

推进沉浸式数据交互的虚拟现实技术

VIRTUAL REALITY FOR IMMERSIVE DATA INTERACTION

1 反思过去

将与特定位置相关的准确记录或数据集融入景观设计之中的传统由来已久，在其影响下，地理信息系统（GIS）于1963年问世^①。随后，伊恩·L·麦克哈格在其著作《设计结合自然》中又将该系统提升到了新的高度。在愈加复杂的环境挑战面前，景观设计通常被置于与生态系统服务相同的层级。因此，在规划过程中，相较于场地特征、场地内在特性以及未来使用人群等数据，与“蓝色和绿色基础设施”相关的数据往往更具影响力。

在《设计结合自然》出版50年后的今天，当我们再次审视这本书的核心思想时，会惊讶地发现尽管我们已取得了巨大的技术进步，记录了不计其数的数据集，却还是未能结合景观本身所具有的巨大力量和演变趋势进行设计^[1]。正如理查德·韦勒、弗雷德里克·斯坦纳和比利·弗莱明总结的那样，“麦克哈格意在指出，开发和改造地球的最佳方式是在规划设计时充分考虑生态与景观特性。”^[2]

2 数据体验

当前，有关虚拟现实（VR）与混合现实（MR）领域中人类与大规模环境数据流进行交互的开创性应用研究正在持续进行中，国际上对于“大数据”主题的探讨也常基于这一研究的部分项目展开^[3]。该研究尤其聚焦于时间、交互、视觉和听觉等元素。

城市区域是实现可持续发展的重要战场，然而，面对景观与城市中层出不穷的复杂挑战，能够与之抗衡的规划设计方法仍显得捉襟见肘。与此同时，人工智能以及VR和增强现实（AR）等沉浸式工具正在迅猛发展，并逐渐成为我们日常生活的一部分。MR技术为更好地地理

① 由罗杰·汤姆森开创性发起、筹划并建立的加拿大地理信息系统（CGIS），促成了世界上首个计算机化GIS于1963年问世。

皮娅·弗里克

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摘要

在这个由技术发展塑造的时代，现实与虚拟世界的边界正在逐渐消融，当下我们面临的挑战是如何重新定义虚拟现实与混合现实在景观设计领域应用的潜力。基于对此类技术的主要应用领域的批判性分析，可以得知当前的研究重点是优化虚拟空间的三维可视化与导航系统。在专业实践，特别是智能建筑行业中，混合现实工具正在被越来越多地应用于市场测试与设计决策的商务沟通。

迄今为止，沉浸式环境在景观设计领域的应用仍缺乏以人为中心的数据交互与空间感知研究。由芬兰阿尔托大学景观设计与都市主义计算方法研究室实践应用教授皮娅·弗里克带领的团队正致力于研究全新的沉浸式协同设计方法，以为参与式设计过程提供极具价值的新型研究路径。由此，混合现实的应用可突破常规用途，并基于数据信息处理促进跨学科沉浸式互动空间的创建。本文展示的研究与教学成果反映了全球对“数字人文——大数据与以人为中心的设计”这一宏大议题的探讨。

关键词

虚拟现实；混合现实；增强现实；景观设计；参与式设计；沉浸式互动；数据分析

ABSTRACT

In a time shaped by technological developments dissolving the boundaries between the real and the virtual world, we are challenged to newly define the potentials of virtual and mixed reality in the field of landscape architecture. Critical analyses of the primary application areas of these technologies show that the current focus mostly lies on the optimization of 3D visualization and navigation in virtual space. Within professional practice, mixed reality tools are increasingly being used to test and communicate design decisions, for marketing purposes, and more often, within the smart building industry as well.

Thus far, the incorporation of immersive environments in landscape architecture is lacking research on human-centered data interaction and the perception of space. At Aalto University, Finland, the team of Pia Fricker, Professor of Practice for Computational Methodologies in Landscape Architecture and Urbanism, researches new immersive co-design methodologies to introduce new meaningful trajectories for participatory processes. Mixed reality applications are thus extended beyond common and conventional uses to help create multidisciplinary immersive interactive spaces using data informed processes. The research and teaching results showcased in the article address international discourse on the larger theme of “Digital Humanism — Big Data and Human-Centered Design.”

