Pai Sho

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Abstract

There are innumerable innovative ways to use the technology of 3-D printing. It will redefine what becomes possible. Limitations cast by expenses, accessibility, tools, or materials, artists, engineers, enthusiasts, inventors, and even the average Joe will be capable of remixing, creating, and fixing products at the push of a button. While it does take some skill to learn the 3-D modeling software, users will find much of the software accommodating the printing world, such as SketchUp, to be approachable and relatively intuitive by design. Among many applications, 3-D printing launches fandom to a new level. Instead of waiting for replicas, fans can create their own, perhaps with an additional, more personalized twist. Instead of just giving a daughter a replica of the Master Sword from the Legend of Zelda, one could theoretically design one, engrave the sword with a favorite quote, a name, or a unique pattern, and hit, "print." Pai Sho, a game from Michael Dante DiMartino and Bryan Konietzko's *Avatar: The Last Airbender* and *The Legend of Korra* series, is not available on the shelves of Barnes and Noble. There is not a comparable computerized interpretation of the game, nor is there any indication that a mass-marketed version of the game will be launched, especially now that the series has come to an end. Enter 3-D printing.

Background: 3D Printing Today

Toys, games, jewelry, and art. Organs, glassware, tools, and food. The list of what can come out of a 3-D printer is difficult to keep track of, as those at the forefront of this new technology persistently redesign and redefine the world we live in. Integrating these devices into mainstream culture to the extent of welcoming them to our doorstep is the current effort of several companies around the globe. What was once used exclusively for its applications in industrial prototyping is now opening its arms to—among many things—ordinary household usage and the revolution of design and the do-it-yourself mentality. 3-D printing opens new doors for creation and customization; however, it inevitably creates a host of copyright issues as well, and attempting to grapple with restrictions on 3-D printing content/design is no easy task.

Scale models, drone parts, operating firearms, organs built from a patient's own stem cells, entire cars, and even personal drink mixers can be manufactured by your own design or by downloading the first readily accessible model on Google. While the hype about this new technology is fairly justified, the 3-D printer is also stirring up controversy, particularly regarding copyright issues. With the rise of 3-D printers, 3-D scanners are also growing into reality. Is it legally permissible to be able to scan and print a company's licensed product in your own home? According to every FBI Ant-Piracy warning that flashes on the screen during movie previews, the answer seems to lean toward the naysayers. But how could this be prevented or enforced? Whether or not the introduction of 3-D printers and their ability to produce exact replicas—or better yet, remixes suited to consumers' exact specifications—will noticeably reduce company profits, the need for shopping centers, and by extension, workers to run them, is uncertain. Companies may have to compete with individual users to make their products superior to those that are easily imitated by enthusiasts. The price of 3-D printers range anywhere from $250, 11 lb. printers that can create pre-designed but customizable objects with the thermoplastic PLA, to $330,000, 984 lb. printers that can print over 1,000 digital materials and combine up to 82 of them into a single product. The more simplistic printers are the ones

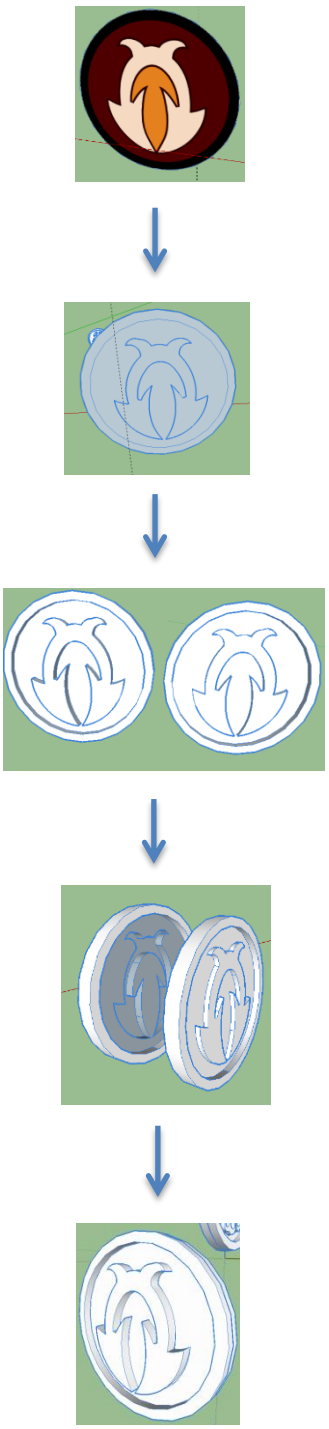
most likely to find a home under the roof of everyday consumers, due not only to cost, but also to practicality. Those at the other end of the scale may call company banners to the ultimate battle of keeping up with the Jones' as they dive in and explore all of the potential this new technology has to offer.

