Pharosphones: interactive audience participation using light

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ABSTRACT

This paper presents a novel approach to live performance that blends audience participation through the use of mobile phone light tracking with music conduction. Drawing from the history of audience engagement in the arts and leveraging advancements in digital technology, we foster a dynamic and immersive interactive model that complements traditional musical conduction techniques. The performance was designed for a 270-degree concert hall, allowing the audience to see one another. In this setting, we explore the symbiotic relationship among the various actors in a performance by employing mobile phones not only as communication devices but also as light emitters. To achieve this, we developed a computer vision system designed to translate audience participation into shaping the performance's sonic landscape. This process, underpinned by considerations of cybernetics and the feedback loop between human participants and technological systems, challenges conventional power structures within performance spaces. Through this work, we aim to expand the boundaries of interactive music creation, offering insights into the potential for technologically facilitated audience entanglement and advancing the discussion within the context of music ecology.

Author Keywords

Audience Participation, Cybernetics, Interactive Music Systems, Light-based Interaction, Mobile Phones, Performance Ecosystem, Computer Vision

CCS Concepts

• **Applied computing** → **Sound and music computing;**

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1. INTRODUCTION

This paper presents an interactive system that allows for audience participation by using light. The work is based on a reflection on cybernetic thought [30] as a lens to conceive performance ecosystems [28], which highlight recursivity and reciprocity among their various actants.

Different forms of audience participation have been explored over the past two decades [10, 31, 5, 33, 4, 16, 29, 1], primarily using mobile phones to send messages as a means of interaction with computer music performance systems. At the same time, light as an input method to control interactive music systems has been widely explored [6, 2, 13, 21]; however, it has rarely been investigated as a means to enable and foster audience participation. We find light to be a valuable medium which can generate poetic and theoretical sparkles. Light is visible, it illuminates (or highLIGHTs) the other, thus it is not just a means of interaction with the sound and the stage, as often done in audience participation pieces with mobile phones, but also renders the individual actions of each audience member visible to others.

The use of light is particularly interesting from the perspective of investigating performance ecologies [28] as it implicitly creates a "network" of visible "connections" among all the actants involved in the performance, facilitating the creation of recursive loops of mutual exchange among all the actants involved. In particular, we conceive this visible and audible ecosystem as a cybernetic circuit, with cybernetics being the study of "control and communication in animal and machine" [30], particularly investigating *feedback loops.* Composing a piece that encompasses various activities (writing code, fabricating materials, engaging with the audience, and the act of composition itself) is recognized in the language of cybernetics as a *purposeful activity*[30].

We embrace cybernetic thinking to conceptualize the musical ecosystem wherein the initial goal-directed impetus is dispersed into a mosaic of autopoietic processes. In other words, the overall design of the system functions as a *purposeful activity* that works by establishing feedback loops in a complex cybernetic circuit. A recording of the performance can be found at: `https://zmk5566.github.io/res/pharosphones.mp4`.

2. BACKGROUND

2.1 Music Ecosystems as Cybernetics of Cybernetics of Cybernetics

The concept of performance ecosystems has emerged recently as a way to understand the complexity of intertwined connections in the context of a music performance. Simon Waters in his topical essay analyzed performers, instruments, and environment as part of a performance ecosystem [28]. Similarly, Gurevich and Trevino proposed considering the "relationships between composers, performers, and listeners as a part of a system," [8] In line with this reasoning, Rodger and colleagues have recently pointed out that "instruments are better understood in terms of processes rather than as devices, while musicians are not users, but rather agents in musical ecologies" [24].

We propose that cybernetics offers an interesting way of looking at performance ecologies, supported by the fact that both belong to a shared theoretical lineage [11]. Cybernetics provides a systematic analysis of complex phenomena specifically looking at *feedback loops* as a way of establishing circular causality [11]. Within NIME, the notion of cybernetics has been previously used in the context of a critique of aesthetic and relational hierarchies [22] and in the analysis of feedback musicianship tracing how the concept of feedback that emerged as a technical endeavor has been subsumed as a cultural idea [18].

