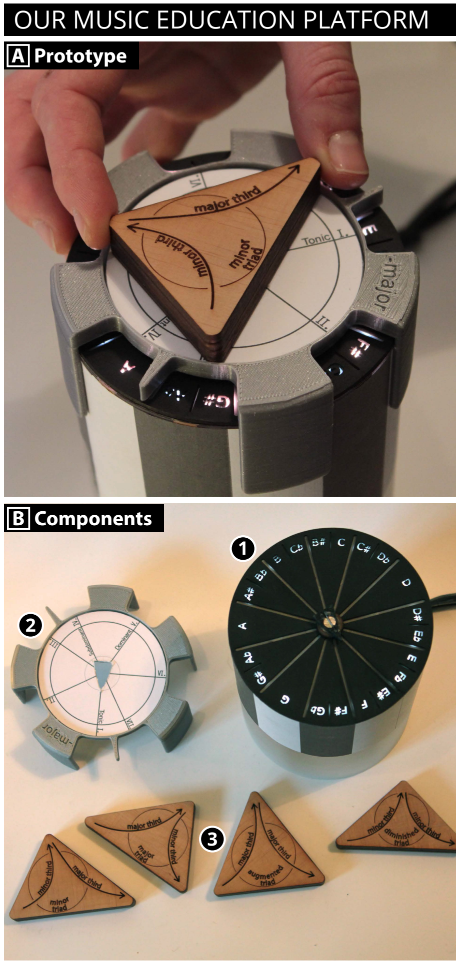


**Figure 1: ScaleDial (A) teaches music theory by transferring musical geometry to physical representations. Scale caps (B2) and triad tokens (B3) can be arranged on top of an interactive scale cylinder (B1).**

# ScaleDial: A Novel Tangible Device for Teaching Musical Scales & Triads

**Konstantin Klamka, Jannik Wojnar, Raimund Dachselt**
Interactive Media Lab Dresden, Technische Universität Dresden, Germany
{firstname}.{lastname}@tu-dresden.de

## ABSTRACT

The teaching of harmonic foundations in music is a common learning objective in many education systems. However, music theory is often considered as a non-interactive subject matter that requires huge efforts to understand. With this work, we contribute a novel tangible device, called ScaleDial, that makes use of the relations between geometry and music theory to provide interactive, graspable and playful learning experiences. Therefore, we introduce an innovative tangible cylinder and demonstrate how harmonic relationships can be explored through a physical set of digital manipulatives, that can be arranged and stacked on top of an interactive chromatic circle. Based on the tangible interaction and further rich visual and auditory output capabilities, ScaleDial enables a better understanding of scales, pitch constellations, triads, as well as intervals. Further, we describe the technical realization of our advanced prototype and show how we fabricate the magnetic, capacitive and mechanical sensing.

## CCS CONCEPTS

• **Human-centered computing** → **Interaction devices**; *Interaction techniques*; *Auditory feedback*.

## KEYWORDS

music education; tangible; physical computing; scales; keys; intervals; triads; TUI; digital manipulatives;


*CHI'19 Extended Abstracts, May 4–9, 2019, Glasgow, Scotland UK*

ACM ISBN 978-1-4503-5971-9/19/05.
https://doi.org/10.1145/3290607.3313238

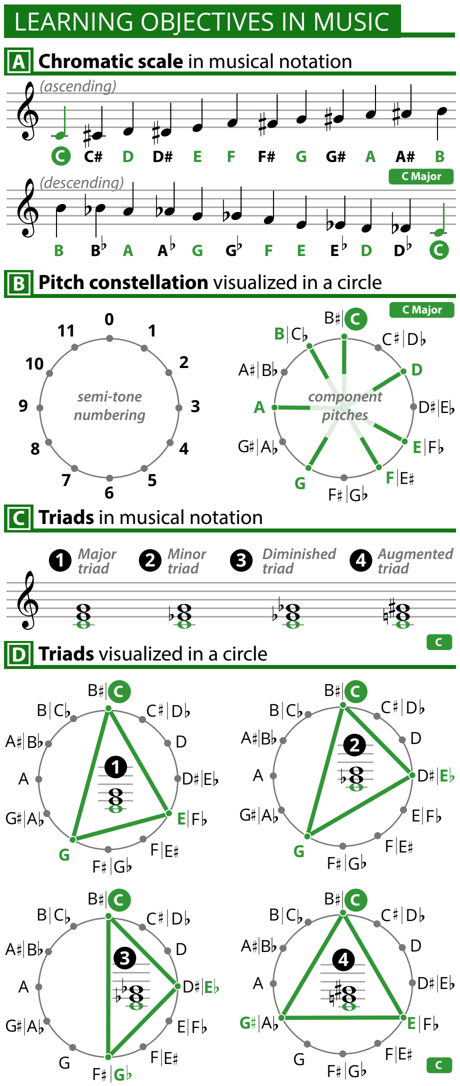


**Figure 2: Scales (A), pitches (B) and triads (C+D) are essential learning objectives in *harmonic analysis* (cf. [3]), however, they are often theoretical and boring to learn.**

## INTRODUCTION

Music has a long tradition in history and is an essential part of our identities and cultures. The knowledge about playing music (e.g., understanding scales, pitch constellations, triads and intervals; cf. Figure 2, A-D) has been passed down over generations. However, the way how teaching and learning activities are organized is characterized by educational paradigms. While early history was dominated by strict, teacher-centered lessons, pioneers, like Froebel [11] and Montessori [8] introduced new tangible approaches that encourage young pupils to get literally in touch with abstract concepts. Nowadays, physical computing allows us to create a new generation of interactive tangible interfaces that provide digital input and output capabilities. With this work, we especially want to investigate on how music geometry could be transferred to interactive tangibles to teach music theory concepts.

