SUTD Leap

[RE]IMAGINE EDUCATION

A weekly Design.AI newsletter

BUILDING REAL-WORLD AI: LESSONS FROM DESIGN, ARCHITECTURE AND EDUCATION

Associate Professor Stylianos Dritsas , ASD
In Conversation with Dr. Nachamma Sockalingam, OSP

Associate Professor
Associate Head of Pillar
(Education)

https://www.sutd.edu.sg/profile/stylianos-dritsas/

In this issue, we feature Associate Professor Stylianos Dritsas, a founding faculty member at the Singapore University of Technology and Design (SUTD), where he explores the intersection of design computation and digital fabrication. His work focuses on how computing can transform how we design and make things.

From 2020 to 2023, he collaborated with Robert Simpson from EPD and Kenneth Chua from Changi General Hospital to use machine learning and light imaging to improve how hearing aids are designed, automating complex 3D modelling tasks and handling real-world “noisy” data with precision. In this conversation, we will hear his perspectives on applying AI to real-world design challenges and what this means for the future of computational design.

Editor of Newsletter:
Dr. Nachamma Sockalingam, Office of Strategic Planning

Design-Built Rationalization Strategies and Applications

In his 2012 IJAC article, Dritsas employs unsupervised machine learning methods to improve the constructability of complex shape architecture, that is minimizing the number of different dimensionally varied parts in a building's facade. The case study of the SportsHub pioneers the use such methods for the building industry in Singapore.

This philosophy underlies his more recent work with Changi General Hospital, where he and his team applied machine learning to automate and refine the 3D modelling of ear canals, even in noisy, incomplete data settings, pushing the boundary of how AI can engage with spatial design.

Architectural Space to Anatomical Space with AI

Stylianos' approach to AI in design is deeply rooted in his architectural research, where computation is to rethink how form, structure, and function emerge. The same principles that guide his exploration of architectural morphology now extend to human anatomy, where AI helps interpret and model the complex geometry of the human outer ear canal. This transition from *architectural space* to *anatomical space* reflects his belief that design computation can bridge disciplines, expanding traditional approaches and uncovering new design possibilities.

Medical Image Analysis 94 (2024) 103152

Contents lists available at ScienceDirect

Medical Image Analysis

journal homepage: www.elsevier.com/locate/media

ELSEVIER

Classification, registration and segmentation of ear canal impressions using convolutional neural networks

Stylianos Dritsas [a,*], Kenneth Wei De Chua [b], Zhi Hwee Goh [a], Robert E. Simpson [c]

[a] Singapore University of Technology and Design, 8 Somapah Road, 487372, Singapore
[b] Changi General Hospital, 2 Simei Street, 3, 529889, Singapore
[c] University of Birmingham, Edgbaston, B15 2TT, UK

ARTICLE INFO

MSC:
41A05
41A10
65D05
65D17

Keywords:
Ear canal impression
Classification
Registration
Segmentation

ABSTRACT

Today, fitting bespoke hearing aids involves injecting silicone into patients' ears to produce ear canal molds. These are subsequently 3D scanned to create digital ear canal impressions. However, before digital impressions can be used they require a substantial amount of effort in manual 3D editing. In this article, we present computational methods to pre-process ear canal impressions. The aim is to create automation tools to assist the hearing aid design, manufacturing and fitting processes as well as normalizing anatomical data to assist the study of the outer ear canal's morphology. The methods include classifying the handedness of the impression into left and right ear types, orienting the geometries onto the same coordinate system sense, and removing extraneous artifacts introduced by the silicone mold. We investigate the use of convolutional neural networks for performing these semantic tasks and evaluate their accuracy using a dataset of 3000 ear canal impressions. The neural networks proved highly effective at performing these tasks with 95.8% adjusted accuracy in classification, 92.3% within 20° angular error in registration and 93.4% intersection over union in segmentation.

1. Introduction

Hearing loss is an important public healthcare problem that affects the quality of life for 1.5 Billion people around the Globe. Those suffering from hearing loss have an increased risk of dementia. These problems are expected to worsen with the globally aging population. It is not surprising, therefore, that improved access to hearing aids is one of the key actions recommended by the World Health Organization (WHO, 2018). The morphology of the outer ear canal is not only highly important for a good hearing aid fit (Paulsen et al., 2002), but also essential for a wide range of scientific and clinical purposes (Voss et al., 2020). There has been, however, limited data available that can be used to understand the ear's anatomy and variations among individuals (Voss et al., 2020). Fortunately, the advent of technologies such as 3D scanning, computer-aided design and additive manufacturing transformed the design, production and fitting of hearing aids (Valente et al., 1998) simplifying the measurement of the ear canal's cavity (Pirzanski, 2006), integrating electrical and mechanical components, and 3D printing, rather than casting, bespoke in-the-ear shells (Sickel et al., 2011; Baloch et al., 2010). Nevertheless, creating a digital model still requires injecting silicone into the ear canal to produce an Ear Canal Impression (ECI) which is afterward digitized using a 3D scanner (Sullivan, 2007).