Project Introduction & Methodology

The goal of the project was to create a faithful representation of the fictional game Pai Sho. The first step was condensing the multiple fan-made rules and variations into one set. This involved sitting down, scrolling through several pages of suggestions, pictures of home-made tiles, and bullet point after bullet point of rules and classifications, and finally picking and choosing which portions to incorporate into this particular version. The next step was the production of the actual tiles, which followed the same process for all twelve tiles. After saving picture files of the various tiles as PNG files, they were imported into SketchUp as images. The tiles were traced from the inside of the tile, outward, making most use of the 2-point arc and line tools. The sketch on top of the imported image was copied and pasted. The sketch was made into a 3-D model with the Push/Pull tool. The tiles all have a variety of flowers or symbols in the center, and select portions were given raised edges, and like a checker, the outer perimeter of the tile was raised. The 3-D model had one face with the raised edges and the other side was completely flat. Once created, the model was copied and pasted, and one piece was rotated such that both of the flat sides of the models faced each other. Then the two were sandwiched together, resulting in an identical, two-sided piece resembling a checker.

In the *Avatar* universe, the origins of Pai Sho stretch back to ten thousand years and each culture that encountered it has adopted its own strategies, rules, and pace of gameplay. Pai Sho is played with multiple checker-sized pieces and a large circular board with 256 squares. Each piece has either one of eight flowers or one of four elements painted on its surface and, like chess, assumes a unique pattern of movement and abilities. This type of game is the most intriguing because of the relatively even balance of strategy and chance. It makes it such that a wide variety of players can play together and while it does require focus, it is also casual enough such that aspects of fun and relaxation attract people to the board even after a long day of work. The nature of the game reminds is slightly reminiscent with those of chess and Risk, but comparing it only to these battle-oriented and winner-loser-declarative games does not do justice to the complexity of Pai Sho.

THE PROCESS



1) **Import picture**
2) **Trace picture**
3) **Make picture 3-dimensional**
4) **Duplicate 3-dimensional model**
5) **Rotate and orient models**
6) **Combine models into one, two-sided tile**

Figure 1 – ***Modeling the tiles***

Rules and Gameplay of Pai Sho

The Board

The game is typically played with two players, but it could possibly be played with four if you have enough tiles! The players sit across from each other at the small red triangles called "ports" and relative to your perspective, the closest port is called the "Home Port," the one furthest away is called the "Foreign Port," and the ones to your left and right are called the "West" and "East Port" respectively. The center point is called the "Mid Port."

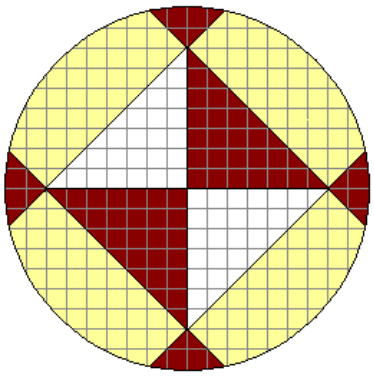


Figure 2 - *The Pai Sho board*

The Tiles

The fan-made rules are inspired partially by Ikebana, that is, the Japanese art of flower arrangement. Ikebana is a type of floral art in which artists arrange flowers, branches, grasses, leaves, etc. in a way that harmoniously flows and expresses an intimate appreciation of the living and ever-changing existence of nature. In Pai Sho, there are three types of white flower tiles: jasmine, lily, and white jade, and three types red flower tiles: rose, chrysanthemum, and rhododendron, some of which form harmonies which each other, while others form disharmonies. There are also four types of non-flower tiles, the rock, knotweed, wheel, and boat, which represent one of the four elements: earth, fire, air, and water, respectively. Lastly, there are two special flower tiles, the white dragon, representing yin, and the white lotus, representing yang. Each player receives 54 total tiles, consisting of three of each specialty flower and non-flower tile, and six of each flower tile. For a full description of tile movements, see Figures 4 and 5 below.

