ATLAS data sonification: a new interface for musical expression and public interaction

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The goal of this project is to transform ATLAS data into sound and explore how ATLAS audio can be a source of inspiration and education for musicians and for the general public. Real-time ATLAS data is sonified and streamed as music on a dedicated website. Listeners may be motivated to learn more about the ATLAS experiment and composers have the opportunity to explore the physics in the collision data through a new medium. The ATLAS collaboration has shared its expertise and access to the live data stream from which the live event displays are generated. This talk tells the story of a long journey from the hallways of CERN where the project collaboration began to the halls of the Montreux Jazz Festival where harmonies were performed. The mapping of the data to sound will be outlined and interactions with musicians and contributions to conferences dedicated to human-computer interaction will also be discussed.

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1. Introduction

Quantizer is a project that transforms live collision data from the ATLAS Experiment at CERN [1] into an audio stream. The project seeks to explore how creative musical pieces can educate and inspire artists and the general public. An associated web page (www.quantizer.media.mit.edu) enables the public to listen to real-time experimental data. Music is a very popular medium, used by ATLAS for public outreach both as an explanatory tool, and as a means to reach new audiences. Quantizer specifically:

- **Who**: Targets members of the public with an interest in music or science, who might or might not already be familiar with the experiment;

- **When**: Provides continuous music streams, either via the live transformation of LHC collisions or via pre-recorded data when the LHC is not in collision mode;

- **Where**: Engages a worldwide audience, requiring only access to the internet;

- **How**: Encourages listeners to further explore ATLAS, the LHC, and particle physics, as well as the methods of sonification. It also invites the public to compose their own musical streams and in the process learn more about ATLAS and the role of data in experimental physics.

2. ATLAS, Data, Tools, and Sonification Methodology

ATLAS is one of the main detectors at CERN's Large Hadron Collider (LHC). The ATLAS Collaboration uses the detector to probe some of the deepest questions of nature: "What is the nature of dark matter?", "What is the origin of mass?", and "Are there any deeper symmetries that govern the laws of our universe?". A tiny subset of particle collision event data is routed through a sonification engine designed to map incoming data to audio properties in real-time.
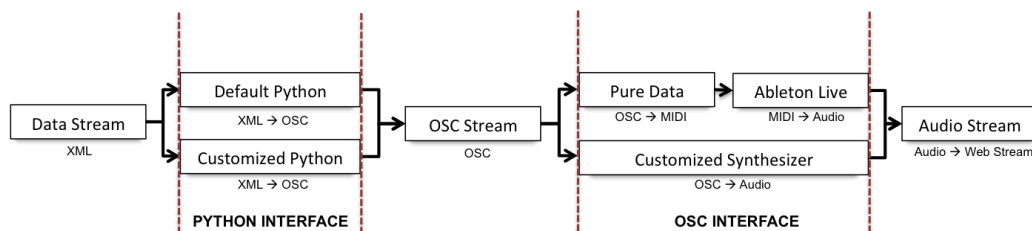

Figure 1: Chart depicting flow of data through the Quantizer platform [2].

The Quantizer sonification platform was designed so that anyone can compose music and learn about particle physics. The composition engine consists of two main interfaces (see Figure 1) that accommodate users of various levels of physics and music knowledge. The default Python interface filters data in accordance with basic approaches used by ATLAS to isolate useful information for an analysis. Physics enthusiasts can choose to write their own custom Python code to parse the data. Composers can choose to integrate custom-built audio synthesis patches to create music driven by the Python filtered data streamed as OSC messages (an industry standard). The default

OSC interface was designed to enable users to easily produce more traditional styles of music. The default and custom interfaces have so far been used to create a variety of musical styles including: samba, blues, classical, pop-rock, electronic, and experimental.

The default sonification engine takes data from the collision event, scales and shifts the data (to ensure that the output is in the audible frequency range) and maps the data to different musical scales. From there, a midi stream triggers sound samples according to the geometry and energy of the event properties. The data currently being streamed includes: energy deposit data from the hadronic endcap calorimeter, energy deposit data from the liquid argon electromagnetic calorimeter, momentum data for particle tracks, and location data from a muon trigger (RPC).
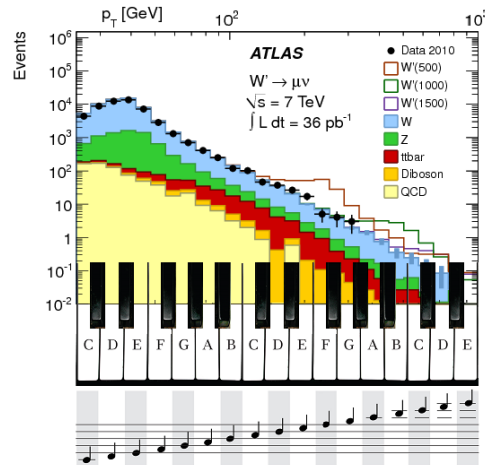
Figure 2: The muon transverse momentum from a W' search [3] binned onto a musical scale.