Today it is common for audiologists to use 3D scanners to create digital models of ECIs and large volumes of human ear canal scans now exist. This offers an opportunity to study the ear canal's morphology using computational methods. Indicatively, 10,000 ECIs were available here, whereas in past works only a few dozen (Stinson and Lawton, 1989; Paulsen et al., 2004) to low hundreds were examined (Baloch et al., 2010; Voss et al., 2020). However, before the data can be useful they must be substantially 3D edited. Indicatively, only 3000 ECIs were used due to the manual labor required to pre-process and normalize the data. Pre-processing ECIs presents two major challenges that stem from (a) the ambiguity of associating anatomical semantics with geometric features, and (b) the discrepancies introduced by creating and digitizing the silicone impressions.

While the anatomy of the outer ear has been extensively studied in the past (Alvord and Farmer, 1997; Møller, 2012) and regions of the ear's surface have been qualitatively attributed, translating those descriptions into quantifiable geometric features is non-trivial (Baloch et al., 2010). Additionally, inconsistencies in the silicone injection process, and modifications to the ear molds or 3D scans thereof, introduce substantial variations among ECIs. For instance, the scanned ear canal's length is affected by the insertion depth of a cotton block, which is

* Corresponding author.
E-mail address: dritsas@sutd.edu.sg (S. Dritsas).

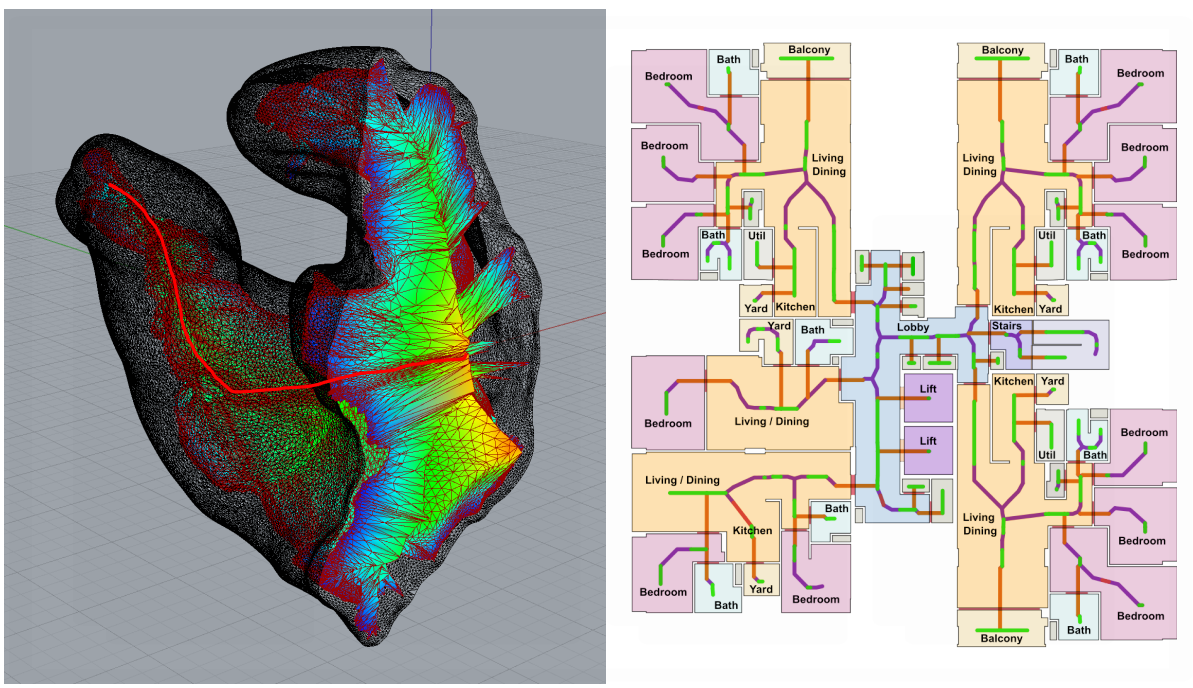
https://doi.org/10.1016/j.media.2024.103152
Received 15 May 2023; Received in revised form 12 December 2023; Accepted 20 March 2024
Available online 21 March 2024
1361-8415/© 2024 Elsevier B.V. All rights reserved.

https://doi.org/10.1016/j.media.2024.103152

The AI-driven ear imaging project is a collaboration between Assoc. Prof. Robert E. Simpson and Stylianos Dritsas from SUTD and Dr Kenneth Chua from Changi General Hospital, focused on improving how custom hearing aids are designed and fitted.

