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# Exploring Augmented Reality Waste Data Representations for Eco Feedback.

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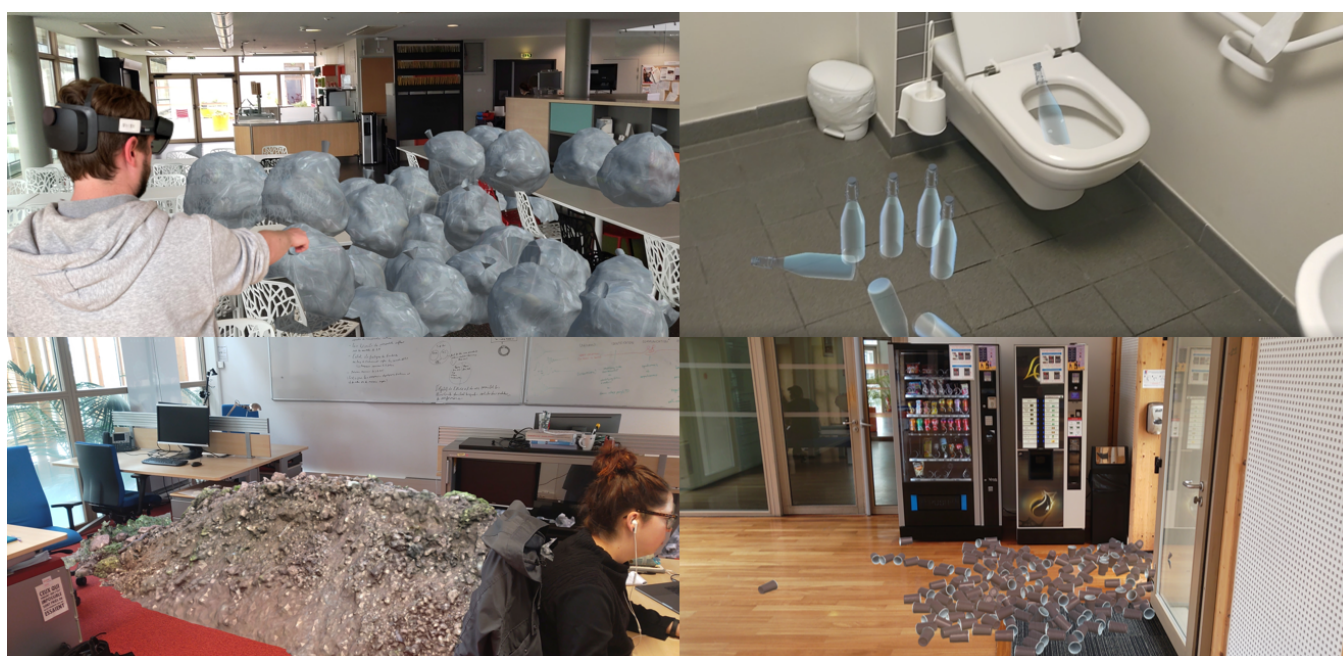
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**Figure 1:** Illustrative examples of ARwavs we prototyped. (a) On the top left hand corner, a user looks at the amount of waste produced by his corporate restaurant in a week. The waste is represented by virtual trash bags which are displayed directly in the restaurant using augmented reality. (b) On the top right hand corner, 9 Litres of water represented using water bottle next to the toilets (average flush amount of water). (c) On the bottom left, the approximate amount of material displaced and emitted to manufacture 8 smartphones. (d) Bottom right, the quantity of single-use plastic cups accumulated for a given period of time. Captured with Hololens.

## ABSTRACT

In this demo, we show how Augmented Reality can be used to visualize waste accumulation data in an engaging and visceral way.

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The negative impact humans have on the environment is partly caused by thoughtless consumption leading to unnecessary waste. A likely contributing factor is the relative invisibility of waste: waste produced by individuals is either out of their sight or quickly taken away. Nevertheless, waste disposal systems sometimes break down, creating natural information displays of waste production that can have educational value. We take inspiration from such natural displays and introduce a class of situated visualizations we call *augmented-reality waste accumulation visualizations* or ARwavs, which are literal representations of waste data embedded in users'

familiar environment. We implemented examples of ARWAVs and will present them at the venue.

## KEYWORDS

Visualization, Concrete Scales, Augmented Reality, Embodied Interactions.