KEY WORDS

Virtual Reality; Mixed Reality; Augmented Reality; Landscape Architecture; Participatory Design; Immersive Interaction; Data Analysis

翻译 李慧彦 田晓劼

TRANSLATED BY LI Huiyan TIAN Xiaojie

解、设计和管理周遭环境带来了空前的机遇。这些技术的巨大潜力在于其能够将人们对于环境的不同构想图示化，并支持有着不同学科、专业和背景的人士对此进行探讨。此外，与MR技术相整合的新技术能够更好地处理抽象数据集，不仅可直接实现数据的可视化，而且能够在参与式过程这一广泛主题下将协同设计提升至新的高度^[4]。

以上发展现状不仅与麦克哈格的核心思想密切相关，也与阿兰·伯格的新近设计实践有着重要关联，他提出，“我们必须利用设计智慧和强大的新型分析工具，创造性地恢复由短期经济模式、左右摇摆的政治决策、临时性开发、公众参与缺失，以及尚待完善的环境政策所导致的碎片化区域景观系统。”^[5]

3 基于MR的协同式设计

沉浸式技术使不同背景的人们可以产生直观互动；这种互动仿佛是在现实环境中发生的自然过程^[6]。基于VR和AR提供的可靠原型，我们可以实现技术的快速迭代。在可预见的未来，VR设备和各种在线实时应用程序将成为我们日常生活的一部分。

然而，直到现在，融合了VR技术的现有参与式系统仍无法将实际发现整合到互动过程之中，且无法将某一场景的潜在特质或参与者的沉浸式关联植入场地历史。这主要是由于当前应用于参与式过程中的VR与AR相结合的方法一直以来都将关注点放在了沉浸式空间体验的打造，尤其是未来场景的精细化建模上。

与当前力求在VR中营造逼真视觉效果和攻克技术壁垒的趋势不同，皮娅·弗里克教授重点关注发展协同设计方法，意在将人工智能、机器人技术、VR和数据可视化等不同主题整合至一个平台之上。2016年，在关于该课题的首批研讨会中的讨论框架中，就已提出了核心的引导性问题，这些问题也被用作更高层级的框架，并在弗里克教

