# Tok! : A Collaborative Acoustic Instrument using Mobile Phones

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## ABSTRACT
*Tok!* is a collaborative acoustic instrument application for iOS devices aimed at real time percussive music making in a co-located setup. It utilizes the mobility of hand-held devices and transforms them into drumsticks to tap on flat surfaces and produce acoustic music. *Tok!* is also networked and consists of a shared interactive music score to which the players tap their phones, creating a percussion ensemble. Through their social interaction and real-time modifications to the music score, and through their creative selection of tapping surfaces, the players can collaborate and dynamically create interesting rhythmic music with a variety of timbres.

## Keywords
Mobile Phones, Collaboration, Social Interaction, Acoustic Musical Instrument

## 1. INTRODUCTION
*Tok!* is a networked mobile music instrument which provides a collaborative environment to create percussive music. It focuses on acoustic music making through the use of mobile devices to generate percussive sounds by tapping them on hard surfaces. It enables a networked musical collaboration among the players through their real-time manipulation of a shared, loop-based music score. The goal of *Tok!* is to create a networked ensemble of mobile acoustic instruments which is capable of creating interesting percussive music. It is achieved through a collaborative social interaction among the players in a co-located setup by effectively utilizing mobile phones and available hard surfaces as the source of music.

This paper describes the background in which *Tok!* was developed, discusses the concept and motivation, briefly describes the design and implementation of the application, and finally assesses user experiences. We specifically address the design considerations that lead the application towards collaborative music making, as opposed to a competitive networked music game.

## 2. BACKGROUND
The last decade has seen a substantial growth of mobile phones in the field of computer music. The computational capability of such devices has increased multi-fold and their mobility, complemented by on-board sensors, allows new forms of musical expression. Researchers initially focused on the audio synthesis capabilities of mobile platforms [4, 6] and the use of multiple sensors and network protocols [5, 8]. More recently, many researchers have sought to turn smart phones into self-contained musical instruments. Mobile phone orchestras have created a new form of electronic ensemble [7, 11]. With the appearance of iOS devices and the opening of App Store to developers, a number of mobile music applications, such as *Ocarina* [12], have become commercially available.

### 2.1 Collaborative Music Making in Mobile Music
Owing to the inherent network capabilities of mobile phones, researchers have used them to facilitate collaborative music creation. Tanaka presented a co-operative music-making system on PDA where gestural inputs of each peer helped create streaming music [10]. A number of mobile music applications allow synchronous interactions among users in a co-located setup. *ZoozBeat*, a mobile music studio environment, connects multiple users and allows them to play music at the same time or simply take turns as if playing the "Hot Potato" game [13]. *Sound Bounce* (2009), a gesture-controlled instrument, allows players to "bounce" virtual sounds, "throw" them to other players, and compete in a game to "knock out" others' sound [3].

### 2.2 Utilizing Mobility in Acoustic Music
In most of examples mentioned above, researchers exploit the portability and wireless communication capabilities of the mobile devices. But the small size of these devices often presents a challenge. Most mobile music systems, for instance, must address the poor-quality internal speakers on mobile devices; they either use supplementary external speakers to increase the quality and volume of sound or limit themselves to narrow dynamic and frequency ranges [7, 11].

Schiemer and Havryliv, in contrast, embrace the small size for a unique acoustic purpose. For their pieces *Mandala3* and *Mandala4*, a mobile phone instrument named *Pocket Gamelan* was developed [9]. In the performance, mobile phones were mounted in a specially devised pouch attached to a cord. Players physically swung phones in the pouch while others operated handheld phones to change audio algorithms of swinging phones over the network. As the phone swung around, it produced audible artifacts such as Doppler shift, and its sonic output in the performance was a merged result of a generated tone, Doppler effect and spatialization due to its movement. The project not only incorporated the network


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capabilities of mobile phones by building a collaborative and accessible instrument, but also utilized the small size of the devices to introduce a novel approach to sound effects and spatialization.