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## 1 INTRODUCTION

The adverse impact humans have on the environment (through, e.g., air pollution, plastic pollution, soil erosion, or damage to biodiversity) is one of the biggest challenges currently faced by our society. Although the causes are complex and numerous, individual behavior and lifestyles have been identified as among the key contributors [1, 11]. A factor that likely contributes to the excessive consumption and unnecessary waste production is the *invisibility* of waste there: when we buy a new smartphone, we do not see the metal mines that went into its construction; Even when we directly create waste, it quickly goes away and becomes invisible (dirty water flow to the treatment plant after showering or flushing, trash is picked up by garbage collectors). We propose to use augmented reality to recreate these accumulations in the direct surroundings of users. These visualizations fill a gap in eco-feedback research [9], where most systems convey resource consumption and waste production using units and visual representations that are useful but often abstract and potentially difficult to grasp intuitively. Because ARWAVs use literal representations of waste amounts [5] (e.g., 300 litres of garbage can be represented with ten 30-litres trash bags), we expect them to give a more visceral sense of quantities and stand as more engaging representations. However, ARWAVs may not be self sufficient in some situations, as when a quick value judging is necessary. Hence, we are starting to explore embodied transitions with 3D classic aggregates (barplots, tables...) and include them in our demonstration. We already conducted a study suggesting that ARWAVs yields more emotions compared to less immersive display modalities (3D on screen) and simpler information representations (numerals); results are under review and available as a preprint [2]. In this interactivity paper, we : (1) Present the prototypes we plan to demonstrate: several 1:1 scale ARWAVs pictured within scenarios and an embodied way of transitioning with 3D aggregates. (2) Explain the advantages of participating in this interactive experience and clarify the opportunity of initiating novel discussions among the community.

## 2 BACKGROUND

In this section we give an overview of AR-HCI research on eco-feedback, i.e., “*technology that provides feedback on individual or group behaviors with a goal of reducing environmental impact*” [9] and will present some related work in information visualization. A complete related work review is available at <https://hal.inria.fr/hal-03907474>.

### 2.1 AR Eco-Feedback interfaces

Some explorations in AR has been considered for eco-feedback technologies like AR overlays of energy consumption on physical building models [7], and heat cameras to visualize thermal loss [3]. But as far as we know, enhancing real-world environments with AR for eco-feedback purposes has been only mentioned as a possibility in past research (e.g., in [4, 8, 12]). The only example of ARWAV we currently know of is a mobile app where users can visualize a year worth of trash bags in augmented reality [13]. This prototype has directly inspired our work, but has not been discussed in the academic literature, nor has it been generalized to other cases or evaluated. This paper fills this gap.

### 2.2 Information Visualization

Strategies for representing large quantities or unfamiliar units next to familiar landmarks have been formalized in information visualization under the *concrete scale* framework [5]. Inspired by this framework, Lee et al. [10] introduced the concept of *data visceralization* focusing on VR experience, as “*a data-driven experience which evokes visceral feelings within a user to facilitate intuitive understanding of physical measurements and quantities*”. These article does not discuss eco-feedback as a possible application and the latter identify AR as a possible direction for future work. Following Drucker and Fernandez[6] definition, ARWAVs are unit visualizations: “*each data item becomes a unique visual mark; such visualizations strictly maintain the identity of each visual mark and its relation to a corresponding data item.*”<sup>1</sup>. However they may not be adapted to every situations: one could benefit from the advantages of aggregates regarding value judging or readability. Animations and transitions on on-screen unit representations are already explored to tackle its weaknesses[6]. In our scope direct interactions enabled by AR units and 3D representations of classic aggregates 1 (barplot, graph...) opens of wide range of explorations toward embodied transitions.

## 3 IMPLEMENTATION

The ARWAVs were implemented with a Microsoft Hololens 2. The see-through holographic display was equipped with 4 visible light cameras for head tracking and map building. IR-reflectivity steams are used to compute depth along with a depth camera that operates in two modes: high-frequency (45 FPS) near-depth sensing used for hand tracking and low-frequency (1-5 FPS) far-depth sensing used by spatial mapping. The display is equipped with speakers enabling built-in spatial sound. We developed with Unity 2020.3.18f1 and used the MRTK toolkit<sup>2</sup>. We enabled hands, head tracking, and set the spatial awareness module to scan the environment at start (update interval of 3.5 seconds). The objects making up the ARWAVs (trash, bottle, mud and plastic cup) where either found on the Unity Asset Store or download and adapted from free 3D models browsers<sup>3</sup>. The abstract representation have been adapted from