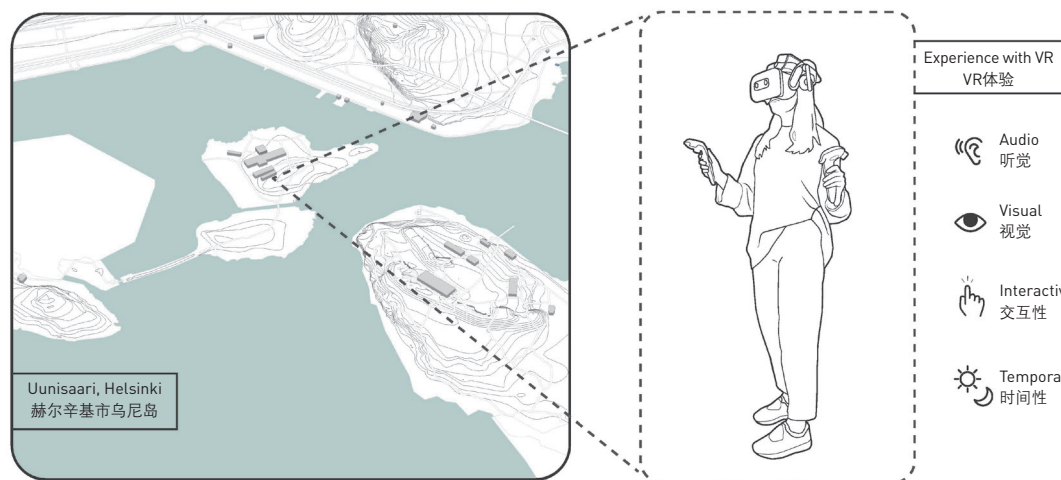
授的项目中得到了解决。

在将创造性应用整合到大规模规划设计活动中时，虽然可以得到相应技术的支持，但仍存在以下问题：如何将整合了大数据、VR/AR技术及机器人技术的共生体用于挖掘景观设计与城市设计专业的潜能？通过在虚拟空间中置入数据，我们创造出了怎样的体验？如何通过整合VR开辟新的参与式系统或协同系统，以理解未来工作的复杂性和可能性（即结合气候变化挑战、国内与国际社会挑战等）？这些均与数据集相关而又彼此关联的问题又将如何为气候变化议题下的景观设计领域提供新的优势，以拓展并强化我们对韧性、可持续性 & 生态技术等概念的理解？^[7]

跨学科是该系列研究的重点。阿尔托虚拟影院实验室^②的一部分研究员来自电影领域，通过与他们进行合作，研究团队获得了更多有关叙事手法的经验，并认识到“讲好一个故事”的重要性。通过监测“叙事电影对大脑活动和眼球运动所具有的显著控制作用”^[8]，希恩斯·艾利沙卡指出，认知神经科学可以揭示出这种叙事所起到的效用。人类认知神经科学系统各分支领域（如感知、体验、记忆和决策）的整合，以及极具价值的以未来为导向的可持续城市设计与景观设计方法，为正在进行的该项研究提供了有力支持。通过整合研究方法，分析包括脑电图（EEG）^③、皮肤电反应（GSR）^④在内的生物信号等用户体验数据，并将与抽象数据的交互视作重新畅想城市未来的契机，可赋予相关应用全新的可能性。^[9]

聚类和分类等机器学习技术以及深度学习神经网络已被应用于大数据分析中，但它们在景观及城市规划领域辅助设计和社区决策的潜能仍有待开发^[10]。在本研究探讨的测试案例中，团队利用实时数据分析检验设计场景，并基于实况卫星数据或野外调查数据优化设计决策。通过创建与该任务相匹配的特殊的VR/AR环境，可促进上述内容的整合^[11]。

- ② 虚拟影院实验室（VCL）是面向阿尔托大学虚拟现实研究的前沿机构，为研究人员、教育工作者和业界专业人士提供了交流平台。VCL的研究重点是新兴媒体技术方面的内容创作拟定工作流程，以及为如何使用这些工具叙事和传递情感制定策略，从而加速推动新技术在行业内的应用。
- ③ 脑电图（EEG）是一种非侵入式神经影像技术，即通过头皮电极测量脑电波动。这些波动由大量同时活动且方向相似的大脑细胞突触后电位变化所引起。
- ④ 皮肤电反应（GSR），也被称为皮肤电活动（EDA）或皮肤电传导（SC），是指对皮肤电特性（如由于出汗使人体发生变化从而引起电导）的持续变化所进行的测量。



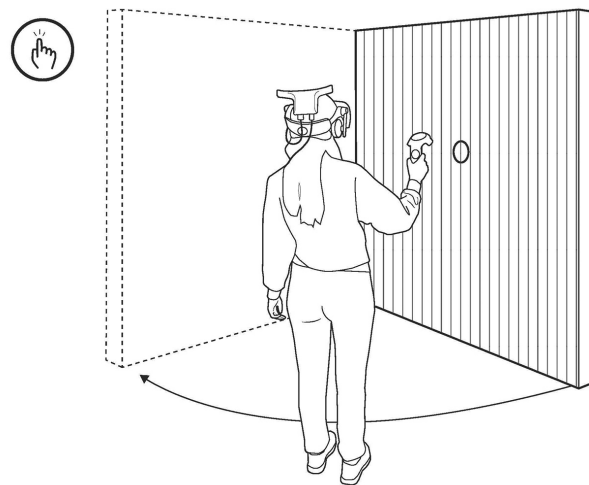
1. 项目研究区域：芬兰赫尔辛基市乌尼岛。VR技术的运用有助于对与空间环境相关的沉浸式协同设计应用在时间、互动、视觉和音效方面的创新进行深入研究。

1. Research project area: Uunisaari in Helsinki, Finland. VR technology has been applied in order to research into novel aspects of immersive co-design applications in relation to spatial conditions. Focus has been set on the investigation of temporal, interactive, visual and audio aspects.

