SyncTus™

Project Members:

Maxwell Bowman
Ellen Fishman
Kamyi Lee
Elaine J. McCarthy
Camilla Tassi
Ashley Tata
Hanoi Hantrakul (Advisor)

Overview

SyncTus™ :

SyncTus™ is a system that enables the conductor to be at the center of a multimedia live performance experience. As both concert and fully-staged performances increasingly integrate video and more complex media into their designs, a stumbling block can be the synchronization of all these elements in a way that does not disturb the organic relationship between maestro and performance. Media should not dictate the timing of the music -- timing should be led by the conductor. With the use of SyncTus, the conductor will no longer need to follow a click track in such a situation. SyncTus allows a conductor to guide the media as robustly as he/she guides the musicians and performers.

Over the years designers and stage managers have become adept at creating calling systems to synchronize seemingly unwieldy cueing sequences. Many designers and directors recognize that there is a handicap when it comes to total synchronization. With video in particular there is frequently time lost during technical rehearsals in needing to re-render sequences of video cues in order to accommodate the slight changes in timing and specificity. Streamlining this process would provide a sizeable cost and time-saving benefit.

SyncTus™ is a conductor's baton using motion from a 3-axis accelerometer and 3-axis gyroscope, coupled with machine learning to accurately determine the occurrence of a musical downbeat, or "ictus". This allows the conductor to be integrated into the cueing system so media elements (video, lighting, etc) can be cued from their baton, instead of a manual cue from another human. With SyncTus™, a conductor can train the system specifically to their own data -- created during prep time before rehearsal and pooled from other conductors -- to provide a robust signal of the downbeat. This downbeat can then be integrated into other performance playback systems. For example, a video stream clocked to the downbeat of music will now reliably slow down based precisely on the conductors' rubato and other slight variations in tempo. A technical appendix is included at the end of the proposal.

Industry Impact

SyncTus allows for live performance to incorporate advanced audiovisual technology and design without sacrificing musicality and the organic flow of live performance.

SyncTus will save both time and money currently lost to re-rendering visual materials, as well as cueing time spent working towards multi-unit synchronization during technical rehearsals.

Development Timeline

Tier 1

Months (1-4)

- Loose prototype creation and testing
- Digital model creation (3D, CAD)
- Software/machine-learning development (programming and training ictus detection algorithm with data)

Months (4-8)

- Development of 3D-printed baton, embedding sensors/circuitry.
    - Fabrication of circuitry
    - 3D Print the baton

Months (8-12)

- Conductor prototype testing and creating instructional material for use in signal extraction/OSC incorporation
- Possible incorporation of working prototype into production of *On the Threshold of Winter* on April 2020

Tier 2 (Next stage grant needed)

- Improving materials and model of baton (design)
- Data collection: conductors record data with baton and computer
- Refining algorithm on the software end
- Plugin building (Disguise, Watchout, Isadora integration)
- Exploring development of baton-less option with wrist-worn accelerometer device

Budget
The budget below refers to Tier 1 of the project.

Prototype:	
Hardware:	
3D model creation	$1250
3D printing (Shapeways)	$1000
Circuitry materials* (see appendix for details)	$ 100
Circuitry fabrication	$ 500
Software:	
Programming hours, machine learning algorithm training ($60/hr programming rate)	$3000
Data collection & Instructional Material Conductors testing (3)	$3750
Travel	$1000
Postage & Shipping	$ 250
Total	**$11350**

TECHNICAL APPENDIX

Example scenario: The singer of an aria is performing a rubato at the end of the piece. Normally, the lighting designer would have to manually trigger a lighting scene change to synchronize with the rubato. Here, the lighting can synchronize to the slower rubato because of the increasingly long downbeats detected by SyncTus.

One-line description
SyncTus outputs a signal (a “bang” in Max/MSP, or an OSC message or a MIDI note) when it detects the ictus performed by a conductor.

Why is SyncTus any different in 2019?
In the last 3 years, advancements in wearable devices like the Apple Watch and Fitbit have improved the accuracy of onboard sensors such as accelerometers and gyroscopes, in addition to longer battery life in small devices. Coupled with recent machine learning successes in analyzing signals from wearable devices for activity detection (running, sleeping etc.), downbeat detection using sensors on a conductor’s baton is a reasonable proposal. In its current form, we

do not handle video warping capabilities or lighting integration etc. We simply output “an ictus downbeat has happened!”.