## RELATED WORK

A body of research that explored tangible & touch music tables (e.g., [4, 5]), token-based sequencers (e.g., [2]), musical building blocks and artifacts, has emerged (see [6] for an overview). For instance, reacTable [5] investigates on how tabletop tangible interfaces could be used for live music performances. Moreover, Noteput [4] is a music table that supports the learning of music notation with tangible notes that can be freely arranged. In addition, systems like P.I.A.N.O. [10] augment instruments with projections to facilitate direct note mappings. Further, Palaigeorgiou and Pouloulis [9] study how ubiquitous music environments can enable novice pupils to participate in active learning classrooms by orchestrating tangible music interfaces. Finally, Isochords [1] highlights intervals between notes and common chords in a 2D graphical user interface. In contrast to prior work, we want to specifically investigate on tangible music geometry approaches for advanced music theory in secondary schools.

## CONCEPT

To consider common music curricula (cf. [3]) and support its learning objectives (see Figure 2, A-D) in an interactive, motivating and serious yet playful way, we introduce the concept of physically deriving geometric relationships to create interactive music tangibles. Next, we will describe each part in detail.

▶ **Explore the Chromatic Scale:** The chromatic circle is a radial representation of the twelve equal-tempered pitch classes showing their geometrical relationships (see Figure 2, B). We use this visualization as a basis to provide an understandable concept for teaching pitch (A+B) and triad (C+D) constellations. Therefore, we introduced a tangible cylinder with touch-enabled segments (see Figure 1, B1) that represent all equal-tempered keys. Further, our concept considers the visualisation of all note names on top of our cylinder. By touching a lateral white or black key the respective (half) note name lights up and the corresponding tone will be played like a rolled piano keyboard (see Figure 3, A).

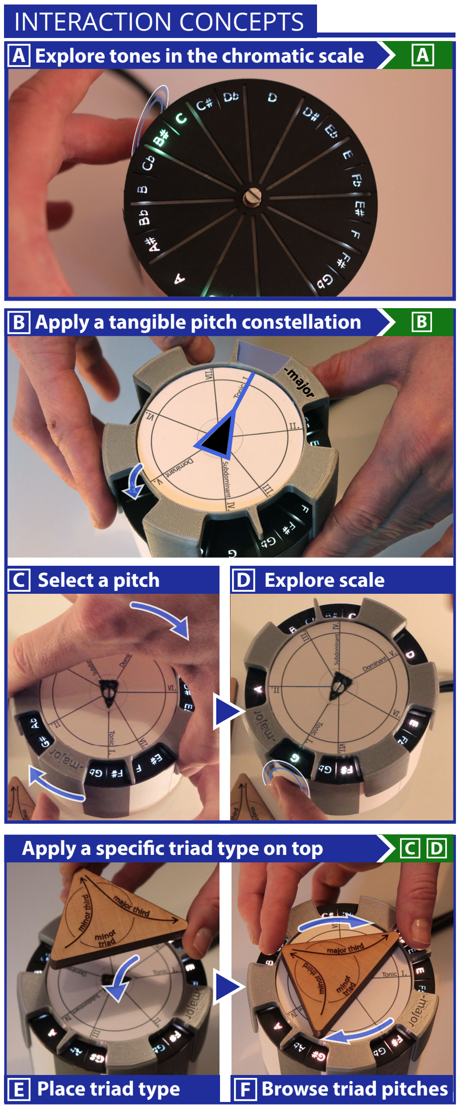


**Figure 3: We contribute an interaction platform to explore chromatic tones (A), apply (B) & change (C+D) pitch constellations and discover triads (E+F) to teach learning objectives (A-D) (cf. Figure 2).**

► **Apply & Understand Scales:** As a next step, we derive pitch constellations from the music geometry to show how specific harmonic relations are built on top of the chromatic scale (e.g., major scale has semi-tone positions at 0-2-4-5-7-9-11; cf. Figure 2, B). Therefore, we introduce exchangeable caps (see Figure 1, B2) that can be put on top of our cylinder (see Figure 3, B; the arrow ◀ represents the major tone) and physically cover all notes outside the selected scale (see Figure 1, A). However, it is still possible to play other notes by touching at a lower position. The scale caps can be rotated in twelve positions (see Figure 3, C) to browse through the key signatures. After a key signature has changed, an audio-visual animation plays the whole scale starting from the currently selected note.