In this paper, we render our performance ecosystem as a cybernetic circuit which generates recursive and reciprocal loops of entanglements among its various actants: both human and technological. We explore this setting in a performance that we developed where we combine audience participation with music conduction and light based in interaction. Our playful notion of *music ecosystems as "cybernetics of cybernetics of cybernetics"* humorously underscores the recursive nature within our system as well as the role of the music ecosystem in the designed performance context. By framing music ecosystems within second-order cybernetics (the cybernetics of observing systems), and then extending it to a third layer which we wish to highlight the intricate feedback loops not only between components within a single system but also across multiple levels of systemic interaction and observation, with a tease on the recursivity.

2.2 Audience Participation

Audience participation has a long history in performance arts and music that can be traced back to the avant-garde (particularly relevant being the Fluxus movement [9]). In the past couple of decades, audience participation in live performances using digital technology was largely investigated over almost two decades. A large number of works rely on audience participation through the use of mobile phones and web communication. For instance, Egozy and Lee use mobile phones in "12" to enable an engaging and individualized experience. Similarly, Zhang et al. developed "Open Symphony," a web-based application enhancing collaborative contribution by allowing audience voting in favor of certain musical attributes during live performances. Likewise, Freeman et al. conceived "massMobile," a client-server system that facilitated mass audience participation through smartphones. The adaptable nature of this system allows for real-time communication across different settings and venues. Distribution mechanisms for enabling audience participation have also been a focal point, with Lee et al. proposing the use of Mobile Ad-hoc Networks (MANETs) to simplify the distribution process of mobile music applications. By decreasing user configuration and infrastructure dependency, they aimed to increase accessibility and encourage broader engagement. The cloud has emerged as a powerful tool for scaling interactive performances. Carvalho Junior et al. showcased how cloud services could facilitate large-scale audience participation with their work "Crowd in C[cloud]," emphasizing the importance of understanding network transactions and scalability.

Recently, based on a large corpus of examples, Xambó et al. contributed a framework for composing network music using mobile phones for audience participation, proposing compositional dimensions that consider various roles and feedback types. Their work underlined the aesthetic considerations crucial to designing audience-centric performances.

While most of the works allowing for audience participation rely on network communication, other examples do exist. For instance, installations such as "Performance Without Borders" and "Embodied iSound" integrated real-time movement tracking and indoor positioning systems affecting audio parameters, to enrich the participatory environment.

We have seen that mobile phones are often used as means to support audience participation. In most cases, they are used as interfaces relying on network communication. In this short paper, we describe a performance that complements these approaches by using conduction in combination with mobile phone light tracking as a means to promote audience entanglements with real-time interactive music creation.

2.3 Music Conduction

Rooted in experimental aleatoric works from the sixties and seventies, such as those by Cage and Stockhausen [12] among others, the practice of conduction refers to a performative improvisation practice where a leading figure (a sort of conductor) directs the improvisational choices of the other members of an instrumental band. The term, which originated with Butch Morris, is derived from physics; with this practice, Morris conducts an improvisation of an ensemble by relying on codified—still open to interpretation —musical gestures [14]. Another important example of this practice is "Cobra" by John Zorn, designed as a ludic compositional system. In "Cobra", Zorn extended the concept of conduction by employing a series of notated cues or "game pieces" that serve both as conducting gestures and compositional elements, guiding the improvisation flow while leaving room for performers' interpretation and interaction, thus creating a dynamic structure of performative improvisation[1].

2.4 Light and Musical Interaction

The use of optical media in the design of musical instruments has a long history, from the early 20th-century avant-garde to contemporary practices in sonic arts. Among recent works, for instance, is the 'light instrument' conceived by Eyes and Jongejan, which allows performers to dynamically manipulate audio elements, relying on a visual method of interaction that directly influences the sonic outcome [6]. Similarly, Cassinelli et al. introduced scoreLight, employing a laser to translate visual patterns into sound [2].

Moving towards participatory installations, Kobori et al. created LINE, where interactivity is catalyzed by light [13]. Audiences engage with the installation, using their movements to affect both the audio and visual outputs, thereby contributing to the performative aspect through light-mediated interactions [13].

Pak explored the use of light to augment musical expression in The Light Matrix [21]. This interface integrates controlled lighting effects that resonate with the musical

[1] A small documentary on the piece is part of Derek Bailey's film "On The Edge" (1992), available at `https://www.youtube.com/watch?v=yp-oZbmsQVw`

performance, crafting a synchronized multisensory experience that strengthens the connection between the artist and the audience [21].