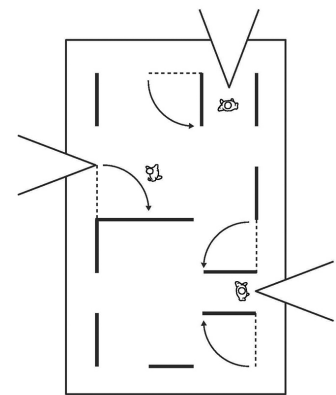
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2. 该项目聚焦于探索迭代设计过程中人们在VR环境中进行交互式体验的潜力。景观是一个动态系统，会随着季节变迁和时间推移而演变。项目从感知、氛围和视线的动态变化等维度，对景观体验进行了研究。此外，项目运用VR技术来探究互动性设计元素的影响与潜力，试图回答“如何运用沉浸式模拟环境来支持设计过程”“为了达到恰当的抽象化程度，使研究重点放在整体设计（而非建模）上，哪些工作流程是必要的”等问题。该项目由迈亚·约恩苏和劳拉·莱多芬尼完成。
- 2-1. 互动式空间系统设计方案
2-2. 可能生成的景观视角总览
2-3. 协同设计阶段：根据使用者和设计师的反馈进行的几轮设计调整

2. This project concentrates on the potential of human interaction in VR in relation to the iterative design process. As landscape is a dynamic system that changes through seasons and over time, the experience of a landscape was researched under the focus of perception, atmosphere, and dynamic changes of views. In addition, the project used VR to understand the impact and potential of an interactive design element. Questions addressed included "how can the immersive simulated environment be experienced to support the design process?" and "which workflows are needed in order to create the right level of abstraction, so that the focus will be on the overall design, rather than modeling aspects?" This project is conducted by Maija Joensuu and Laura Lehtovuori.
- 2-1. Scheme of interactive spatial system
2-2. Overview of possible generated landscape views
2-3. Co-design phase: iteration of design adjustment according to user and designer feedback.



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2-1



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2-3

4 展望

先进的空间现实技术旨在开辟新的模拟途径，将参与式过程融入环境设计与城市开发之中，进而为社会与环境挑战提供可持续的解决方案，以重塑城市未来。该研究项目的创新之处在于能够使人们直接且轻松地参与设计过程并发挥积极作用，从而加强各方的未来福祉。研究团队下一步将聚焦于机器人及物理增强技术，它们在众多面临复杂决策的学科中发挥着关键作用，例如通过数字化制造技术，普通工匠也可以制作复杂的机械零件^[12]。景观与城市设计领域所面临的通常都是涉及上百个参数及要素的复杂决策。在这一情况下，机器人可以连接VR/AR环境与物理世界，以便利用城市与景观增强模型等直观的交互

式空间界面^{[4][13]}。通过三维扫描仪和相机可以将由人类行为或机器驱动所激发的模型变化反馈到数字环境中，从而实现将实时变化融入设计过程。研究并设计此类增强设计环境原型，将真实世界的相关数据融入设计和决策过程之中，将会是下一阶段研究的主要目标。**LAF**

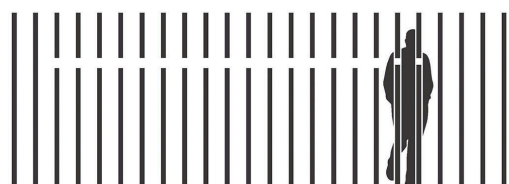
致谢

这一正在进行的由芬兰阿尔托大学景观设计与都市主义计算方法研究室带领的数字景观设计小组主持开展。本文所展示的内容是“进入混合现实”与“虚拟现实中的声音与点云交互”这两个项目的研究成果。由此得到的概念、工作流程和理论问题为该领域的最新研究奠定了基础。