Existing Hardware Approaches

Technology	**Limitations**	**SyncTus™ advantage**
Kinect Skeletal Tracking	-Kinect can be momentarily obstructed -Kinect must have full view of conductor	-Device always sends data -No field of view issues
Camera with object tracking	-Requires calibration before every performance. -May be affected by ambient lighting changes. -An entire frame of video must be processed before the baton tip can be localized. -Cumbersome to set up interface	-Calibration less likely -Not affected by ambient lighting -Lower latency. SyncTus uses small packets of data from an accel. and gyro.
Full Body Suit	-Conductor is unlikely to wear a full body sensor suit -Extremely expensive	-SyncTus takes the shape of a traditional baton in weight and size -Basic hardware can be mass produced at <100$
Infrared Tracking	-IR sensors can be momentarily obstructed -IR LED must be in full view at all times -Cumbersome to setup tracking interface, especially if user needs to collect their own data	- No field of view issues

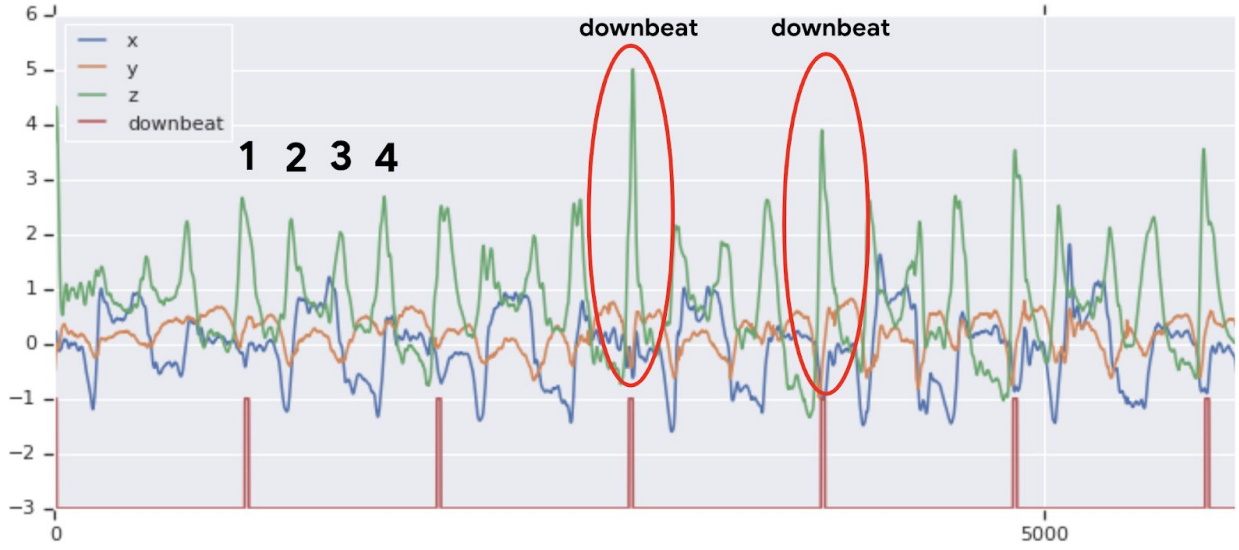
Note: Accurately tracking the location of a conductor’s baton is a *solved technology* using vision based approaches. SyncTus™ is different: it uses lower cost and low-latency sensors embedded on a single conductor’s baton. This enables the critical function of allowing users to collect data by themselves and fine-tuning an existing machine learning model to suit their distinctive conducting movements and “ictus style”. If a user wanted to do the same with a vision based approach, they would either have to own the vision-based system, or we would send them such a system. To re-train the SyncTus system, one would simply re-train the model using the baton embedded with our electronics.

Machine Learning: a departure from previous approaches

In industry and academia, the fields of computer vision and signal processing have been used to track the location of a baton tip and infer musically relevant features such as downbeat and tempo. However many of these approaches are specific to the original setup and are not robust to large and improvisatory movements typical of professional conducting. For this reason, such systems are not employed in professional theater and opera.