Most of the tile movements and restrictions are pretty straightforward, with the exceptions of, as noted (See Figures 4 and 5 below), the boat and the white lotus. The boat can push any piece (regardless of who it belongs to) one intersection away, as long as the intersection is unoccupied and the boat itself is within one intersection of distance from it. The boat can also move up to three of your own pieces (that are all within one intersection of the boat) five spaces in one direction. This ability can only be used if you have not yet moved the boat. The White Lotus belonging to the player that has given up the least amount of tiles to The Pot are considered "blooming." In this state, the lotuses can form harmonies with any other Flower (regardless of who it belongs to). There is initially a lot to this game, but once it is figured out, it offers a lot of entertainment and a fair share of challenges!

The Harmonies and Disharmonies

Harmonies and disharmonies are the backbone of how scoring is achieved in Pai Sho. Pictured below is the harmony wheel. Starting at the twelve o'clock position and moving clockwise, the flowers are: rose, chrysanthemum, rhododendron, jasmine, lily, and white jade. If two flowers are adjacent to each other in the wheel, such as the chrysanthemum and rose, they create a harmony. Two flowers opposite each other, such as the chrysanthemum and lily, create a disharmony. And lastly, if the neither opposite nor adjacent to each other, such as the chrysanthemum and jasmine, they are neutral.

Figure 3 – *The harmony wheel*

To create a harmony, two pieces must be aligned in a straight, uninterrupted line. A flower interacts only with the first flower in its line but it can attain multiple harmonies at once. Each harmony gives a player one point, unless a "natural harmony" is created, in which a red flower in a red space harmonizes with a white flower in a white space. This special scenario generates two points. With the exception of the Blooming White Lotus case, a player can only form harmonies among his or her own pieces. A piece cannot form a harmony before it has moved. Disharmonies are created when an opponent's harmony is disrupted with a piece that is disharmonious with either of the two harmonizing pieces. When a disharmony is created, the offended player loses one point, or two points, in the case of disrupting a natural harmony.

The Gameplay

To start the game, a coin is flipped and the winner of it is given the option of choosing the first starting piece to put on the board or, after all of the pieces have been set, make the first move. To set up the board, six flowers called the "Spring Flowers" are placed on the board. Placement is alternated between the two players such that each player gets the opportunity to determine where three of the Spring Flowers go. Each player must place the same six pieces in the same spot on their respective sides of the board (mirrored). Spring flowers can only be placed on a player's own side of the board and the red and white flowers can only start in spaces that match their flower color. The Spring Flowers are not subject to the above "Starting Point" rules. These rules apply to new tiles as they come into play throughout the game.

On any given turn, a player has the option of 1) Moving a piece already in play, 2) Place a new piece, or 3) Use a non-flower tile's special ability (only after it is first moved). A piece cannot be placed if its starting point is occupied by another piece, even if the said tile can be captured.

As described previously, each tile has a unique moving pattern and special abilities. However, no piece can move into any of the ports, and only the White Dragon and Boat pieces can move over an opponent's piece. Another restriction is that the while the red and white flowers can travel through their opposite color during a move, they must end their move in a tile of the same color. A red flower tile must end finish its move in a red tile, while a white flower tile must end its move in a white tile.

To remove an opponent's tile, a player must land on it with a disharmonious tile (with the exception of the elemental and special flowers, which can be removed by any piece). All captured pieces are placed into The Pot.

Points are awarded at the creation of a harmony. These harmonies can be built upon kind of like words in Scrabble and points can be "added onto" in a chain reaction. For example, imagine that in turn 3, a player has zero points. The player then creates a harmony between a lily and white jade and one point is awarded. In turn four, the player places a jasmine tile in a position also harmonious with the lily. This turn, two points are awarded, one for the existing white jade-lily harmony and another for the new jasmine-lily harmony, such that the total accumulated points is now 3.

The End of the Game

The game ends when one of the following conditions is met: 1) A player forms a chain of harmonies around the Center Point and wins the Pot, 2) A player is left with only three harmonious tiles and the other player wins the Pot, or 3) a player forfeits and the other player automatically wins. The player who wins the pot also wins any wager (like extra points or money) made at the start of the game.

