Construction of a Wine Glass Piano and Discussion of Theory Behind Changing Pitch

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For my project I decided to build a self-designed, original instrument that can be best described as a piano that uses wine glasses for the sound of the different notes. The piano uses eight wine glasses, each one filled with a different amount of water to change the pitch of the sound the wine glass makes when tapped. Each of the eight glasses is tuned to a different note in a major scale. I also wanted to know the physics behind why wine glasses change in pitch with differing amounts of water, so I did some studying on the theory behind why wine glasses change pitch when filled with different amounts of water.

The reason that I chose this as my project is because I wanted to take the opportunity to build something cool that I could keep and use over time. I also wanted to build something unique, that hadn't really been done before. Through searching online, I could not find anyone else who has done this and the instrument was built from an original design that I came up with myself. I wanted to see what the process is like behind making instruments, many people know how to play instruments, but not many people think about the construction behind them, so I thought this would be a good opportunity to see what the general process is like and what things need to be taken into considered.

Before getting into the actual construction of the instrument, I help explain the theory behind how it works i.e. why wine glasses change pitch when water is added to them. As has been talked about, when a wine glass is tapped with silverware, for example, it will vibrate at a certain frequency, corresponding to a certain note. One can imagine any position on a given wine glass to have a displacement "x" from its natural position, at any given time. The equation for x(t) would be given as $x(t)=A\cos(wt)$, where A is the amplitude, or maximum displacement and w is the angular frequency. The wine glass can be approximated to have linear restoring forces similar to a mass on a spring. Therefore we can say that the kinetic energy is proportional to $(dx/dt)^2$ and the potential energy is proportional to x^2. We can therefore write the total energy

as E=C((dx/dt)^2)+D(x^2) where C and D are constants. Putting in x(t)=Acos(wt) for x, we obtain the equation: E=C((-Awsin(wt))^2)+D((A)cos(wt))^2. If we ignore damping then the total energy must be constant and the only way this can be achieved from this equation is if (w^2)=D/C. This gives a constant energy of (A^2)D. Seeing that (w^2)=D/C, it is apparent that w decreases with a larger kinetic energy constant. Since kinetic energy is proportional to mass, then increasing the mass of the system will increase the kinetic energy. Adding liquid to the wine glasses clearly adds mass to the wine glass. This increase in mass causes an increase in kinetic energy and hence a decrease in w, the frequency. When the frequency of the pitch is lowered, the glass plays a lower note. There is also an equation that I found very interesting that related the frequency of a filled wine glass to many other properties of the wine glass. The equation is (Vo/V)^2=1+(b/5)(Pliquid*R/Pglass*a) where Vo is the frequency of the empty wine glass, V is the frequency of the partially filled wine glass, R is the radius of the hollow part of the wine glass, a is the thickness of the glass, Pliquid is the density of the liquid filling the glass, Pglass is the density of the glass, H is the height of the hollow part of the glass, h is the height of the water level in the wine glass, and b is a constant. So it is interesting to see that there is an equation that relates all these quantities. This concept of wine glasses changing pitch is the basis for my project, lining up a set of identical wine glasses and filling each with a different amount of water to form a major scale, then constructing the mechanics to make the instrument play like a piano. (French 688, 699).

The first step in constructing the instrument was finding wine glasses that would be suitable for the instrument. I specifically looked for wine glasses that had thick glass because the plan for the piano would be that the glasses would make noise by being tapped by homemade “piano hammers,” made from tongue depressors, and it was important to have sturdy wine glasses to ensure that when the piano is played the glass doesn’t break. I wanted to make sure at

the same time, however, that the glass was not so thick that wine glasses did not make a good resonating sound when hit, because the thicker the glass the lower the amplitude of vibration will be, causing a quieter noise. So I searched online specifically for sturdy wine glasses and found a set of four that seemed like a good fit. I ordered one set first to test that they would be sufficiently loud when tapped. Fortunately they were and I went on to order a second set of four, giving me a total of eight wine glasses, enough for a full major scale including the upper octave. The next step was tuning the wine glasses. I used an electronic tuner to first determine the note that an empty wine glass plays when tapped. I knew that the highest pitch that I could get from one of the wine glasses would the pitch of an empty wine glass. So, using my tuner, I determined that the notes was an E flat. Since the highest note was going to be the upper octave of the scale, the rest of the wine glasses had to be tuned to make an E flat major scale. Through trial and error I was able to determine the correct water levels in the wine glass for each desired note. The different determined water levels were marked on the glass with sharpie.

