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Erik Goossens

Cheng Yang

Charles Chen

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Providing Guidance and Spatial Awareness to the Visually Impaired

Erik Goossens, Cheng Yang, and Charles Chen

Abstract:

A guidance system uses music in the form of a short sequence of tones to provide guidance and spatial awareness to a visually impaired user. While the guidance system detects obstacles and guides the user to a desired location, the tones efficiently communicate guidance and spatial awareness information to the user. The tones are presented in a predictable natural rhythm synchronized with the user's gait. The various pitches, volumes, and time between the tones communicate directions, clearance widths, alerts, and moving obstacles to the user. The tones are intuitive and non-intrusively played in the background, allowing a user to focus on other activities while responding to directions.

Keywords: guidance, spatial awareness, tones, visually impaired

Background:

Current methods for communicating guidance information involve verbose sentences that are intrusive, annoying, and disrupting. Imagine strolling towards a destination engrossed in personal thoughts when abruptly interrupted by a robotic voice "in 100 feet, turn right" and "in 50 feet, turn right." The train of thought is lost and cannot be maintained with the constant interruptions in the foreground. To solve this problem, a guidance system uses music in the form of a short sequence of tones to communicate guidance information and spatial awareness to a visually impaired user. While the guidance system detects obstacles and guides a user to a desired location, the tones efficiently communicate guidance and spatial awareness information to the user. The tones are presented in a predictable natural rhythm synchronized with the user's gait. The various pitches, volumes, and time between the tones communicate directions, clearance widths,

alerts, and moving obstacles to the user. The tones are intuitive and non-intrusively played in the background, allowing the user to maintain focus on other activities while responding to directions. Example visually impaired users include blind people as well as people involved in other activities such as reading a book, watching a video on a mobile device, and interacting with a cell phone.

Description:

Figure 1 depicts an example guidance system, which includes a camera sensor, an accelerometer, a guidance module, and a communicator. The guidance system can be implemented using a portable computing device, such as a mobile phone.

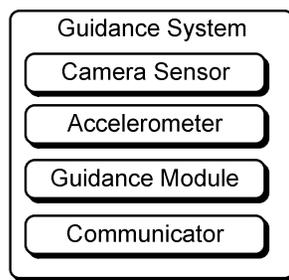


Figure 1

The camera sensor detects the environment, including clearance widths and moving obstacles. The accelerometer detects the user's step interval and gait. The guidance module determines instructions to communicate to the user based on the user's position, destination, and detected environment. The communicator receives the instructions from the guidance module and communicates the instructions as a sequence of tones. Based on information from the accelerometer, the communicator sounds the instructions in predictable intervals that synchronize to the user's gait. The instructions can be sounded using speakers, headphones, or a bone conduction headset.

An instruction comprises multiple tones. Each tone is represented by a quarter note symbol: ♩ . Many different sounds can be used to produce the tone and different sounds can

be used to communicate different information. For example, a click, such as a piezo click, is used to communicate normal guidance information and a horn is used to instruct the user to stop. The quarter note is positioned on a staff to indicate a pitch of the tone. Each line and space on the staff represents a different pitch. As illustrated in Figure 2, the higher the quarter note is positioned on the staff, the higher the pitch of the tone.

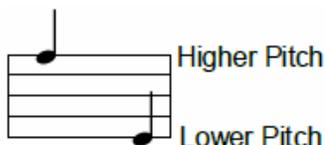


Figure 2

A time or duration between the tones is represented by a quarter rest symbol: . The quarter rest represents ten milliseconds, although other durations may be used. Using this notation, two quarter rests represent 20 milliseconds between tones and four quarter rests represent 40 milliseconds between tones.

The quarter note symbol and quarter rest symbol described above are used to describe the various instructions the communicator can present to the user. Example instructions are discussed in further detail below.

Directions:

In order to convey guidance information, the communicator uses two tones for the instruction and a relative difference in pitch between the two tones to indicate a course adjustment angle. Figure 3 illustrates an example set of instructions for communicating guidance information using two tones.

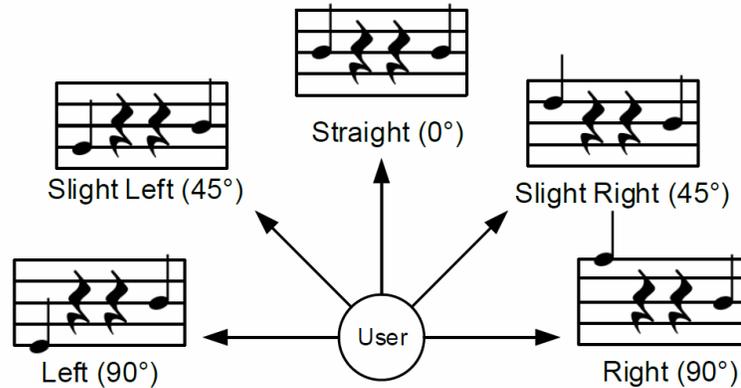


Figure 3

Considering the example in Figure 3, for no course correction (*i.e.*, proceeding straight), the pitch of the first tone is the same as the pitch of the second tone. To indicate a course correction towards the right, the first tone's pitch is higher than the second tone's pitch. To indicate a course correction towards the left, the first tone's pitch is lower than the second tone's pitch. Furthermore, the degree of course correction is indicated by the relative difference in pitch between the two tones. For example, a large course correction to the right is indicated by the first tone's pitch being significantly higher than the second tone's pitch and a small course correction to the right is indicated by the first tone's pitch being slightly higher than the second tone's pitch.