Our research is directly influenced by Schiemer's *Pocket Gamelan* in the way that it uses the size limitations of mobile devices to explore a unique acoustic property. In addition, we follow the spirit of collaborative music making to facilitate social interaction among users, including non-musicians and novices.

## 3. *TOK!* CONCEPT

*Tok!* provides a networked mobile and acoustic musical interface which facilitates social interaction in a music making environment. Players tap the phone on a hard surface, following cues in a graphical rhythm score that is shared among co-located players. *Tok!* makes use of mobile phones as drumsticks to create interesting percussive music, using the physical sounds that the phone makes when tapped on the surface. Mobile phones are thus used as a tool for expressive percussive music. To the best of our knowledge, this is the first mobile application that uses the device itself as an instrument to produce acoustic sounds.

*Tok!* adopts aspects of both shared sonic environments and local interconnected musical networks from Barbosa's classification of networked music [1] to facilitate synchronous interaction in a co-located setup. The music score, which specifies the tapping rhythm for each player on the screen, is shared and synchronized over the network so that users can change their own rhythmic pattern as well as those of the other players.

The basic rhythmic structure of compositions is limited to a relatively simple grid of eighth notes, but a significant part of the creative process lies in the choice of the surface for tapping. By creatively combining support materials such as wood, metal, plastic, a piece of cardboard or even drum surfaces, players can organize their own percussion ensemble using a palette of rich and distinct timbres available naturally.

## 4. DESIGN AND USER INTERACTION

### 4.1 Music Score and Grid

The core of the application is the shared music score, which is created by placing notes (or "Coins" on screen) on a music score grid as in Figure 1. The coins on the grid act as cues for phone taps. A row of cells in the grid corresponds to each player. Players can drag coins from their own coin bin onto any unoccupied location on the score. The players are required to tap their devices according to the beat pattern indicated by the location of coins in their row. An audio-visual metronome indicates the current beat, and the metronome on all the phones is synchronized so that all the players can play in synchrony. The size of the mobile phone screen limits the total number of coin spaces to 16 (eight beats with eighth-note resolution), and the number of players to four.

### 4.2 Tapping

Players must observe the score and tap the phone to make acoustic sounds as cued by the coins. Since they also need to move coins on the grid to change the rhythmic score for themselves and other players, the gesture for tapping is of primary importance to reduce the cognitive load. We evaluated multiple gestures for tapping and decided on holding the phone flat on a surface and tapping one end while holding the other end of the phone firm on the surface (Figure 2). The phone can be tapped on either side. This gesture allows for accurate tapping and provides better visibility of the screen.


**Figure 1 Play screen showing the music score grid, visual cue, the bin, coins, accuracy point bars, and a ghost coin (black) and reward coin (smiley)**

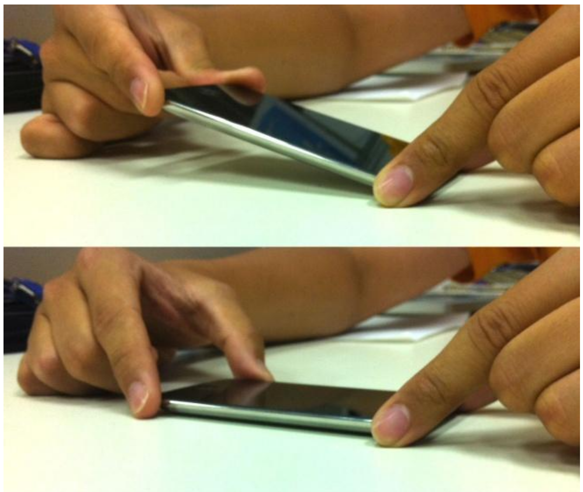

**Figure 2 Suggested Device Tapping Gesture**

### 4.3 Moving coins

Moving coins on the grid is an important aspect of the interaction to create changing rhythms. Initially, each player starts out with four coins in the bin, and the coins from a player's bin can be moved anywhere on the grid. Once on the grid, the coins can be moved within the row, changing one's own personal music score, or moved to a different row, changing the score of other players. Both of these lead to a change in the shared music score and hence change the rhythm being played. Players cannot move coins from another player's row; this effectively distributes creative control of the music across all the players in the ensemble. This also necessitates collaboration in which the group needs to manage limited resources to change rhythm dynamically by borrowing and lending coins.