For constructing the rest of the piano I first had to build a box to hold the wine glasses and all other components. I lined up all of the wine glasses in a row so that they were close together, but still made sure that there was a small distance between each of them because I obviously did not want the glasses to be touching in the final instrument. I then measured the length of ground that all of the wine glasses covered when lined up, I also measured the height of the wine glasses. These measurements let me know roughly the size of the wood board that I would need for the backboard of the box. I determined that the wood board would need to have dimensions of 9-10”, to fit the height of the wine glasses, by 31.5” to fit the length of the wine glasses when lined up. I bought wood boards that had the approximate right height for the backboard and then cut the board with a saw to give it the appropriate length. I also bought wood for building the base and sides of the box, but the sizes to be cut out for the sides and the boards

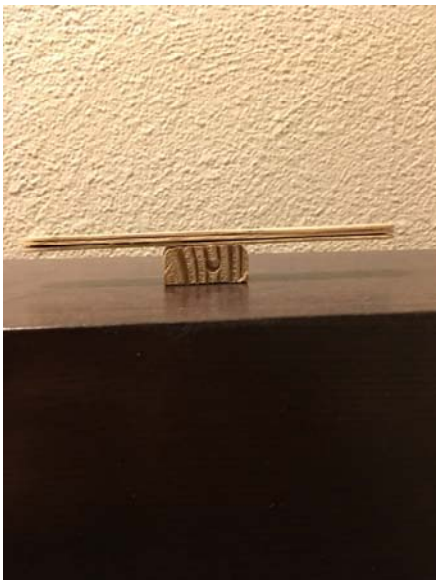
were to be determined later. I next proceeded to make to make what would be used for the piano "keys," which would be used to play the piano similarly to a regular piano, the piano "hammers," which would hit the wine glasses making them vibrate. Both the keys and hammers were made from tongue depressors. For each key I used wood glue to glue three tongue depressors stacked on top of one another. This was to make keys more sturdy than they would be simply using a single tongue depressor. Here's a picture on one of the keys shown below:

For the hammers I glued two tongue depressors together partially stacked between three others and put together at an angle. The pictures below show an example of one, it is hard to describe in words exactly how it was put together, so the pictures should demonstrate it better:

Once I had the tongue depressors and hammers put together, I held them up in the configuration that they would be in relative to the wine glass in the finished in order to figure out what size to make the base of the box so that it could fit everything in this position. I measured that in order for everything to fit in the box in that configuration, the depth of the piano would have to be about 14-15 inches. I then cut out a base that was 14.5”x31.5”, the 31.5” was to match the backboard of the box. The dimensions of the sides were then easy to determine as they needed to match the depth of the base and the height of the backboard, giving them dimensions 9.5”x14.5.” These wood boards were screwed together in the configuration shown in the pictures later that show the final product of the instrument.

The next step was suspending the hammers on a thin metal bar on which they would rotate and hit the wine glasses in the finished instrument. I luckily found a thin metal bar at Home Depot that was the perfect size in diameter for what I envisioned and I then cut it to give it an appropriate length to fit in the 31.5” inch length of the box, the idea was to get the length to be only slightly less than the 31.5” length of the box. I then drilled holes into each hammer so that they could be threaded onto the metal bar. I then held the metal bar in the box and determined the approximate position I would want the metal bar to be relative to the wine glasses

in the finished product. After marking this position, I cut out two small wood blocks, each with a small notch to fit the metal bar, and screwed them into the position on the sides of the box in the position where I would want them to hold the metal bar. The next step was to repeat the same basic process, but with the keys. I determined the position where I would want to have the keys relative to the hammers by placing them on a thin metal bar and holding the bar at a position where I would want the keys to be relative to the hammers. Since the piano keys that I made were ultimately going to be placed flat, perpendicular to the metal bar and the keys that I made are too thin to drill holes into in the same way that I did for the hammers, I had to glue the keys on top of small wood bars and drill holes into those to be threaded on the metal bar. The picture below shows a key on one such wood bar.