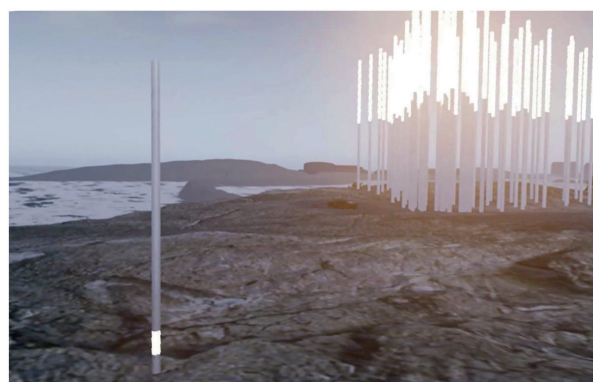
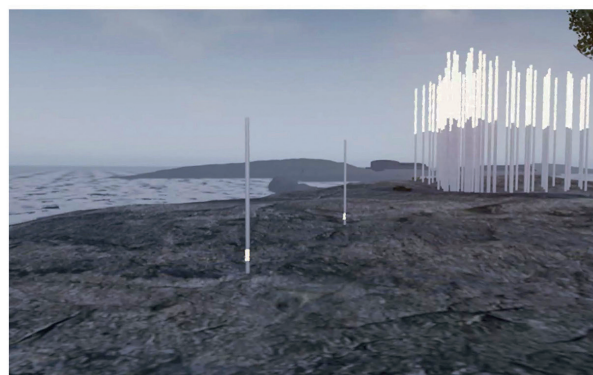
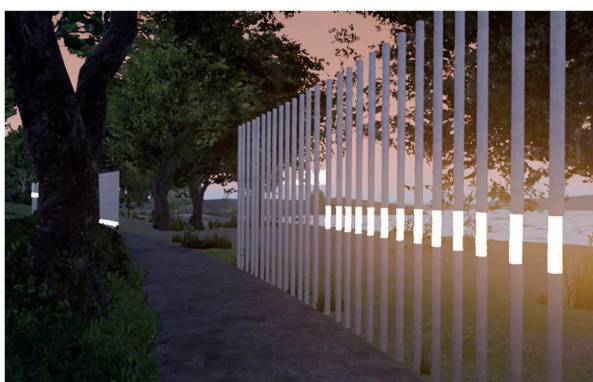
衷心感谢积极参与本次研究的学生们。同时感谢劳里·莱姆梅恩雷迪和米科·维克利提供的重要理论及教学支持，感谢蒂娜·赛波来贾克在图像编辑方面给予的帮助，并特别感谢为本次研究带来极大启发的米科·萨姆斯教授和希恩斯·艾利沙卡，以及阿尔托大学建筑系主任佩卡·海基宁教授。



Horizontal lighthouse
水平方向上的灯柱



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3-1



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3-2

3. 在传统的设计过程中，当地的风力条件及其与设计元素的相互作用难以传达。通过借助由Unity和Cinema 4D编程和建模的动画元素，该项目模拟了不断变化的天气条件。新设计的通风走廊系统拥有众多的“风管”，当行人经过时，不同风速的风管会显示不同的亮度，它们还会随着行人从旁经过而变化亮度。根据使用者的反馈意见，研究对VR环境中的不同氛围条件进行了测试与调整。该项目由伊琳娜·伦科宁和萨拉·萨洛瓦拉完成。

3-1. 交互式灯光设计图。借由综合型传感器，这些风管会根据从旁经过的行人的移动轨迹与身高调整亮度。

3-2. 不同的灯光装置被安装在岛上可饱览波罗的海美景的地方。这些装置会根据天气情况调整照明方式。

3. The local wind conditions and the interaction with design elements are difficult to communicate within a traditional design process. Through animated elements, programmed and modeled in Unity and Cinema 4D, the project gave shape to changing weather conditions. The designed new path system is enriched through “windpipes,” which visually demonstrate the wind speed through the brightness and iteration of the light according to the people walking by. Within the VR environment, the different atmospheric conditions were tested and adjusted according to the feedback of the test user. This project is conducted by Elina Renkonen and Salla Salovaara.

3-1. Scheme of interactive light concept. Through integrated sensors, the light is reacting to the movement and height of the person passing by.
3-2. Overview of different light settings of the installation at the most scenic point of the island, with open view to the Baltic Sea. The lights are changing their behavior according to the weather situation.