SyncTus™ is different: it focuses on the defined task of detecting the “downbeat”. We remind readers who are non-musicians that a downbeat is different from beats in a bar, tempo, meter and time signature. Across Western, Non-Western rhythms and even the most sophisticated of polyrhythms, there is always a defined downbeat that a conductor can signal the “ictus” to. It is this precise action that SyncTus is tracking.

Here is an example signal obtained from a phone during conducting. The green, blue and orange lines show the movement registered by an accelerometer during a 4/4 pattern. The red vertical lines indicate ground truth of a down beat. 2 downbeats are circled for clarity. Examine how there is enough signal and defined shape in the 3 axes of the sensor to distinguish the downbeat from other beats in the bar. A machine learning algorithm, with enough data and optimization, would be able to detect this via 1D convolutions on the incoming signal. This can be designed to work in real time. We expect data obtained from the *tip* of a conductor’s baton to contain even larger inflections that make the task easier for a machine learning model.



The power of using machine learning lies in the ability for the model to fine-tune to a particular conducting style. Compared to previous approaches, machine learning models would be robust to ancillary gestures that are typical to conducting, but would be rejected by SyncTus as actions unrelated to a downbeat. This is possible as the detection algorithm is based on a large dataset of conductors each signalling different types and movements associated with an “ictus”.

Data collection and Training

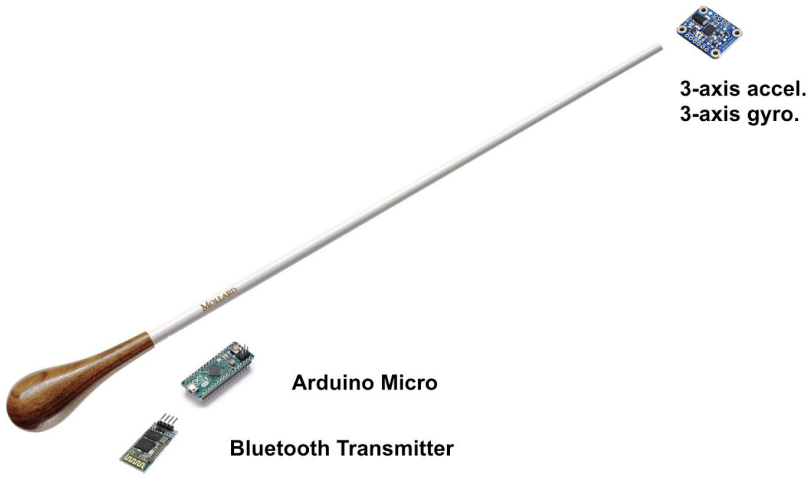
We will collect conducting movements from professional conductors. Such data can be collected in a multitude of ways:

- The conductor conducts to a piece with known downbeats several times (preferred)
- The conductor conducts to a piece or conducts free-form, and presses a button with their left hand whenever they are signalling a down beat (preferred)
- The conductor conducts and synchronizes to a click track (not recommended)

It is also possible to collect data from amateurs and musicians not necessarily trained in conducting. This would serve as “noisy” signals to a model, increasing the pool of available data, since data acquisition from professional conductors is hard to procure at scale. We could train a general model on all data, and then fine tune the model during a second step which is tailored to the specific user.

Musical considerations

- SyncTus™ is tempo and meter agnostic. It is designed to determine a downbeat irrespective of the time signature and tempo by using the characteristic “ictus” motion conductor’s perform to indicate the downbeat.
- SyncTus™ is designed to adhere to the shape, weight and design of a traditional conductor’s baton.
    - Small and lightweight 3 axis accelerometers and 3 axis gyroscopes are placed at the tip of the baton



Materials/Sensors

*Reference sensors (3x each)

https://www.adafruit.com/product/3387?gclid=Cj0KCQjwj_XpBRCCARIsAItJiuSH6rT770a4EzVIfHHebraYcO2UVv5nf46J6Z7uu1wi424LWxN4HhsaAm3rEALw_wcB

https://www.amazon.com/ATmega328P-Microcontroller-Board-Cable-Arduino/dp/B00NLAMS9C/ref=asc_df_B00NLAMS9C/?tag=hyprod-20&linkCode=df0&hvadid=309776868400&hvpos=1o5&hvnetw=g&hvrand=10589005184985244069&hvpone=&hvptwo=&hvqmt=&hvdev=c&hvdvcmdl=&hvlocint=&hvlocphy=9031345&hvtargid=pla-593018008274&psc=1

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