These contributions collectively underscore the significance of light as not merely a stage effect but a powerful medium for interaction. Through the manipulation of light, these technologies enable a richer, more immersive live music experience, showcasing the boundless possibilities for audience engagement and interactive performance art.

3. PHAROSPHONES

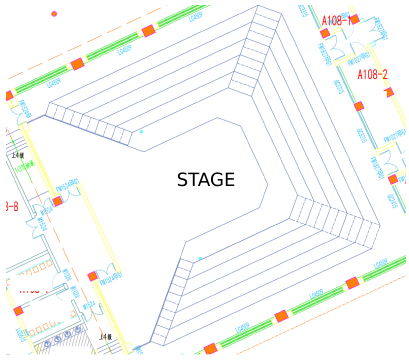

Figure 1: The stage setup.

A new contemporary concert hall at the Zhejiang Conservatory of Music had been built by the time this work was created. Although we were not involved in the venue's design, we, as creators, observed something special about this concert hall. It has a 270-degree circular structure with three audience areas adjacent to the stage. Audience members seated at different angles can watch the stage performance from distinct perspectives and see other audience members, thus becoming a part of the performance landscape themselves.

By examining this specific setting from the perspective of **performance ecosystem and cybernetics** and using light as a medium, we designed a live performance where the audience, without needing a background in musical training, actively participates, becoming part of the loops in the recursive performance system.

3.1 Roles in The Performance

There are three roles involved in this performance: the conductor, the participating audience holding light points, and the system designers on stage. At the beginning of the performance, the conductor signals everyone to turn on the lights of their phones and raise them up, then put them down, and then the performance begins without further communication or training. During the performance, the conductor directs the movement of the lights in the hands of the audience below through his gestures. At this point, through a computer vision system, the condition of the light points in the performance scene is fed back and mapped into sounds. The system developer can monitor the performance through both a data visualization system on the laptop and direct observation of the stage performance.

3.2 Concept of The Performance

Based on cybernetics thinking outlined above, the core concept of our performance is grounded in recursivity and feedback loops. The innovative architecture of the venue inspired us to explore the power dynamics between the stage and the audience. We envisioned an audience interaction system modeled on cybernetic structures. In particular, we were directly inspired by one of the first examples of cybernetics - Wiener's development of a machine "designed with the purpose of impinging upon a moving luminous goal" - originally a moving torpedo - where designing a system that relies on feedback loops to guide and modify its own behaviors to follow the light was considered a "purposeful activity" [25].

Based on foundational cybernetic principles, the overall design of our performative ecosystem is a *purposeful activity* that works by establishing *feedback loops* among audience members, light, a conductor, and a computational system. To do so, we aimed at capturing changes in different areas of the audience on stage. However, unlike traditional uses of cybernetics ([17]), we strived to facilitate audience interactions but aimed not to control the final result. The behavior and specific choices that constitute audience participation (as performers) are uncontrollable and unknowable, barring any possibility of rehearsal; therefore, the conductor needs to improvise and communicate with the audience through gestures that are not commonly defined. Meanwhile, the audience participates based on the conductor's actions, reactions from other audience members, and sound. At this moment, the system developer on stage paradoxically becomes an "audience" of the concert performance, reflecting on the entire performance and the system itself.

3.3 Technical Implementation

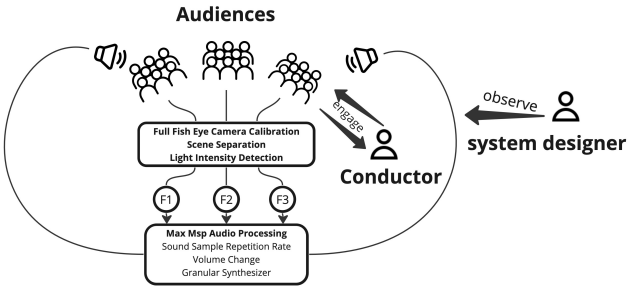

Figure 2: The overview of the Pharosphones System.

For the integrated system's design, we utilized the open-source Robotics Community's toolset, the Robot Operating System (ROS Kinetic)[23], to support our implementation and experimentation efforts. Our hardware setup included a laptop with Ubuntu for visual processing, a fisheye camera, a MacBook for sound output, and a 5G router for connectivity.

