A Design Space for Audience Sensing and Feedback Systems

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Abstract
Audience feedback is a valuable asset in many domains such as arts, education, and marketing. Artists can receive feedback on the experiences created through their performances. Similarly, teachers can receive feedback from students on the understandability of their course content. There are various methods to collect explicit feedback (e.g., questionnaires) – yet they usually impose a burden to the audience. Advances in physiological sensing opens up opportunities for collecting feedback implicitly. This creates unexplored dimensions in the design space of audience sensing. In this work, we chart a comprehensive design space for audience sensing based on a literature and market review which aims to support the designers' process for creating novel feedback systems.

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audience sensing; affective computing;

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H.5.3 [Information Interfaces and Presentation]: Group and Organization Interfaces

Introduction
Gaining feedback from an audience has focussed on live events such as concerts or plays. The audience

reacts to the performance and artists can take this feedback into account and react accordingly. With the advancement in sensing technologies, more implicit approaches for collecting audience feedback have been introduced. In this paper, we present a design space that categorizes the different and novel facets of audience feedback systems based on five dimensions. Through two scenarios we showcase how this new expanded space can help designers answer design questions and drive their design process to consider various dimensions of novel audience sensing systems.

Audience Sensing

Obtaining feedback from the audience is valuable for many domains, including, but not limited to, recommender systems, education [6, 8] entertainment and performance arts [10, 15]. In performance art, audience engagement and enjoyment can be a tool to evaluate how the audience perceives a performance [10]. In education, measuring students' mental workload and emotions in class, can be a metric to predict their learning outcomes [6]. Evaluating media content such as TV series, commercial audience sensing systems exist. These mainly focus on the viewing behavior and subjective feedback from the audience through diaries.

Explicit and implicit sensing techniques have been utilized for obtaining audience feedback. Explicit systems for collecting large-scale feedback are widely available. For example, surveys and voting systems are used during live performances, presentations and lectures (e.g. [2, 18]) to gather feedback. While these methods have their virtues and are straight-forward to interpret, they impose several challenges. Polling devices used to provide real-time feedback usually put effort on the audiencer [10]. Other forms of explicit feedback are usually collected at the end of the performance, or lecture. While this provides a general overview, these methods miss out on valuable fine-grained feedback [8, 10].

Advances in physiological sensing created an opportunity for employing sensors to implicitly sense the status of the audience and provide objective, fine-grained feedback.For example, in theater, feedback on audience excitement was implicitly collected using skin conductance levels [15, 19]. In learning contexts, feedback about students' cognitive workload and engagement was implicitly sensed using electroencephalography [8, 16]. Recent technology advancements are changing performances, classrooms and meeting rooms. These domains are moving from traditional one-to-many scenarios to cover more dimensions of location, timing, and different stakeholders. Performances are no longer constrained to collocated artists performing on stage [20]. Modern teaching techniques are moving away from traditional classroom scenarios to flipped learning [16]. Overall, the barriers between performers and audiences in all domains are slowly vanishing.

Through a literature and market research on current audience sensing and feedback systems using the terms *audience feedback, sensing*, we chart the design space based on more than 30 research and market applications. We expand the existing space taking into account the new arising dimensions due to sensing technologies and different models of performance and presentation to audiences.

Design Space Dimensions

Table 1 depicts the design space with exemplary related work positioned in the respective cells. The empty cells show the prospective opportunities for designing further novel systems covering the whole space.

Sender Receiver Cardinality	Audience Feedback Style: Explicit — Audience Location: Collocated	Explicit — Distributed	Implicit — Collocated	Implicit — Distributed	Synchronicity of Feedback
1:1			Pay Attention[b][17], Chollet et al.[e][4], Mello et al.[c][6], MACH[9][e], Yan et al.[b][22]		Sync
1:1			Artful[16][b], ROCSpeak[7][e]	Artful[16][b]	Async
N:1	CrowdFeedback[b][18], Live Interest Meter[b][13], Chamillard[b][3],	Curmi et al.[e][5]	EngageMeter[b][8]		Sync
N:1	Live Interest Meter[b][13]		EngageMeter[b][8], Ranjan et al.[e][12]		Async
N:N	Backstage[b][2]	WorldCupinion[b] [14]	Cheering Meter[e][1]	Bravo[b][11]	Sync
N:N		Netflix Viewing Data[e,2]	Latulipe et al.[b][10], Silveira et al.[b][15], Wang et al.[b][19]	Netflix Viewing Data[e,2], Nielsen TV Meters[e,1]	Async

Table 1: Design space dimensions: Sender-Receiver cardinality, Feedback style, synchronicity, Audience location & Sensor location (indicated by the superscripts *(b)* for on-body & handheld sensors, *(e)* for environement-based, *(c)* for combinations of both.

Sender and Receiver Cardinality

In audience sensing and feedback systems, information is typically sent by one or more audience members (sender). A receiver is one or more stakeholders interested in receiving this information. This perspective implies that there are several options for sender (sensed person) and receiver cardinality: one-to-one, many-to-one, and many-to-many respectively.