Traditionally, audiologists inject silicone into the ear to create a physical mould, which is then scanned and digitally cleaned up, a process that is slow, manual and qualitative. This project aimed to replace much of that work with light imaging and machine learning, allowing computers to automatically process and interpret ear canal scans, even when the data is “noisy” or incomplete.

By using AI-assisted ear canal modelling, the system simplified processing of digital ear canal impressions with a broader aim of improving comfort and fit for users while making hearing aid production faster and more reliable. The long-term goal is to develop automated, data-driven tools that standardize ear canal analysis and streamline design for hearing rehabilitation devices.



Shape analysis of the outer human ear canal and SUTD staff housing using skeletonization to graphs

Stylianos's understanding of geometry proved essential in the CGH ear canal imaging project. Working alongside optics researchers and audiologists, he brought a unique ability: seeing form and structure in spatial data. The machine learning model understood how to automatically process ear canal impressions despite significant variations due to human anatomy as well as the procedures of silicone injection, mould pre-processing and 3D scanning.

Even better? He later reused some of the same analysis methods for urban planning and now in a biodiversity project. This crossover between domains shows the deep logic of design computation: it is not domain-specific. It is understanding space and structure and using technology to traverse different domains.

AI in Teaching

When asked how he applies AI in teaching, Stylianos was candid in response that AI is not a novelty or trend to chase. "*There are many kinds of AI. I am not interested in using AI just for the sake of it*," he states. His applications of AI are grounded in solving specific, often complex problems.

As his research work is more advanced in nature for his classes, Stylianos chooses to teach the fundamentals such as gradient descent, design optimization, and computational reasoning, that is, the mental frameworks that power intelligent systems. He believes that true understanding starts with basics, not buzzwords.

His students might not code neural nets, but they understand how systems behave, evolve, and self-tune. This equips them to engage AI critically and not blindly adopt it.

His pedagogical approach is rooted in depth over breadth. It is not about building quick-fix AI projects, but laying the intellectual scaffolding for real, sustainable innovation.

Infrastructure of Innovation

When asked on what is needed for such innovative work, Stylianos cited curiosity, openness, adaptability, persistence, creating value and considering the impact of work as some of the important factors.

In addition, he noted that "*you need substantial investment to be cutting edge. You cannot just slap a new layer on top of off-the-shelf solution and pretend you have done something new.*"

Stylianos draws a parallel between AI and robotics: both require time, hardware, expertise and money. "*Just to train the model, I had to buy a new GPU*," he says, pointing to the real economic barriers in AI experimentation.

At SUTD, Stylianos helped pioneer robotics in architecture over a decade ago. Today, he sees the same curve repeating with AI. The early adopters bear the weight, the cost, the risk, and the learning curve.

He warns against superficial AI usage: layering tools over systems without real integration. His message is clear: real innovation is infrastructural, not cosmetic. And AI, to be meaningful, must be earned through effort, understanding, and access. He iterates time and again, that application is context-specific, even when applying generalizations.

Self-Taught, System-Driven

When asked how he learns new skills such as AI, his response was, "*I had to teach myself how to train models.*" Stylianos tests, learns from failure, and evolves through experimentation. Much of his understanding of machine learning and computational methods comes from self-training. "*I didn't get it right the first time*," he says, describing long hours debugging neural networks, misreading results, and refining workflows.

This personal journey of figuring things out is what makes his work so grounded. It is not just about technical skill; it is about developing intuition with the system on what works and not through practice. Stylianos models an agile learning mindset that is crucial in fast-evolving domains like AI.

Stylianos reminds us that intelligence is not in the tool. It is in how we shape, question, and apply it. His work urges us to look beyond the interface, beyond the hype, and into the actual mechanics of thinking. Whether it is a geometry-driven ear canal or a robotic arm printing a facade, the common thread is rigorous design logic, not novelty.

In a world obsessed with speed and spectacle, his philosophy is a powerful reminder: real innovation is slow, strategic, and deeply grounded in systems thinking. As we reimagine education and AI, we need to focus on the fundamentals as must as the inspiring ideas.

What struck us most in this conversation is not just the practical intelligence behind his projects, but also the humility, the willingness to say, "*I tried something else, and the machine did it better.*" That is a mindset many educators and innovators can learn from.

"Real innovation is infrastructural, strategic,
and deeply grounded."

Associate Professor Stylianos Dritsas's work, from geometric architect to AI-driven ear canal modeling, illustrates how design logic can power breakthroughs that transcend disciplines. Time and time again, we hear from our SUTD faculty members about the importance of foundations in Design.AI. His story reminds us that innovation is earned, not outsourced, and that good design starts with understanding, not tools alone. We need the AI tools to partner with us as Teammates, but we also need the foundations more importantly.