### 4.4 Accuracy and Points

In contrast to traditional acoustic instruments, *Tok!* is designed to assess the player's accuracy at playing the music score, much as in rhythm games such as *Guitar Hero*. The application measures the accuracy of players' taps and computes cumulative rhythmic accuracy as an exponential moving average. The accuracy scores are displayed to all players, but with the goal of improving collaboration rather than inspiring competition: the ensemble is rewarded only when all players' points rise above a marked threshold.

Even while the coins are being moved, the metronome continues to tick and the players need to follow rhythm. The players are free to stop playing anytime while playing and resume later. However, if they stop playing, their rhythmic accuracy points decrease. This is to ensure continuity of rhythm over cycles and provides room for virtuosity in tapping the phone while changing the rhythm at the same time.

## 4.5 Collaboration

The design principles of *Tok!* could be directed towards two extremes: an improvisatory music collaboration or a competitive rhythm following game. For example, players can compete with each other by keeping their own row as simple as possible to get the best accuracy and frequently changing the rhythms of other players. This leads to a competitive interaction that has its own merit but does not necessarily lead to the creation of good music. *Tok!* is instead designed to serve collaborative music-making, and the main goal of the application is to create engaging music.

*Tok!* has additional features to promote collaboration. When the rhythmic accuracy of all the players remains above a certain threshold for a pre-defined period of time, a reward coin(or a "Smiley" coin) is added to the bin of the player with the best accuracy thus far. Rewarding group accuracy motivates all the players to play in a group rather than distracting others with sudden coin moves.

In addition, players can choose to automate the changes in rhythm for a different form of collaboration. In case the music score of a player remains static for a certain period of time, one of the coins is converted to an automated coin (or a "Ghost" coin), which moves randomly to an empty cell on the score when accurately tapped. The ghost coin slowly fades out with each accurate tap. It finally disappears from the score after it has been accurately tapped for seven times by the players and it is removed from the play. The ghost coin also slowly fades out with each accurate tap and finally disappears from the score when it's correctly tapped 7 times. It facilitates collaboration with a common goal of "killing" ghost coins. Having many ghost coins on the score leads to an automated change of rhythm without the intervention of players. This is useful especially for novices by reducing the load of coin moving gestures. A demo video is available at:
http://www.weibinshen.com/tok.html

# 5. SOFTWARE

The core of the application was developed in Objective-C to support iOS devices. The main software components of the application include clocking and synchronization, Bluetooth communication, sensing and scoring, and the graphical user interface as shown in Figure 3.

Bluetooth is used for co-located peer-to-peer communication. We chose Bluetooth because the latency of 3G/4G would have been too high and because we did not want to restrict users to playing in locations with WiFi networks. The communication is full duplex and string messages are used to communicate the coin locations on the grid, coin movement events, and accuracy points, apart from the initial synchronization and configuration. Synchronization between the devices is necessary to share the same clock among the devices. A master-slave approach for synchronization is used, where one of the devices acts as the master and synchronizes with other phones. An estimate of round-trip network latency (about 100 ms) is obtained and incorporated at each device to maintain time sync.

The tapping accuracy is computed using the time stamp obtained by detecting the accelerometer movement while tapping the phone. The accelerometer data is filtered through a moving average filter to smooth data and minimize false positives that occur due to the high sensitivity of the sensor. Using the suggested tapping gestures also improves accuracy.