However, like catching the Golden Snitch during a Quidditch match, winning the Pot does not necessarily lead to automatic victory. There are a few last-minute opportunities for point addition when one of the game-ending conditions is met. For starters, each player gets one extra point for each of their opponent's tiles in the Pot. There is also a final point total counted up on the board, similar to that in Rummy 500. As they do during gameplay, harmonies generate one point and natural harmonies generate two. Each flower tile a player owns that falls within 3 spaces from a White Lotus tile is considered "protected" and gains a player extra points. The remaining, unprotected pieces are considered "dead" and a player loses one point for each on the board. The player with the most remaining points wins.

Project Results

The project has culminated in the print of just one white jade flower tile. SketchUp does not recognize the two separate coins sandwiched together as a uniform, printable solid. Instead, Solid Inspector repeatedly flagged the error "internal face edges," but as a novice to SketchUp, the implications of this error were unknown, and as a consequence, all twelve tiles were created using the same flawed method. Fixing this error involves making a cross-sectional cut into the tile, removing the bases of both coins and then rejoining them. In this way, a coin with two heads and a consistently solid center will be made. Think of the situation in terms of Hershey kisses. Putting the bases of two Hershey kisses together does not make them one object. Each kiss still has its own edges and thus the left can be separated from the right. This is analogous to the incorrect method that was used to "fuse" the two coins. However, cutting out base of each Hershey kiss and putting them together will make

a single object that share a common edge. If the two faces share the same edge, SketchUp will treat the coin as a wholesome object and the smooth layer by layer construction will happen effortlessly.

Other problems included tracing some of the tiles. Once the 2-point arc, rotation, and line tools were figured out, the process was straightforward. But there were a few instances, particularly with the wheel tile, where the smallest break in the line of a shape would cause SketchUp to treat the shape as incomplete, and as a result, the Push/Pull tool or any other manipulation would affect unintended areas of the design. If there was an extension available to aid this problem, by identifying breaks in a way other than scrolling around on maximal zoom and attempting to pinpoint the location of the line break by hand, it would have been of great value!

Discussion

3-D printing presents incredible possibilities. The range of objects able to be created with it is endless. One of the major things learned during this project was that it also takes a lot of skill to personally create your own designs. While I did not wholly design the tiles, I did take the time to trace, size, manipulate, and orient the tiles with just a rudimentary understanding of the tools available in SketchUp by default and by extension. With more time and instruction, SketchUp could certainly be an accessible and very useful program.

3-D printing has a very unique culture in that designs are available for anyone to use and/or modify. Traditionally, innovation is not as easily or largely collaborative as this culture allows. And as the old saying goes, two heads, if not two hundred or perhaps two thousand, are better than one. The odds of one person out of 2,000 figuring out a solution to a problem as opposed to just one or two people are most likely higher, under the assumption that both are randomized samples. But statistics aside, it seems that the culture of 3-D printing is aiming to include users of all ages and levels of ability, and having an open-source mindedness with sites like Thingiverse to host the massive store of files is the perfect solution.

The major selling point of 3-D printing is its ability to support innovation. On the site promoting its Replicator 2, Makerbot greets the user with a, “Bring your projects to life,” and further down, it boldly states, “Start a revolution on your own desk with a fast, easy, and affordable tool for making professional-quality models.”

While 3-D printing is capable of doing both of these things, it has the strange juxtaposition of “easy” and “professional.” In the true spirit of today’s instantly gratified consumers, 3-D printing is making the very skilled ability to effectively imagine and design 3-dimensional objects in a computer program seem very simplistic. This is true if you boot up, log onto Thingiverse, download a design, and print it. But for anyone who wishes to use it as a platform for inventions, it will, like any other art, such as playing an instrument, sculpting a model, painting a landscape, cooking, welding, or glass-blowing, require a progressively fine-tuned set of skills that come with practice.

3-D printing also has serious implications that need to be considered. One of the first issues that came to mind regarding 3-D printing, particularly after seeing a 3-D scanner, was copyright infringement. It is one thing to be inspired by an idea, put in the work to significantly modify it, and then call it an original, but another thing entirely to scan an object, print an effective duplicate, and call it an original. 3-D scanners make it possible to create exact replicas of objects for potentially (depending on material used) lower prices with no acknowledgement or appreciation of the original designer or the people behind its production. It is assisting the movement to make technology the primary vehicle through which the daily tasks of life are performed. Trips to the store, trips to the backyard, trips to meet people for coffee, and trips to classrooms are rapidly being replaced, arranged, and/or blended with technology. It will not be much longer before this technology revolutionizes the way in which things are imagined and built and by extension, we will see novel products that were not previously possible.