<sup>1</sup>They are distinguished from aggregate visualizations (i.e. in which multiple data item are merged into visual aggregates that cannot be separated and that does not keep identity properties)

<sup>2</sup><https://docs.microsoft.com/fr-fr/windows/mixed-reality/develop/unreal/unreal-mrtk-introduction>

<sup>3</sup><https://free3d.com/>, <https://www.turbosquid.com/fr/>, <https://sketchfab.com/store/3d-models>

Unity Packages<sup>4</sup>. They have been modified to take input from csv files with the data shown. We adapted the visualizations to make them AR compatible, enable manipulation of elements and make them dynamic to interact with units.

## 4 WALK-THROUGH

Augmented-reality waste accumulation visualizations or ARWAVs aim to help people better perceive the quantitative impact of their actions and decisions in order to inform them, raise their awareness, or encourage them to change their habits. Figure 1 (a) illustrates a scenario where employees can perceive directly in their corporate restaurant a week of collective waste production represented with virtual trash bags. In the following sections we introduce the ARWAVs we'll present at the venue. The last scenario put in context our current explorations on transitions with more classical representations such as 3D bar charts.

**Scenario 1: Personal motivation, water use.** Water is a resource that many of us abundantly use at home when we take a shower, wash our hands, flush our toilets, or use appliances like washing machines. As water immediately disappears through the pipes, it can be hard to get a good impression of the amount we use over time. Knowing numbers is a good start, but is likely not enough. For instance, it might not seem a lot to consume 5 m<sup>3</sup> of water in a month, but it actually represents about 28 full bathtubs, or an average bathroom filled with water up to 2 m high. ARWAVs can literally show these volumes of water to make abstract numbers more concrete. Figure 1 (b) shows an example where a user sees the amount of water used for a flush next to the used toilets.

**Scenario 2: Group dynamics, ecological rucksack.** Computers and mobile devices are powerful tools with many useful applications, but they have a significant ecological footprint. One way to capture this footprint is the concept of *ecological rucksack*, which is the amount of matter displaced to build an object.<sup>5</sup> A smartphone requires an ecological rucksack of about 70kg, which includes the amount of soil mined to obtain the metals that go into its fabrication, and the amount of CO<sub>2</sub> emitted during transportation and manufacturing.<sup>6</sup> Since the metal mines and the CO<sub>2</sub> emissions are typically situated far away from where the phone is purchased and used, it is hard for people to have a vivid picture of them in their mind, even when they heard about them. In addition, computing devices often look clean and beautiful, so looking at them does not bring about any association with mines, soil, or greenhouse gases. With ARWAVs, we can make those waste products more salient to users. For example, imagine a research team discussing whether to buy eight new smartphones for a project or use old ones. An eco-conscious member of the team could use AR to show them the size of the ecological rucksack necessary to build the new phones, as a pile of soil (Figure 1 (c)). Having this heap of soil appear as if it was in the room (as opposed to, e.g., on a computer screen or a magazine) could give the team members a more visceral sense of quantity and size. It also adds a dramatic dimension, which can

help make environmental issues more salient and more influential in the discussion.

**Scenario 3: Support for policies, plastic cups.** Single-use plastic cups have a negative repercussion on the planet. It is estimated that more than 50 billions are used in the US in one year.<sup>7</sup> Yet manufacturing them is costly in energy and resources, they are hard to recycle, and they are one of ten most commonly found waste items in European beaches<sup>8</sup>. However, plastic cups are still routinely given away in cafés, shops and companies, and thus it remains easier for many people to use them instead of bringing a reusable cup. In this third scenario, a company chooses to ban plastic cups as part of a program to reduce its ecological footprint, but is afraid that not all of its employees will agree. The company has already communicated about the issue through figures and charts, but they went largely ignored. Therefore, the company decides to organize an event, with a booth in front of the coffee machine, where employees can observe through an AR-HMD (Head-Mounted Display) an ARWAV composed of all plastic cups typically used over a week (see Figure 1 (d)). With this immersive experience, most employees get a much better sense of the amount of plastic cups accumulated over time, and many become more willing to make the effort to bring their own reusable cup.