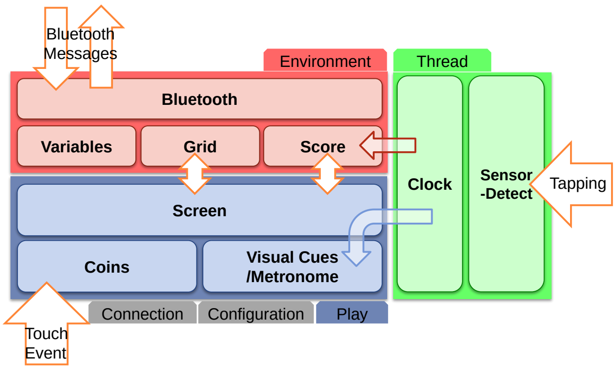


**Figure 3 System Architecture**

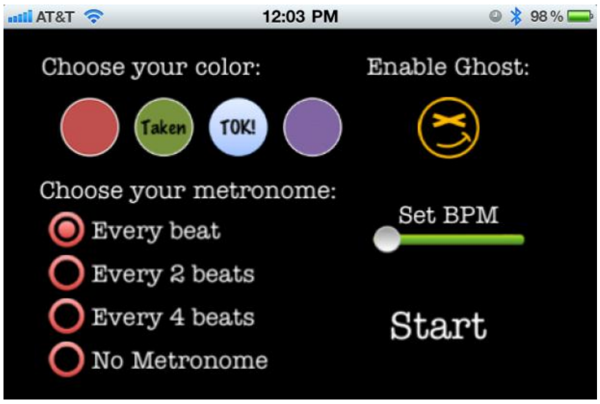


**Figure 4 Configuration Screen**

In order to support playing on inclined surfaces, the phone is calibrated at the beginning of interaction. Asynchrony, the interval between the actual tap time and the required tap time, is used to calculate four different levels (Perfect, Good, Okay, and Miss) with corresponding accuracy points accumulated to the current individual accuracy.

*Tok!* uses the cocos2d API [2] for its graphical user interface. There are three screens: connection, configuration and play. On launch of the application, the connection screen allows the player to find other players and connect to them through Bluetooth. The phone which begins the play after connecting is selected as the master phone. In the configuration screen (Figure 4), the players can choose the metronome option and the color of their coins. Tempo selection and ghost coin options can only be configured only from the master phone.

The play screen (Figure 1) shows a clear grid with a bin where the coins are placed initially. The metronome starts to indicate the beginning of the performance. The coin movement is through a two-step process of tapping on the source coin and then on the destination cell. This is in contrary to the common drag and drop used for a similar purpose. In this case, since the music score needs to be performed while moving the coin, the effort of coin moving is divided into two separate steps, so that the players can continue playing between the source selection and destination selection. The destination cell selection is guided by cross-hairs. The cross-hairs help to precisely move the coin to the required cell. These features help to reduce the cognitive load of simultaneous playing and score modification. The accuracy points of all players are shown using smoothly changing accuracy bars at the bottom of the screen. Each tap shows a message indicating the accuracy level of the tap.

# 6. ASSESSMENT

We present a preliminary assessment of *Tok!* based on our limited user feedback in a class setting during the development of the application. In general, participants felt engaged in

**Figure 5 Three Players Playing *Tok!***

making sounds by physical tapping and interacting with other players (Figure 5). Further, our observation of participants and expert feedback from a percussionist suggested that it was intuitive to tap to a given rhythmic score. Since a few participants expressed their concern about damaging their devices by tapping them, we recommend gentle tapping and the use of protective cases. (We believe this concern is unwarranted, since no device has ever been damaged by using *Tok!*)

Participants tend to create interesting rhythms both by listening to the overall sounds and watching the shared score. An evaluation by a professional percussionist indicates that it is straightforward to follow the rhythmic score accurately and to imagine the notated rhythms. The automated movements of ghost coins were effective in introducing dynamic rhythms with less effort by the players.

As we expected, a variety of social interactions emerged while playing. *Tok!* initially appealed to most of the users as being competitive, through activities such as moving all coins to other rows. In one interesting case, a participant made an ally with another player and attacked the third player of the group by placing all coins in his row. However, as the players continued to compete, they soon found out that competing with each other was not musically interesting. They gradually began to think through moves that would instead build up musical rhythms. Since the players were co-located, they spoke and discussed during the performances, which resulted in good teamwork; for instance, asking for a coin from other players or deciding to create a particular pattern.