The default OSC interface translates energy and momentum information from the calorimeters and tracks into musical notes (MIDI notes). This mapping connects a particle's de Broglie wavelength to an audible sound wave as shown in Figure 2.

3. Events

In July 2015 a Quantizer workshop was held at the International Conference on Auditory Display where many participants composed using custom OSC interfaces. At least one participant posted their musical composition online after the workshop. Later that month a live duet was performed at the Montreux Jazz Festival with jazz pianist Al Blatter as part of CERN's "The Physics of Music and the Music of Physics". Al Blatter and the Quantizer team improvised together a 10 minute musical piece based on only hours-old ATLAS data. The platform enabled the composers to customise the tempo, instrumentation, and musical scale to the preferences of the pianist.

In May 2016 a poster was presented at a conference for computer-human interaction held in San Jose - CHI 2016. One CHI paper reviewer commented that "novelty and value of the work arise not just from using the LHC data source, but also in the demonstrated method of artistic engagement with the system and the description of the LHC data." Quantizer's CHI paper [4] is the 5th most downloaded Late-Breaking Work paper (out of 585) and in the top 100 most downloaded

papers of all types at CHI this year (out of 1131). A paper was also given as a poster at the conference for "New Interfaces for Musical Expressions" 2016 [2].

On May 20 2016, the Quantizer website was officially launched to the public (see Figure 3 - left). In the first month of the website being public there were over 28 000 visitors where more than 2000 of them returned to the website (see Figure 3 - right). The visitors were from ~ 150 countries from around the world. Thirty-three visitors emailed the Quantizer group with positive comments and 23 requested to become composers. Several unsolicited articles were also written about Quantizer in at least 10 different languages.
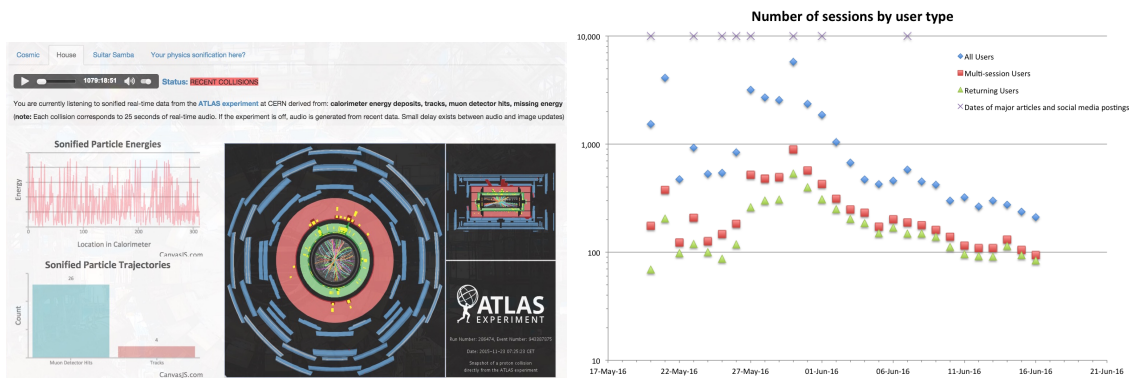
Figure 3: Screenshot from the Quantizer website (left), and a plot of the number of visitors to the website during the first month of its launch.

4. Conclusions

The Quantizer platform is an interesting new tool that has been created to allow live ATLAS data to be transformed into music. It has strong outreach potential by attracting more and new interest in ATLAS and gives composers the chance to interact with the data in a different way. Several public events have taken place that have received positive feedback. Further work is required to improve the platform, share it more broadly, and to evaluate its outreach capabilities. The Quantizer team will work with more composers one-on-one to create more interesting audio.

References

[1] ATLAS Collaboration, The ATLAS Experiment at the CERN Large Hadron Collider, JINST 3 435 (2008) S08003.

[2] J. Cherston et al., *Musician and Mega-Machine: Compositions Driven by Real-Time Particle Collision Data from the ATLAS Detector*, in proceedings of the *International Conference on New Interfaces for Musical Expression*, (2016).

[3] ATLAS Collaboration, *Search for high-mass states with one lepton plus missing transverse momentum in proton-proton collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector*, *Phys. Lett.* **B701** (50-69) 2016 [arXiv 1103.1391].

[4] J. Cherston et al., *Sonification Platform for Interaction with Real-Time Particle Collision Data from the ATLAS Detector*, in proceedings of the *CHI Conference Extended Abstracts on Human Factors in Computing System*, (2016).