As another example, instead of using multiple tones to convey an instruction, a constant tone may be used. Using the above symbols, a pitch of the constant tone is indicated by the quarter notes and the quarter rests represent the duration between the first pitch and the second pitch. During the duration, the pitch of the constant tone can remain the same as the first pitch or incrementally change from the first pitch to the second pitch.

Clearance Width:

The communicator also uses the two tones in the instruction to communicate the clearance width of the user's path, such as a width of a hallway or a width of a sidewalk. The clearance

width is indicated by the pitch of the second tone. For example, the higher the pitch, the larger the clearance width and the lower the pitch, the smaller the clearance width. The clearance width is combined with the directions by shifting the pitches of the first tone and the second tone according to the clearance width. Figure 4 illustrates example instructions for communicating clearance widths and directions.

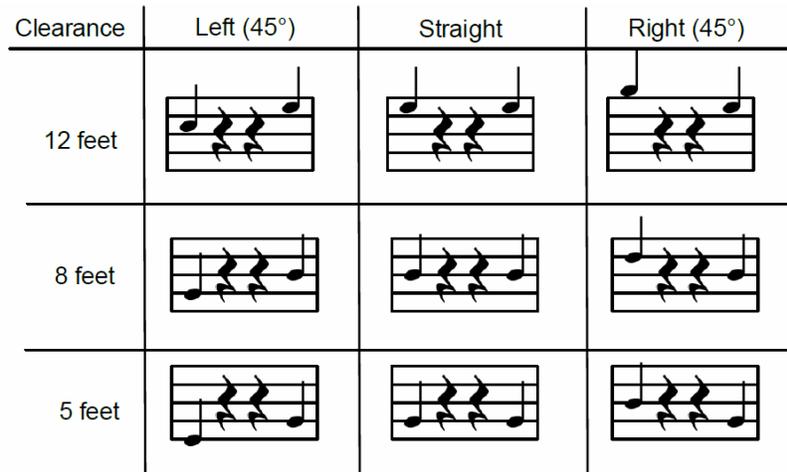


Figure 4

Considering the example in Figure 4 for a straight (*e.g.*, no course correction) guidance direction, a clearance of eight feet is indicated using a middle pitch for both the first and second tone, a clearance of twelve feet is indicated using a higher pitch for both the first and the second tone, and a clearance of five feet is indicated using a lower pitch for both the first and the second tone. Comparing the examples for a straight guidance direction with the examples for a left or right turn, the pitch of the second tone remains the same to indicate the clearance width and the pitch of the first note is adjusted relative to the pitch of the second tone to indicate the turn.

Alerts:

In order to alert the user, the communicator adjust the volume of the tones and the duration between the multiple tones within the instruction. The change in volume and change in duration between the tones within the instruction indicates to the user to slow down and be alert for following instructions.

The communicator uses a normal volume represented by a piano dynamic sign ***p*** when providing periodic guidance and spatial awareness instructions. However, to alert the user to an upcoming change, a louder volume, represented by a forte dynamic sign ***f***, is used to attract the attention of the user. The guidance system can determine if the user received the alert by detecting the user slowing down and in response, the communicator can reduce the volume of subsequent tones.

Furthermore, the communicator alerts the user by changing the duration between the two tones within the instruction. For example, the duration between tones within the instruction can be increased from 20 milliseconds to 40 milliseconds to provide the user an additional amount of time to listen and receive each tone within the instruction. Alternatively, the duration between the tones within the instructions can be decreased to enable a faster response by shortening the time required to communicate the instruction.

The communicator can also sound the instructions at different step intervals, particularly in accordance to a type of maneuver or environment. Presenting the instructions in shorter intervals provides the user with faster feedback, allowing the user to execute complex maneuvers in challenging environments. As an example, the instructions can be provided multiple times throughout the duration of the turn and within each instruction, the pitch of the first tone is adjusted

by the degree of the turn remaining for the user to execute. Additionally, the instructions can be provided at different intervals to further attract the user's attention.

Figure 5 illustrates an example timeline and series of instructions for alerting a user.