While most of the participants were improvising with *Tok!*, one of the authors (Tronel) composed a four minute piece where the authors had a chance to practice, rehearse together and perform it in an informal setup. The composed piece consisted of a series of target rhythms for each player, the number of cycles for each target rhythm and transition time. The target rhythm was specified using a grid of markers for coin locations. The music composed for *Tok!* was limited by its note resolution and its looped structure. For better flow and continuity, we had to constrain the composition to evolve through a slowly changing score so that players could revise the rhythm by moving only one coin at a time. Synchronized group collaborations such as simultaneous coin exchanges among the players led to a more dynamic score. Even though composing was a challenge because of the inherent non-pitched sounds, the music sounded rich due to the use of a different support surface by each player.

## 7. Future Work

With the motivation of incorporating mobile phones in the context of acoustic music, *Tok!* seems effective in engaging mobile phone users with novel gestural control and social musical experiences. However, much work remains to be done. First, network communication needs improvement. Bluetooth was robust for two users but connection stability falls sharply with three or four users. We wish to either switch to another network architecture or improve the existing Bluetooth network.

Second, many users are apprehensive to play *Tok!* due to its tapping gesture which they thought might damage their device (even though no device has ever been damaged by using *Tok!*). While we wish to keep the idea of an acoustic instrument, alternative gestures and appropriate sensing technology would help. We want to deploy microphone sensors to detect acoustic sounds such as clapping, so that we can keep the idea of an acoustic instrument while offering an alternative means of acoustic interaction for those with concerns.

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## 9. REFERENCES

[1] Barbosa, Á. Displaced soundscapes: A survey of network systems for music and sonic art creation. Leonardo Music Journal, 2003: p. 53-59.

[2] COCOS2D API. Available from: http://www.cocos2d-iphone.org/.

[3] Dahl, L. and Wang, G. Sound bounce: Physical metaphors in designing mobile music performance. In *Proceedings of the International Conference on New Interfaces for Musical Expression (NIME)*, Sydney, Australia, 2010.

[4] Essl, G. and Rohs, M. Mobile STKfor symbian os. In *Proceedings of the International Computer Music Conference*, New Orleans, USA, 2006.

[5] Essl, G. and Rohs, M. Shamus-a sensor based integrated mobile phone instrument. In *Proceedings of the International Computer Music Conference*, Copenhagen, Denmark, 2007.

[6] Geiger, G. PDa: Real time signal processing and sound generation on handheld devices. In *Proceedings of the International Computer Music Conference*, Singapore, 2003.

[7] Oh, J., Herrera, J., Bryan, N.J., Dahl, L., and Wang, G. Evolving the mobile phone orchestra., In *Proceedings ofthe International conference on New Interfaces for Musical Expression (NIME)*, Sydney, Australia, 2010.

[8] Rohs, M., Essl, G., and Roth, M. CaMus: live music performance using camera phones and visual grid tracking. In *Proceedings of the International Conference on New Interfaces for Musical Expression (NIME)*, Paris, France, 2006.

[9] Schiemer, G. and Havryliv, M. Pocket Gamelan: Tuneable trajectories for flying sources in Mandala 3 and Mandala 4. In *Proceedings of the International conference on New Interfaces for Musical Expression*, Paris, France, 2006.

[10] Tanaka, A. Malleable mobile music. In *Proceedings of the conference on Ubiquitous Computing (UbiComp)*,Tokyo, Japan,2004.

[11] Wang, G., Essl, G., and H. Penttinen. Do mobile phones dream of electric orchestras? In *Proceedings of the International Computer Music Conference*, Belfast, UK, 2008.

[12] Wang, G. Designing smule's iphone ocarina. In *Proceedings of the International Conference on New Interfaces for Musical Expression (NIME)*, Pittsburgh, Pennsylvania, 2009.

[13] Weinberg, G., Beck, A., and Godfrey, M. ZooZBeat: a Gesture-based Mobile Music Studio, In *Proceedings of the International Conference on New Interfaces for Musical Expression (NIME)*, Pittsburgh, Pennsylvania, USA, 2009.