New levels of personalization and accessibility have manifested themselves in 3-D printing. No longer will minor dissatisfactions occur. A child could buy a toy, scan it, modify it, and reprint a new one for a fractional cost. A person could be inspired by a picture frame in the store, go home, redesign it to fit the exact dimensions of a photo, and print it. In regards to accessibility, no longer will lack of transportation, inclement weather, stores out of stock, or stores too far away have an effect on the ability to receive items. Bettering even Amazon by eliminating shipping time and taxes, 3-D printing allows the items to be printed right at home. Instead of just “Googling” it, the solution of the future will be just “Printing” it.

References

"How to Play the Ancient Game of Pai Sho." *wikiHow*. Mediawiki, n.d. Web. 11 March 2015.

"Replicator 2." *Makerbot*. Makerbot Industries, n.d. Web. 19.April. 2015

"The Desert" *Avatar: The Last Airbender, Season 2*. Prod. Bryan Konietzko, Michael Dante DiMartin, et. al. Voices: Mako Iwamatsu, Dante Basco Peter Jessop. WGBH, Boston. 14 July 2006.

"The Stakeout" *The Legend of Korra, Season 4*. Prod. *Bryan Konietzko, Michael Dante DiMartin, et. al. Voices:* Janet Varney, David Faustino, P.J. Byrne, Seychelle Gabriel. Nickelodeon. WGBH, Boston. 6 October 2014.

"What is Ikebana?" *Ikebana International*. Ikebana International, 2005. Web. 11 March. 2015.

"What is Pai Sho?" *Pai Sho*. Webs, 2008. Web. 11 March 2015.

D., Dennis. "Official Pai Sho Rules and Gameplay" *Pai Sho Board and Tiles*. Lyris Laser Studio, 2015. Web. 11 March 2015.

Dunn, Emory. "Wiki Pai Sho." Photograph. *Etsy*. Etsy Inc., 11 April 2015. Web. 27 April 2015.

Flamingtunapictures. "How to play Pai Sho." Digital art. *DeviantArt*. DeviantArt, 14 Feb. 2014. Web. 11 March 2015.

Red Kutai. "Wiki Pai Sho." *The Pai Sho Project*. PBWorks, 12 March 2010. Web. 11 March 2015.

The Tiles (Detailed)

Classification	Name	Starting Point	Movement	Direction	Restrictions	Special Abilities
Non-Flowers	Rock	Any space	Does not move		May be put on board after first three turns May be removed by any piece but the piece that does so is also removed	If a Flower (exc. Special Flower) is adjacent to Rock, it takes on all harmonious and disharmonious traits of that Flower
	Wheel	Any yellow space	Any number of spaces	One direction	"	Moves all pieces adjacent to it in a clockwise or counterclockwise rotation to any degree
	Boat	Any space with red and white	Up to 5 spaces	Any combination of directions	"	May travel over other pieces Does not disrupt harmonies/disharmonies Can move tiles as it travels (see details)
	Knotweed	Any point NOT within one space of any port	May not move on its own (only by boat)		"	All pieces adjacent to knotweed cannot be moved or form harmonies (i.e. drained)
Special Flowers	White Dragon	Foreign Port side of board	6 spaces	Straight line	May be put on board only after first three turns of each player May be captured by ANY piece	May capture enemy pieces Can move over other pieces
	White Lotus	Home Port side of board	2 spaces		May be removed by ANY other tile	May take any tile off board "Blooming" White Lotus

Figure 4 – *The special tiles*

Classification	Name	Starting Point	Movement	Direction	Restrictions
White Flowers	Jasmine	Home Port	1 or 3 spaces	Straight line	
	Lily	East/West Port	4 spaces	L-shape (2 &2)	
	White Jade	Mid Port	5 spaces → 3 spaces →	One direction Any combination of directions	Cannot use boat
Red Flowers	Rose	Foreign Port	1 or 3 spaces	Straight line	
	Chrysanthemum	East/West Tip	4 spaces	L-shape (2&2)	
	Rhododendron	Mid Port	5 spaces → 3 spaces →	One direction Any combination of directions	Cannot use boat

Figure 5 – *The flower tiles*