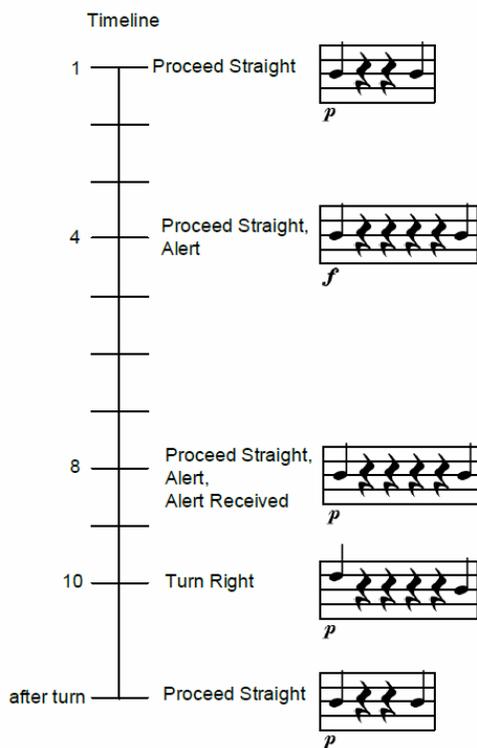


Figure 5

The numbers on the left of the timeline correspond to the number of steps taken by the user. As previously mentioned, the instructions are coordinated with the user's steps. On the first step, a first instruction directs the user to proceed straight. On the fourth step, a second instruction alerts the user to an upcoming change by using a louder volume and increasing the duration between the tones within the instruction to 40 milliseconds. On the eighth step, a third instruction directs the user to proceed straight and continue to be alert for an upcoming change in instructions. Since the guidance system detected the user slowed down in response to the prior alert, the communicator uses a lower volume to communicate the third instruction. On the tenth step, a

fourth instruction directs the user to turn right. After the turn is completed, a fifth instruction directs the user to proceed straight.

Moving Obstacles:

In order to provide information regarding moving obstacles detected by the guidance system, the communicator adds a third tone to the instruction. The pitch of the third tone is adjusted to indicate the location of the obstacle with respect to the user. For example, to indicate the obstacle is on the left of the user, a lower pitch is used for the third tone and to indicate the obstacle is on the right of the user, a higher pitch is used for the third tone.

In addition to direction, the relative distance of the obstacle is also indicated by the pitch of the third tone. For example, the higher the pitch, the farther the obstacle is on the right of the user and as the obstacle approaches the user on the right, the pitch decreases. As another example, to indicate to the user that the obstacle is about to collide with the user, the third tone can have a same pitch as the second tone. Figure 6 illustrates an example sequence of instructions presented when an obstacle approaches and passes a user on the left.

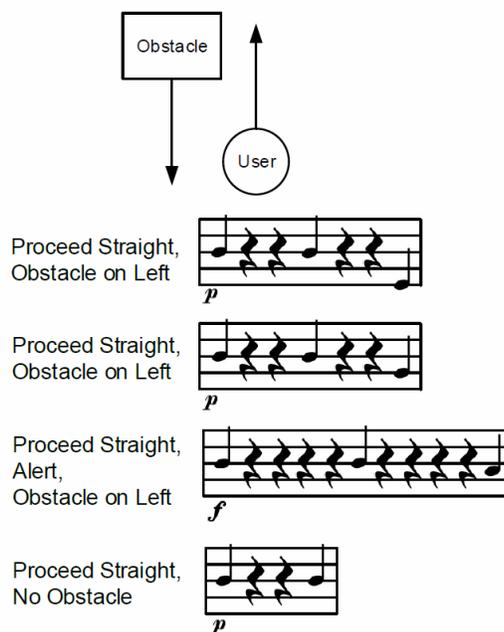


Figure 6

In Figure 6, the guidance system detects an obstacle approaching on the left of the user. In response, the communicator sounds a first instruction with a third tone at a lower pitch than the second tone to communicate this information to the user. The pitch of the third tone is significantly lower initially to indicate the obstacle is at a farther distance from the user. As the obstacle approaches the user, the second instruction includes a third tone with a higher pitch compared to the first instruction. When the obstacle is very close to the user, a third instruction alerts the user using a louder volume and longer duration between the three tones within the instruction. After the obstacle passes the user, a fourth instruction includes only two tones to indicate that the obstacle has passed. The technique illustrated above can also be used to convey the relative position of an obstacle crossing in front of the user. Furthermore, the guidance system can predict the path of the obstacle and provide directions to avoid a collision with the obstacle.

The communicator can also sound the instructions at different intervals in response to detecting a moving obstacle. For example, the instructions can be sounded by the communicator

in shorter intervals in order to provide the user with continuous feedback on the position of the object. The time period between the instructions can be adjusted depending on how fast the obstacle is moving and/or the distance between the obstacle and the user. For example in Figure 6, additional instructions can be presented to the user between the first, second, and third instructions effective to communicate the approach of the obstacle in finer detail.