**Scenario 4: Transitioning with classic representations in the 3D space.** In scenario 3, a company organized an event for plastic cups usage awareness. The organizers have in mind to recreate this meet-up to sensitize about the company's waste. However, the charts they want to communicate are large datasets and the ARWAVs they want to use (50L trash bags) are quite voluminous. This makes the experience difficult to put up. The marketing team choose to keep charts as they present advantages including easiness on value judging or readability on large datasets; however they don't want to drop ARWAVs that were appreciated for their emotions raising. To keep both, they introduced a 3D barplot in the AR space and allowed embodied transitions with ARWAVs. Employees can grab a bar from the barplot and throw it on the floor to see the amount of trash bags it represents appear and get the scaled reality of it. They can grab the trash bags and put them back in the chart to clean the space and continue to navigate in the dataset.

## 5 DEMONSTRATION

*In the demo booth, we plan on showing the average amount of water used for a 6'30 min lasting shower with water bottles, the amount of soil needed to build 5 and 10 smartphones, the amount of plastic cups use in a day at our lab (before the no-plastic recent policy) and an example of transitions between a barplot about trash emission and ARWAVs.*

ARWAVs act as situated information displays that are unique in their ability to convey waste production in a way that is immediately understandable by a large audience and can carry emotional impact. Testers get to experience these with integrated scaled Holograms that may raise some awareness and initiate self-reflections. They will also be able to appreciate several embodied ways of transitioning from more classic representations of the same data. To

<sup>4</sup><https://assetstore.unity.com/packages/tools/gui/3d-interactive-bar-chart-157887>

<sup>5</sup><https://www.gdrc.org/sustdev/concepts/27-rucksacks.html>

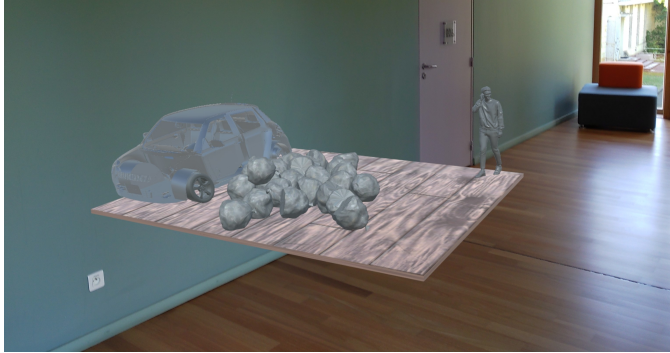
<sup>6</sup>[https://ec.europa.eu/environment/ecoap/about-eco-innovation/experts-interviews/friedrich-schmidt-bleek\\_en](https://ec.europa.eu/environment/ecoap/about-eco-innovation/experts-interviews/friedrich-schmidt-bleek_en)

<sup>7</sup><https://plastic.education/the-problem-with-disposable-cups/>

<sup>8</sup>[https://ec.europa.eu/environment/pdf/waste/single-use\\_plastics\\_factsheet.pdf](https://ec.europa.eu/environment/pdf/waste/single-use_plastics_factsheet.pdf)



tackle the potential layout issues and people flow abundance, we developed a 1:10 scale scene showing ARWavs, see Figure 2. This *mini mode* allow observers to see the entire ARWAV without having to move their head or step back. This version will not be showed systematically, but will be if it is appropriate within the discussion with the tester or if it is more convenient due to the layout business. Not only this version tackles layout limits but it also fits Hololens



**Figure 2: Miniature view of an ARWAV, with a car and standing man silhouette as reference points.**

2 boundaries; indeed, the display FoV is ( $43^\circ \times 29^\circ$ ) which does not allow to get the full AR scene without moving. Through this scaled version, users can have a first appreciation of the possible trade-offs that can be operated for such AR visualizations and these elements will be even more relevant for HCI or visualization researchers. This large-scale expert conference is a great opportunity to put light on of the challenges of eco-feedback. More broadly this interactive experience will potentially generate discussions in the community to imagine and design around environmental issues. The conference already shows sustainable HCI interests through workshops and talks and this demo will suitably feed these exchanges. Also, experts feed-backs are precious to push our work in the best direction.

## 6 CONCLUSION

In this paper, we presented *augmented-reality waste accumulation visualizations* or ARWavs, which are literal representations of accumulated waste embedded in users' physical environments. We went through several examples of ARwavs to illustrate the variety of situations where they can be useful. Minimizing the negative impact of humans on the environment is an incredibly complex problem, and ARwavs could play a useful role if they usefully inspire future research or demonstrate to successfully engage visitors.

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