3.3.1 Input

Regarding visual input, we employed a fisheye camera alongside the OCamCalib visual algorithm[26] to achieve a corrected Panoramic view. We segmented the performance area into three zones based on their actual physical seating, which served as regions of interest for the algorithm.

3.3.2 Processing Input

Through thresholding techniques for graphic segmentation, we processed the real-time light conditions from users' flashlights in each zone. Before the performance, scenes showing audience members toggling their phone flashlights provided

reference frames. By comparing current bitmap frames to these references, we established a mapping function.

3.3.3 Sound Design

The visual data from audience phone lights was intricately converted into three precise floating-point values, representing the performance areas. These values were sent in real-time via the Open Sound Control (OSC) protocol[2] to a granular synthesizer in Max/MSP[3], driving sound generation. Given the reliance on mobile phones for audience interaction, we leaned heavily into using phone-related audio materials—a homage to McLuhan's insight, "the medium is the message"[20]. We included vibrations, ringtones, busy signals, and other concrete sounds, stored for granular synthesis.

Based on stage setup, we divided the audience into three zones, each linked to specific sample sets. Light intensity levels from these zones modulated sampling parameters: reversing, granular density and rate, and filtering. Each performance zone had its set of phone-related samples, with the conductor free to switch between them via keyboard interactions.

3.3.4 Pilot Setup

During development, ten volunteers from the venue assisted in recording movement data across different areas in an experimental phase. Using ROSBAG[27], we captured these movements, enabling us to refine the computer vision algorithm for our final setup.

4. DISCUSSION

The approach of considering music ecosystems as second-order cybernetic circuits introduces a novel perspective on analyzing audience participation. Additionally, the way this specific interactive piece of music is conceived and presented as a cybernetic circuit adds another possible reading of participation in large interactive ecosystems. Overall, this work contributes a fresh perspective to the current debate on interactive music systems, with audience participation conceived as performance ecosystems.

We will follow the discussion based on the experience of the performance throughout the process and then talk about how this overall process can be linked with conceptual analogy.

Figure 3: The photo of the live performance of Pharosphones.

[2]https://ccrma.stanford.edu/groups/osc/index.html
[3]https://cycling74.com/products/max

4.1 A Retrospective Reflection on the Roles in the Performance

For the performer conducting on stage, the experience is unique: faced with a large audience (200+), and with the audience area lights turned off, it is impossible to discern any hint of individual audience member's features. Yet, during this process, the conducting performer (third author of this paper) still experienced a sense of organismic feedback from the audience both visually (as moving light points) and acoustically (as changes in sound). This sensory feedback loop directly informed the technical implementation, as the real-time visual data captured and processed by our computer vision system not only guided but was shaped by these improvisational interactions, highlighting the interplay between technology and human response in a performance evolving over time. Consequently, while on stage, the performer would respond to the audience (or their perception thereof) with improvisational choices in response to such sensations. We noticed that the audience members would also interact with others in a similar manner.

These spontaneous phenomena formed a recursive loop for improvisation as the performance would evolve into a successor of itself during its runtime. The recursivity does not only stop there: as the system designer (first author) observed the performance from his position on stage with bare eyes and observed data streams from the control system development tool (visualization system/command-line tools), thereby analyzing the performance of the technical system and encouraging further exploration.

4.2 Some Final Remarks on Music and Cybernetics

By retrospectively analyzing this project, the main lesson we learned is that such complex performance ecosystems, which engender multiple roles (technician-performer, conductor-performer, and audience-participants), multiple feedback loops emerge. While other studies have aimed to analyze these loops in a formal way ([19]), in this work, we embrace these feedback loops as integral parts of the artistic vision. This allowed us to use light in a new way that complements the work on audience participation presented at NIME [5, 33, 29, 15, 3, 32, 7].

Framing our work in cybernetic terms represented a fundamental step in embracing the circular causality established by *feedback loops* [11] as part of the aesthetic discourse rather than as an analytical post hoc study of the performance ecology. This has been done before with feedback musicianship [18], but still is new in the design of audience participation systems. Indeed, the overall design was grounded in the conceptual language of cybernetics and conceived as a *purposeful activity* that works by establishing *feedback loops*.