I then screwed two more wood blocks into the sides of the box in order to hold this second metal bar in place. Finally I cut a wood bar slightly less than 31.5” long to run along the piano. This was screwed into place underneath where the keys would be, for them to rest on. Next it was time to fully thread all of the keys and hammers onto the metal bars into appropriate

positions for the hammers to hit the wine glasses. To keep the keys and hammers from sliding side to side on the metal bar I threaded the whole bar with metal nuts and clothespins. These crowded the whole length of the bar, holding the keys and hammers in their desired positions snuggly, but not so tight that they would have trouble rotating on the bar. The clothespins were used because they are easily removable and allow for adjustments to be made if need be in the future. The wine glasses were placed in the box in ascending order from left to right. More specifically, the wine glass that holds the most water, the lowest pitch note, was paced farthest to the left. The wine glass one to the right of that wine glass is the wine glass that holds the second most amount of water, the second lowest note. This follows all the way to the wine glass farthest to the right, the empty wine glass, the highest pitch note. The way that I kept the wine glasses held in placed was using a putty meant for hanging posters. I evenly distributed a fair amount underneath each glass so that each would be stuck to the base sturdily. The putty is a good way to hold the glasses in place because it holds the wine glasses sturdily, as described, but it also allows the wine glasses to be removed if need be. This is convenient for filling them, emptying them, or readjusting their positions. I roughly evenly spaced each wine glass and but also made sure to place them at positions relative to the hammer where they had a good resonating sound when tapped.

Here’s a shot of the finished product of the piano.

And this shot shows a close up of the keys and hammers, from a different angle.

Now that you have seen the finished product and had the construction explained, I will now explain the mechanics of how it works in greater detail. The way that the mechanics of the piano ultimately works is that one end of each the hammers lays on top of one end of the keys, as shown above. When the piano keys are pushed at the front, they rotate on the metal bar, pushing the hammer resting on top of the key upward, this is because the hammers are also allowed to rotate freely on the metal bar they are threaded on. So as the key is pushed down and the hammer rotates forward the top end of the hammer moves forward and hits its respective glass. After the glass is hit and the piano key is released, the hammer rotates back into position, pushing the key under it back into position as well. The reason that the hammers rotate back into position is because I weighed down the side that is on top of the keys by electrical taping metal washers to that end, as is shown in the picture.

There are a few things in the future I may do to improve the piano. Firstly, the noise that the keys make when they click back into place is kind of loud. This is something that Professor Errede told me happens in the construction of so I may put some soundproofing foam underneath them to prevent that clicking noise. Also I may come up with a solution for holding the wine glasses in place more permanently, because the putty may wear down somewhat over time. If I were to find a way to hold the wine glasses in place permanently I would buy some sort of syringe for the wine glasses that allows me to add and remove water.

Ultimately, this project taught me a lot about what goes into constructing an instrument. There are many things that need to be taken into consideration regarding the sound of the instrument, like, as I mentioned, I needed to make sure that the wine glasses that I bought gave off a reasonably loud sound when tapped. Also, I know that silencing the keys from clicking is important because otherwise it creates too much background noise that distracts from the noise of the wine glasses. Also, just like real instruments, I had to take into account the longevity of

the piano, because this is something that I intend to keep, so I needed to do things like use sturdy wine glasses and glue several tongue depressors for the keys and hammers to make those sturdier as well. Additionally, this project taught me about the concepts behind wine glasses changing pitch. This was interesting because it took familiar mechanics concepts and applied it to a specific, practical example. I feel that if you are going to build an instrument, it is good to know the physics that makes the instrument work.

References

French, Anthony P. *In Vino Veritas: A Study of Wineglass Acoustics. Nikhef*. Physics Department, Massachusetts Institute of Technology, n.d. Web. 26 Apr. 2016.