1 Reflection on the Past

The integration of site specific, accurate, and relevant records or data sets in landscape architecture has a long tradition. It led to the establishment of the Geographic Information System (GIS) in 1963^①, which was raised to the next level by Ian L. McHarg in his book *Design with Nature*. Fostered by continually more complex environmental challenges, landscape architecture is often put on the same level as the term “ecosystem services.” As a result, data from the area of “blue and green infrastructure” tends to have more influence in the planning process than data relative to the character and inherent characteristics of a site and its future user groups.

When one examines the central message of *Design with Nature* today almost 50 years after its publication, it is remarkable to note that despite all technological advancements and recordings of endless data sets, we have not been able to design together with the immense power and flow of the landscape^[1]. As concluded by Richard Weller, Frederick Steiner, and Billy Fleming: “McHarg meant that the way we occupy and modify the earth is best when it is planned and designed with careful regard to both the ecology and the character of the landscape.”^[2]

① Roger Tomlinson's pioneering work to initiate, plan, and develop the Canada Geographic Information System (CGIS) resulted in the first computerized GIS in the world in 1963.

4. 该项目旨在通过听觉分析VR中的抽象空间的体验。声源来自中国南京：均经由抽象化，以一种空间建构的方式得以表达。这种新的空间构成与芬兰景观的“原型”相互呼应，形成了一种新的空间形态。该项目试图研究受声音和景观本身影响的设计策略的基本方向和导航行为。在实验中，声音与其来源之间的联系及空间规模和联系被模糊化，以增强VR的效果。该项目突破了视觉和听觉之间的界限，将听觉体验转化为视觉体验，以表现与场所和声音相关的不同体验。该项目由詹娜·阿霍宁和艾达·格里希特完成。

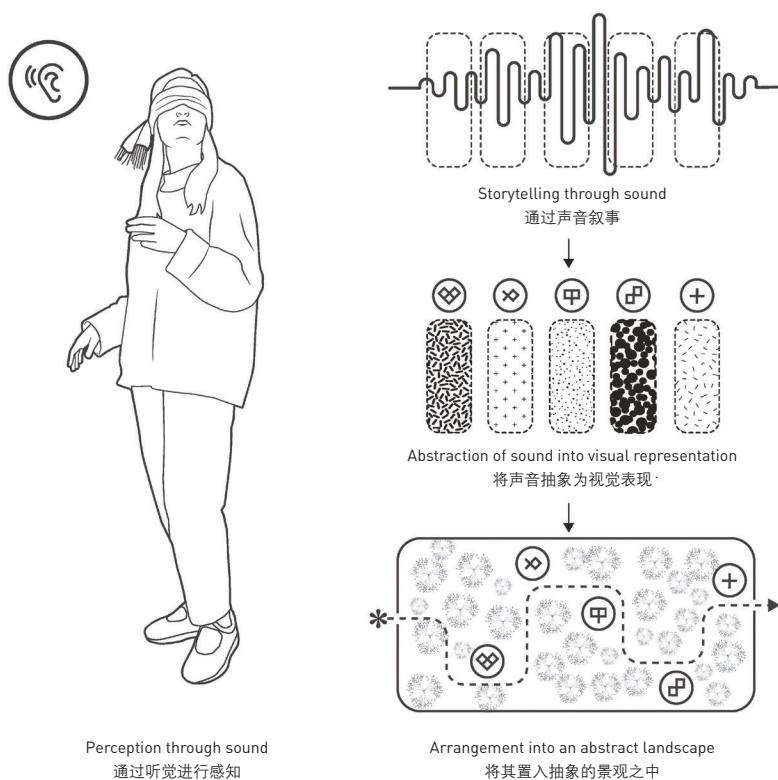
4. The conceptual idea of the project was to analyze the experience of an abstracted space in the VR environment through sound. The sound sources were captured in Nanjing, China: all were abstracted and expressed in a spatial construct. This new spatial configuration was then juxtaposed onto the "prototype" of a Finnish landscape to create a new composite. The project aimed at researching basic orientation and navigation behaviors influenced by design decisions relative to




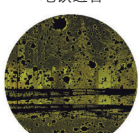
sound and landscape. Within the experiment, the connection between sound and their sources, as well as the scale and relations of space were blurred to enhance the effect in VR. The project pushed the boundaries between the visual and the audio, translating audio experience into a visual articulation in order to represent different experiences related to place and sound. This project is conducted by Jenna Ahonen and Ayda Grisiute.