5. CONCLUSION AND FUTURE WORK

In this article, we discussed a live performance designed for a unique concert hall that utilizes light as a medium and encourages audience interaction. Through a computer vision system developed with cybernetic principles, the audience, the conductor, and the system designers collaboratively shaped an experiential landscape that extends beyond traditional cybernetics. By employing mobile phones as sound sources, we stimulated audience reflections on technology and its intrinsic challenges. We aim for this paper to inspire further research into the recursive processes within

music ecosystems, drawing upon and expanding beyond existing cybernetics literature.

6. ETHICAL STANDARDS

The software code underpinning the robotics used in this project adheres to open-source principles. Audience engagement was highlighted and recognized in the program materials before the performance started, and no data were collected from the audience. Although the primary attendees were faculty and students from the Zhejiang Conservatory of Music, the event was open to the general public, promoting wider societal participation.

7. REFERENCES

[1] K. C. Baird. Real-time generation of music notation via audience interaction using python and GNU lilypond. In *Proceedings of the International Conference on New Interfaces for Musical Expression*, pages 240–241, Vancouver, BC, Canada, 2005.

[2] A. Cassinelli, Y. Kuribara, A. Zerroug, M. Ishikawa, and D. Manabe. scorelight : Playing with a human-sized laser pick-up. In *Proceedings of the International Conference on New Interfaces for Musical Expression*, pages 144–149, Sydney, Australia, 2010.

[3] A. D. de Carvalho Junior, S. W. Lee, and G. Essl. Understanding cloud support for the audience participation concert performance of crowd in c[loud]. In *Proceedings of the International Conference on New Interfaces for Musical Expression*, pages 176–181, Brisbane, Australia, 2016. Queensland Conservatorium Griffith University.

[4] J. Eaton, W. Jin, and E. Miranda. The space between us. a live performance with musical score generated via emotional levels measured in EEG of one performer and an audience member. In *Proceedings of the International Conference on New Interfaces for Musical Expression*, pages 593–596, London, United Kingdom, June 2014. Goldsmiths, University of London.

[5] E. Egozy and E. Y. Lee. *12*: Mobile phone-based audience participation in a chamber music performance. In T. M. Luke Dahl, Douglas Bowman, editor, *Proceedings of the International Conference on New Interfaces for Musical Expression*, pages 7–12, Blacksburg, Virginia, USA, June 2018. Virginia Tech.

[6] B. J. Eyes and L. E. Jongejan. How to stop sound: Creating a light instrument and 'interruption' a piece for the mimerlaven, norberg festival 2015. In *Proceedings of the International Conference on New Interfaces for Musical Expression*, pages 373–374, Brisbane, Australia, 2016. Queensland Conservatorium Griffith University.

[7] M. Gimenes, P.-E. Largeron, and E. Miranda. Frontiers: Expanding musical imagination with audience participation. In *Proceedings of the International Conference on New Interfaces for Musical Expression*, pages 350–354, Brisbane, Australia, 2016. Queensland Conservatorium Griffith University.

[8] M. Gurevich and J. Treviño. Expression and its discontents: toward an ecology of musical creation. In *Proceedings of the 7th international conference on New interfaces for musical expression*, pages 106–111, 2007.

[9] H. Higgins. *Fluxus experience*. Univ of California Press, 2002.

[10] T. Hopkins, E. Doherty, N. Ofer, S. C.-C. Weng, P. Gyory, C. Tobin, L. Hirshfield, and E. Y.-L. Do. Stringesthesia: Dynamically shifting musical agency between audience and performer based on trust in an interactive and improvised performance. May 2023.

[11] Y. Hui, editor. *Cybernetics for the 21St Century Vol.1 Epistemological Reconstruction*. Hanart Press, Hong Kong, 2024.

[12] M. Iddon. *New Music at Darmstadt: Nono, Stockhausen, Cage, and Boulez*. Cambridge University Press, 2013.

[13] D. Kobori, K. Kagawa, M. Iida, and C. Arakawa. Line: Interactive sound and light installation. In *Proceedings of the International Conference on New Interfaces for Musical Expression*, pages 110–113, Paris, France, 2006.

[14] C. Larkin. The guinness who's who of jazz. *(No Title)*, 1992.

