: Three and a half centuries after their conception, Kepler's data plotting the harmonic movement of the planets have been realized in sound with the help of modern astronomical knowledge and a computer-sound synthesizer. *American Scientist*, 67(3):286–292, 1979.

[32] C. L. Ruggles et al. *Handbook of Archaeoastronomy and Ethnoastronomy*. Springer New York, 2015.

[33] A. Salt. *Development of Archaeoastronomy in the English-Speaking World*, pages 213–226. Springer New York, New York, NY, 2015.

[34] L. G. d. Souza and R. V. Santos. Perfil demográfico da população indígena xavánte de sangradouro-volta grande, mato grosso (1993-1997), brasil. *Cadernos de saúde pública*, 17:355–365, 2001.

[35] UNESCO. 2019 - international year of indigenous language. `https://en.iyil2019.org/`, 2018. Accessed: 2019-01-18.

[36] Various. Indian music of the upper Amazon, 1954. Catalog numbers FW04458, FE 4458. People groups of Asháninka, Cocama, Shipibo and Shipibo-Conibo.

[37] Various. Music from Mato Grosso, 1954. Catalog numbers FW04458, FE 4458. People Groups of Caboclos, Iwalapeti, Kamaiura, Kayabi and Xavante. Recorded by Edward M. Weyer Jr.

[38] D. E. Wilson Jr. *Partido Alto: Rhythmic Foundation Analysis of Aquarela Do Brasil*. PhD thesis, Youngstown State University, 2010.

[39] I. Xenakis. Formalized music, thought and mathematics in music, revised edition, 1992.

[40] A. Znamierowski. *Flags Through the Ages: A Guide to the World of Flags, Banners, Standards and Ensigns*. Anness, 2000.

[41] A. Znamierowski. *The world encyclopedia of flags: The definitive guide to international flags, banners, standards and ensigns*. Hermes House, 2002.

[42] G. Zotti. Towards serious gaming for archaeoastronomical simulation. *Mediterranean Archaeology & Archaeometry*, 14(3), 2014.

[43] G. Zotti, F. Schaukowitsch, and M. Wimmer. The skyscape planetarium, 2017.