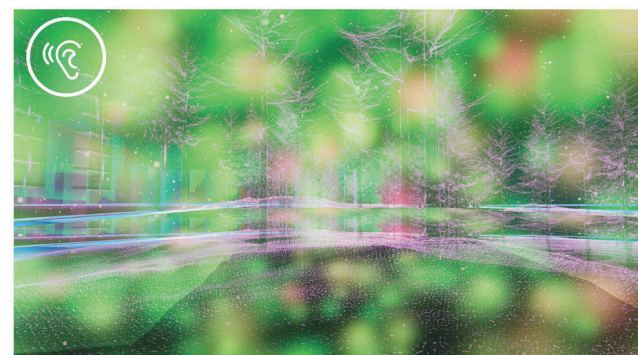
2 Let Us Experience Data

Within the international discourse on the theme of Big Data, the introduced projects are part of an ongoing research into visionary application fields of human interaction with large-scale environmental data flow in the realm of Virtual Reality (VR) and Mixed Reality (MR)^[3]. Special focus is set on the research of temporal, interactive, visual, and audio elements.

While urban areas play a key role in attaining sustainable development, planning and design is struggling with insufficient methods to deal with the increasingly complex emerging challenges to landscape and cities. Artificial Intelligence (AI) in connection with immersive tools such as VR and Augmented Reality (AR) are rapidly emerging as a part of our daily lives. The MR technology offers an unprecedented opportunity to understand, design, and manage our surroundings better. They possess great potential for illustrating alternative visions of our environment and supporting discussions of the implications between people of different disciplines, professions, and backgrounds. Moreover, through the integration of MR, new technologies are given new possibilities of dealing with abstract data sets, not only to gain direct access to data visualization, but also to be able to define a new level of co-design in the broad theme of participative processes^[4].



-  Retail advertisements
零售广告
-  University radio
校园电台
-  Metro announcements
地铁通告
-  Public radio streaming
公共广播电台



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5. VR技术提供了探索景观设计时间维度（季节变换、昼夜更替）的机会。通过由Cinema 4D集成的植被参数模型，可以体验和评估景观设计的特殊品质。该项目由埃娃·迈亚·埃克曼和海蒂·塞斯托完成。

5. VR offers the opportunity to discuss the temporal (seasons, day-night) element of landscape design. Through the integration of parametric models of vegetation within Cinema 4D, the special qualities of the landscape design can be experienced and evaluated. This project is conducted by Eeva-Majja Ekman and Heidi Seesto.



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This is closely connected to the central message of McHarg and is placed in critical relation to current practice by Alan Berger: “We must deploy design intelligence with powerful new analytical tools to creatively recover pieces of regional landscape systems left in the wake of short-term economic schema, political indecision, ad hoc development, a negligent public, and flawed environmental policy.”^[5]

3 MR-Based Collaborative Design

Immersive technologies allow for an intuitive interaction of people of various backgrounds; the interaction is comparable with natural processes in real environments^[6]. VR and AR do as well enable us to have more informed prototyping, allowing iterations with little loss of time. Within the foreseeable future, the usage of VR devices and different kinds of online real-time apps will be part of our daily life.

Up until now, the developed participatory systems integrating VR could not contribute real findings into the process and do not

transmit any hidden layers of a place or an immersive connection to the history of the place. That is primarily due to the fact that current methods for the integration of VR and AR for participative processes previously placed their focus on immersive spatial experience, especially on the detailed modeling of future scenarios.