[15] S. W. Lee, G. Essl, and Z. M. Mao. Distributing mobile music applications for audience participation using mobile ad-hoc network (MANET). In *Proceedings of the International Conference on New Interfaces for Musical Expression*, pages 533–536, London, United Kingdom, June 2014. Goldsmiths, University of London.

[16] S. W. Lee and J. Freeman. echobo : Audience participation using the mobile music instrument. In *Proceedings of the International Conference on New Interfaces for Musical Expression*, pages 450–455, Daejeon, Republic of Korea, May 2013. Graduate School of Culture Technology, KAIST.

[17] G. Lovink. Cybernetics for the twenty-first century: An interview with philosopher yuk hui. 2019.

[18] T. Magnusson, C. Kiefer, and H. Ulfarsson. Reflexions upon feedback. In *Proceedings of the International Conference on New Interfaces for Musical Expression*, The University of Auckland, New Zealand, jun 2022.

[19] R. Masu, M. Bettega, N. N. Correia, and T. Romão. Investigating performance ecologies using screen scores: a case study. *Personal and Ubiquitous Computing*, 27(5):1887–1907, 2023.

[20] M. McLuhan. The medium is the message. In *Communication theory*, pages 390–402. Routledge, 2017.

[21] J. Pak. The light matrix: An interface for musical expression and performance. In *Proceedings of the International Conference on New Interfaces for Musical Expression*, pages 342–345, Paris, France, 2006.

[22] P. J. Preece, M. Jack, and G. Lepri. Oscillations: Composing a performance ecosystem through a sonic cyberfeminist lens. In M. Ortiz and A. Marquez-Borbon, editors, *Proceedings of the International Conference on New Interfaces for Musical Expression*, pages 307–313, Mexico City, Mexico, May 2023.

[23] M. Quigley, K. Conley, B. Gerkey, J. Faust, T. Foote, J. Leibs, R. Wheeler, A. Y. Ng, et al. Ros: an open-source robot operating system. In *ICRA workshop on open source software*, volume 3, page 5. Kobe, Japan, 2009.

[24] M. Rodger, P. Stapleton, M. Van Walstijn, M. Ortiz, and L. Pardue. What makes a good musical instrument? a matter of processes, ecologies and

specificities. In *Proceedings of the international conference on New Interfaces for Musical Expression*, pages 405–410. Birmingham City University, Birmingham, UK, 2020.

[25] A. Rosenblueth, N. Wiener, and J. Bigelow. Behavior, purpose and teleology. *Philosophy of science*, 10(1):18–24, 1943.

[26] D. Scaramuzza, A. Martinelli, and R. Siegwart. A toolbox for easily calibrating omnidirectional cameras. In *2006 IEEE/RSJ International Conference on Intelligent Robots and Systems*, pages 5695–5701. IEEE, 2006.

[27] D. Thomas, T. Field, J. Leibs, and J. Bowman. Rosbag-ros wiki. *URL: http://wiki. ros. org/rosbag*, 2014.

[28] S. Waters. Performance ecosystems: Ecological approaches to musical interaction. *EMS: Electroacoustic Music Studies Network*, pages 1–20, 2007.

[29] N. Weitzner, J. Freeman, S. Garrett, and Y.-L. Chen. massmobile -an audience participation framework. In *Proceedings of the International Conference on New Interfaces for Musical Expression*, Ann Arbor, Michigan, 2012. University of Michigan.

[30] N. Wiener. *Cybernetics: Or Control and Communication in the Animal and the Machine*. MIT Press, 1948.

[31] A. Xambó and V. Goudarzi. The mobile audience as a digital musical persona in telematic performance. In *Proceedings of the International Conference on New Interfaces for Musical Expression*, The University of Auckland, New Zealand, jun 2022.

[32] A. Xambó and G. Roma. Performing audiences: Composition strategies for network music using mobile phones. In R. Michon and F. Schroeder, editors, *Proceedings of the International Conference on New Interfaces for Musical Expression*, pages 55–60, Birmingham, UK, July 2020. Birmingham City University.

[33] L. Zhang, Y. Wu, and M. Barthet. A web application for audience participation in live music performance: The open symphony use case. In *Proceedings of the International Conference on New Interfaces for Musical Expression*, pages 170–175, Brisbane, Australia, 2016. Queensland Conservatorium Griffith University.