In one-to-one settings, the 'audience' consists of one sensed person. This is typical for adaptive education systems such as one-on-one teaching, where the teacher or system receiving feedback needs to respond to the state of one student. Research explored adaptive techniques tailoring feedback on students' engagement [17, 16] or affect [6, 21]. An example, where the receiver is a system, is an advertising screen that, based on the mood of the person in the vicinity, decides which content/advertisement to show. One-to-one can also mean that the sender and receiver are the same person, constituting a feedback loop. For example, users can prepare and enhance their public speaking or social skills with the use of automated systems giving feedback [7, 9].One-to-many refers to one presenter and multiple audience members. This is the case in a regular classroom context, a public speech, or a media producer who is interested in audience opinions. This has been broadly explored in prior work on explicit feedback sensing [3, 18]. Many-to-many situations arise if several stakeholders on the presenter side exist, such as theater actors, directors or TV commercial producers [10, 15, 19, 22].

Location of Audience

The audience location with respect to the presenter constitutes an important dimension of the design space. Audience and presenters could be *collocated* or *distributed*. An audience attending a performance or students in a classroom are *collocated* with the presenter/performer. Collocated audience and presenters have been subject to prior research in explicit [13, 18] and implicit [15, 19] feedback systems.

The rise of online learning platforms created the model where students study at home and class is used for activities and questions. In this case, the audience (i.e., students) is *distributed* in location. Sensing and responding to the cognitive state of students is particularly useful to make sure learning outcomes are achieved without being in class. Another example of a distributed audience is TV show screenings where feedback drives show ratings. Several entertainment platforms currently use ratings collected from a distributed audience to drive decisions about their presented media (e.g., Netflix Viewing Data).

Feedback Synchronicity
The feedback given to the presenter or producer of presented content can be *synchronous*, that is, in real-time for the presenter to directly act upon, or *asynchronous* so as to reflect on it post-hoc. Asynchronism of feedback refers to both the timing of providing the feedback to the presenters and the way in which the feedback was accumulated over time.

Synchronization of feedback strongly depends on the context and the envisioned value of feedback timing. *Synchronous feedback* provides opportunities for immediate reaction. An example is detecting declines in students' engagement in class and attending immediately to it [18, 8]. Synchronous feedback also poses challenges, for example, presenters can be distracted as they need to interpret feedback in real-time. Post-hoc feedback allows presenters to reflect on points of weakness in their presentation. *Asynchronous feedback* could be valuable in performance arts and TV shows where the collected feedback per performance or episode can be accumulated and used to enhance the series/performance in the long-term.

Sensor Location
Sensor data can be collected *on-body* (e.g., a wristband), from the *environment* (e.g., a camera), or through a combination of sensing technologies. On-body sensors include psycho-physiological sensors, mobile eye trackers, or smart glasses, which can provide insight about users' cognitive state. We also include hand-held devices as they are with the audience. A drawback is the need to wear a device, which may cause discomfort and social awkwardness or create effort to hold it and actively enter feedback. Environment-based sensors include audio sensors which sense crowd sounds such as applause, cheering or cameras and microphones to detect speaker changes [1, 12]. A combined solution with environment and on-body sensing could provide a more accurate view of the audience state and help leverage the advantages of both [6, 21].

Feedback Sensing Style
Feedback can be provided implicitly or explicitly. Implicit feedback refers to measuring information about senders without them being consciously aware of it (e.g., sensing mood or level of engagement). In contrast, explicit feedback mainly captures subjective responses of the user, for example, through questionnaires, diary, or dedicated applications (e.g., [18, 14]). Note, that there may be cases where this distinction is not clear, for example, social media posts (explicitly provided by users) may be mined to obtain a larger picture of the current overall mood of all users (implicit).

Using the Design Space
Through two exemplary scenarios, we showcase how the design space may supports the creativity of designers and facilitate defining technical implementations.

Scenario 1: Distributed Students' Stress Awareness
Stress in academic life is an aparent problem that impacts the performance and mental wellbeing of students. Being aware of students' wellbeing can have

benefits on the individual level (per student), as well as drive the collective policy of the college or school. Approaching the use case of designing a collective student stress sensing and feedback system can start with answering several questions based on the defined design dimensions. For example, who are the system stakeholders? Possibly the students are interested in their own stress levels (1:1), their lecturers maybe interested in the collective trends of their stress levels (N:N). What will the *stress sensing style* be? Explicit sensing can be done by regular surveys on the phone, implicit sensing can be done using physiological and environmental sensors. Using cameras on campus and heart rate wristbands on students may reduce the effort on students to continously supply feedback. Stress sensing is not only done during *colocated* classes, but also in a *distributed* manner through their work and life on campus. Answering these questions, the designer would get a further deeper insight about the different opportunities for designing the system.

Scenario 2: TV Event Rating
Distributed audience engagement and emotional assessment during a TV event could provide valuable feedback – both for particular scenes or overall to the enteratinment industry. Designers of such a system may consider the dimension of *feedback synchronisity* depenting on the presented media. For example, a real-time feedback design could be useful during a sports event where a goal or controversial decision made by the referee creates a lot of engagement among the audience. In such cases, the director may decide to instantly offer a replay of the respective scene. Aysnchronous post-hoc feedback with fine-grained data on audience engagement could help screenplay writers or directors to identify scenes that received high uptake among the audience. As a result, future episodes could exploit this information by adjusting the plot or through the choice of actors to further increase engagement.

Conclusion
We presented a novel expansion of the design space of audience feedback incorporating new dimensions of sensing style, location, synchronization and cardinality of stakeholders, accounting for new trends in sensing, and the blurred lines between audience and presenters. We envision that this space would foster designer creativity and support design processes.

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