► **Explore & Apply Triads:** Finally, we introduce four physical triad tokens (see Figure 1, B3) that can be placed on top of a pitch constellation (see Figure 3, E) and also rotated in twelve discrete positions (see Figure 3, F) to explore various triad types in different pitches (cf. Figure 2, C+D). Every triad use the same geometry as in the music theory circle visualization (cf. Figure 2, D) and is labeled with its type and underlying intervals. The angular characteristic also facilitate an understanding of the triads' construction and intervals. For instance, a diminished triad feels literally smaller than an augmented one. When a pupil places and rotates a token (or the whole pitch cap with a token), the ScaleDial immediately plays the corresponding sound. In addition, all involved triad notes light up.

## REALIZATION

Our **Interactive Chromatic Scale Cylinder** consists of twelve touch sensors that are equally distributed around an acrylic cylinder (Ø10*cm*). The sensors are made of copper tape and are capacitively sensed with an MPR121 chip and a Raspberry PI. To visualize states, e.g., note selections or triad positions, we integrate 21 RGBW-LEDs on top (see Figure 4, A). This enables us to highlight every note in the chromatic scale including the ones with sharps or flats. We covered the LEDs with exchangeable diffuser and stencil masks making ScaleDial suitable for different notation system and languages. For audio output, we use MIDI and wave samples that are managed by the Raspberry PI and a speaker.

To realize the **Rotatable Pitch Constellation**, we 3D-printed a major scale cap that can be put on top of our interactive cylinder. The cap physically covers all notes outside the major scale (cf. Figure 2, B) with extruded circular segments (Figure 1, A) and can be rotated in twelve discrete positions. For the sensing, we integrate a rotary stepping switch in our scale cylinder that is able to measure the absolute radial position of the cap and also provide pleasant tactile dents (see Figure 4, B). To ensure that the cap is correctly connected to the stepper switch (C), we attached an alignment part ◀ to the shaft (Figure 1, B2) that connects the cap. In addition, we realized a recessed hole in the cap that acts as a mechanical guide for the triad tokens and integrated a graphic with harmonic constellations.

REALIZATION

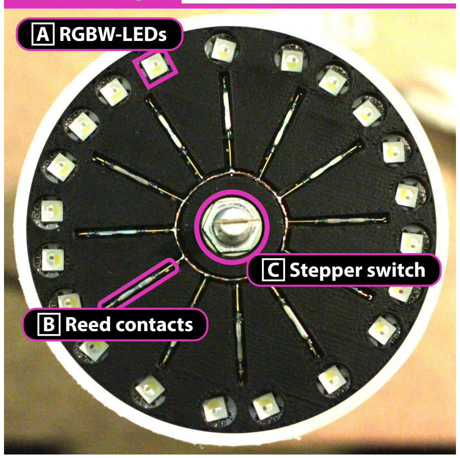


**Figure 4: Important electronic parts of ScaleDial are RGBW-LEDs (A), reed contacts (B) and a stepper switch (C).**

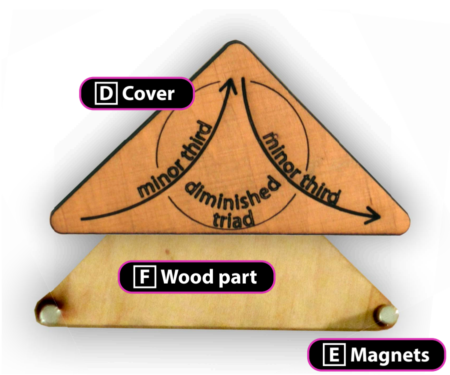


**Figure 5: Our triad tokens are made of wood (F) as well as magnets (E) and have engraved its type and intervals on top (D).**

[1] **Further fabrication details:**
https://www.imld.de/scaledial/

Our four **Triad Tokens** are made of wood and tiny neodymium magnets (see Figure 5) to provide a pleasant feel and aesthetic design. Therefore, we laser cut four layers of birch plywood and glued them together. The top layer (see Figure 5, D) is engraved with the triad type and corresponding intervals to provide further information. The magnets (E) are placed in holes that are cut out (F). The triad token can be placed on top of a pitch cap and seamlessly snaps in the recessed hole. Twelve reed contacts (see Figure 4, C) in the top of our chromatic scale cylinder identify the token presence, type and its current angular position since every triad form consists of a unique magnetic constellation. In addition, the magnets ensure a pleasant snap in twelve discrete positions[1].

## CONCLUSION AND FUTURE WORK

We presented ScaleDial, a novel tangible approach that make use of musical geometry to provide playful learning experiences focusing on the common learning objectives of scales, triads, and intervals in music. We demonstrated how harmonic relationships can be interactively explored through a physical set of digital manipulatives, that can be arranged and stacked on top of an interactive chromatic circle with audio output. Further, we described the realization of our advanced prototype.

For future work, we aim to evaluate our approach in semi-structured expert interviews, hands-on sessions with teachers and in-class studies focusing on self-determined work lessons. In addition, we plan to extend ScaleDial with interactive and illuminated music sheets (cf. [7]), that highlight notes on notation paper, and combine digital instruments, such as keyboards that are able to light up keys.

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