Contrary to current trends, the overcoming of technical hurdles of photorealistic visualization in VR, professor Pia Fricker focuses on the development of co-design methods, which combine different themes like AI, robotics, VR, data-visualization together in one platform. Already in 2016 within the framework of one of the first research colloquiums on the subject, central guiding questions were developed, which were used as a higher-level framework and addressed in professor Fricker’s project as well.

Technologies are available where the innovative application areas can coexist within large-scale planning and design activities. However, the questions remain: how can the symbiosis of the themes of big data, VR / AR, and robotics capture new possibilities for the profession of Landscape Architecture and urban design? What kinds of experiences do we create through the engagement of data in virtual spaces? How can we achieve a new way of participatory

- ② Virtual Cinema Lab (VCL) is the front-end for content facing VR research at Aalto University. It connects researchers, educators, and industry professionals. VCL's research is focusing on developing the workflows for content creation in emerging media technologies as well as developing strategies to use these tools to tell stories and convey emotions in order to promote and accelerate their implementation within the industry.
- ③ The electroencephalogram (EEG) is a non-invasive neuroimaging technique that measures brain voltage fluctuations at scalp electrodes. These fluctuations are generated by post-synaptic potential changes from a large number of simultaneously active and similarly oriented cortical cells.
- ④ The Galvanic Skin Response (GSR), also named Electrodermal Activity (EDA) and Skin Conductance (SC), is the measure of the continuous variations in the electrical characteristics of the skin, i.e. for instance the conductance caused by the variation of the human body sweating.

or collaborative systems by integrating VR in order to understand the complexity and potential of the future task, i.e. integrating the challenges of climate change, national and international societal challenges, etc.? How do these interrelated questions on data sets offer new vantage points on the landscape architectural ramification of climate change, extending and amplifying our understanding of ideas such as resiliency, sustainability, and eco-technology? ^[7]

One important part in this research constellation is the interdisciplinary aspect. The collaboration with researchers out of the area of film, being part of Aalto's Virtual Cinema Lab^②, opens up to the experience in the area of storytelling and their importance. Synes Elischka points out that cognitive neuroscience reveals the power of storytelling by measuring that narrative "films can exert considerable control over brain activity and eye movements."^[8] The integration of the field of aspects of the human cognitive neuroscience system, such as perception, experience, memory, and decision making for the development of meaningful future-oriented methods for sustainable urban design and landscape architecture are elements of the ongoing research. The integration of research methods to analyze user experience data, including data from bio-signals such as electroencephalography (EEG)^③, Galvanic Skin Response (GSR)^④, opens up a new dimension in application possibilities, as they have opened up a new understanding of interaction with abstract data as a source to re-imagine alternative futures^[9].

Although machine learning techniques, like clustering and classification, and the use of neural nets in deep learning have been already employed in big data analysis, their potential for aiding design and community decisions in landscape and urban planning is still largely unexplored^[10]. Within the test cases explored in the research, workflows make use of real-time data analysis to test out design scenarios and make informed decisions based on current real-world data acquired from satellites or gathered on the field. Thus, this integration is facilitated through special VR / AR environments made fit for the task^[11].

4 Outlook

The resulting cutting-edge spatial reality aims to open up new ways of simulation and integrating of participatory processes in environmental design and urban development to give sustainable answers to societal and environmental challenges and to shape the future. The novelty in the research project lies in the direct and effortless involvement of humans into the design process to empower them to play an active role in the process and enhance their future wellbeing. The next step will be the investigation of

robotics and related technologies in physical augmentation, as they play a key role in many disciplines which require complex decision-making, for example digital fabrication techniques which enable crafters to produce complex mechanical parts^[12]. Complex decision-making involving sometimes hundreds of parameters and key players is inherent in the landscape and urban design field. In this context, robotics can provide a link between the VR / AR environment and the physical world to utilize interactive and intuitive spatial interfaces like augmented urban and landscape models^{[4][13]}. Changes done on these models through human interaction or machine actuation can be fed back into the digital environment through 3D scanners and cameras and enable real-time integration in the design process. Investigating and prototyping these kinds of augmented design environments, which integrate relevant real-world data in the design and decision-making process, would be the primary research goal in the next stage. **LAF**

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