DESIGN OF AUTONOMOUS REARRANGING CHESSBOARD FOR HANDICAPPED USERS

THE EFFECT OF THE CONSTRUCTION OF TECHNOLOGICAL ARTIFACTS ON THE MARGINALIZED MEMBERS OF SOCIETY

A Thesis Prospectus
In STS 4500
Presented to
The Faculty of the
School of Engineering and Applied Science
University of Virginia
In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science in Computer Engineering

By
Bryam Ayvar

November 1, 2022

Technical Team Members:

Bruce Bui, Marshall Mcllyar, Selena Pham

On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

ADVISORS

Catherine D. Baritaud, Department of Engineering and Society

Harry Powell, Department of Electrical And Computer Engineering

When new technology emerges, the concept of accessibility is frequently an afterthought or it is applied in ways that do not improve the lives of the people who need assistance (Titchkosky, 2003). There have been multiple instances where members of the handicapped community have been held back because of technologies, particularly the physically impaired (Foley & Ferri, 2012). According to Burgstahler (2003), early access to electronic and information technology has the potential to promote positive academic and career outcomes for students with disabilities (p.1). As an example of technology limiting the capabilities of some users, CNC machining and computer graphics enabled a child who suffered from cerebral palsy to design a fully functioning and award winning CO_2 car in a Florida Middle School (Lintz, 2004). The hidden ability of this user highlights the necessity for developers to examine their product's user base more carefully. Due to these reasons, engineers and inventors must start considering whether the devices readily available are enough for them to couple normally to society.

The technical portion of this project is moderately coupled with the STS research topic. Taking the account of assistance for handicapped people, the main objective of the technical project is to design and manufacture an autonomous rearranging chessboard. It caters to handicapped users suffering from a physical impairment, as it is able to rearrange pieces through a simple push-button, and the base design is intended to be further implemented to a fully-functional game with voice commands. Board games are an area where there are only a few options for the handicapped to adapt to, as there have been low strides in enabling them for handicapped users (Heron et al., 2018). Most of the handicapped board game efforts have gone into fully-software built systems, such as online games (Shin, 2020). However, these designs mostly augment a single game, even though they are built on the same framework. The piece movement and recognition algorithm that ReChess, our technical project, possesses could be repurposed to play any board game, such as checkers, tic-tac-toe, and even monopoly to an extent. The basic capabilities that the ReChess hardware engine provides are piece recognition and piece movement. Using this technology, board-game companies would have the opportunity to cater to the handicapped community by simply making a few modifications to their pieces. This work will be accomplished during the Fall 2022 and Spring 2023 semesters amounting to a total of 28 weeks, as depicted in Figure 1. The technical portion will be implemented during Fall 2022 and the Science, Technology, and Society portion will be completed by Spring 2023.

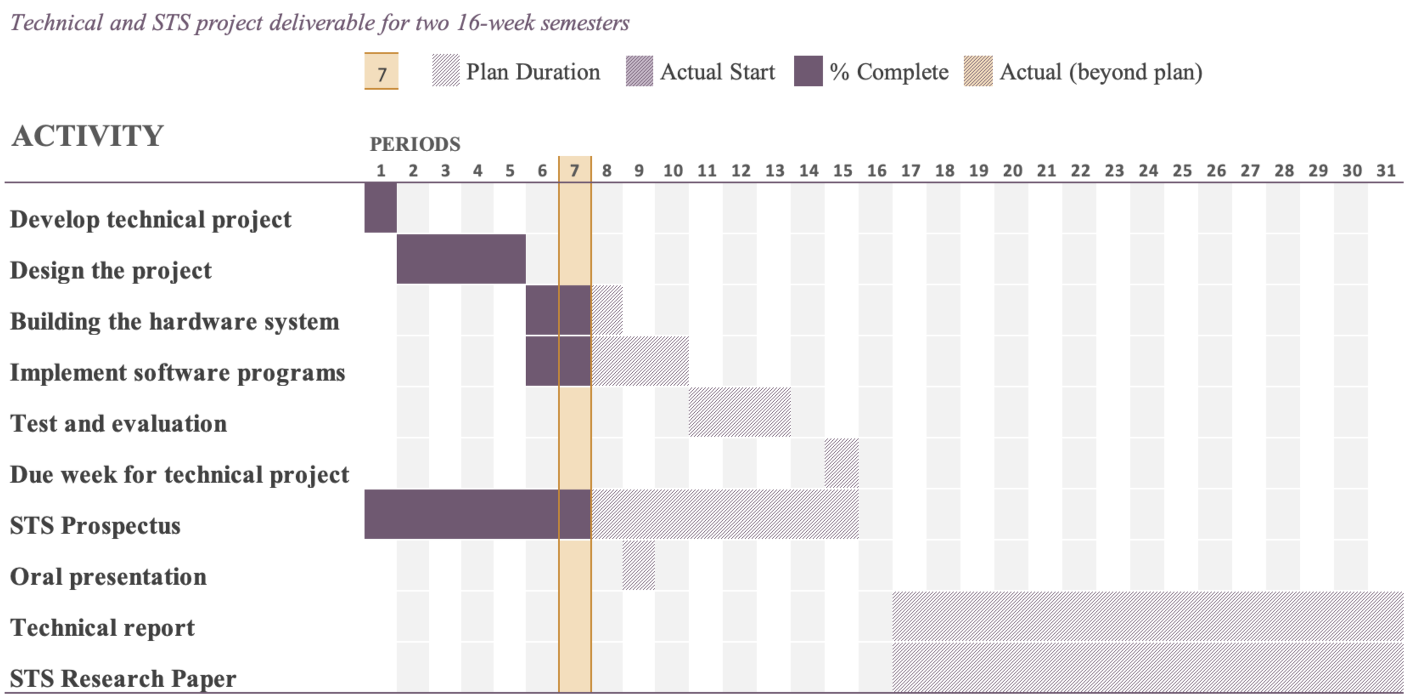

Figure 1: Gantt chart Self-rearrangement Chess. This figure depicts the expected timeline for the technical project and STS research in 32 weeks (Adapted by Ayvar (2022) from Pham, 2022).

DESIGN OF AUTONOMOUS REARRANGING CHESSBOARD FOR HANDICAPPED USERS

In light of the limited technologies available for handicapped users, engineers have made an effort to increase the inclusiveness of technologies. We have already witnessed this in structural design and architecture, as all of the North American buildings are required to have a pathway for wheelchair users to be able to reach any part of the building (Church & Marston, 2003). This is also a requirement that must be met to construct any public building. However, there are also other types of technologies that handicapped users can benefit from, and we need to start asking ourselves if building accessibility is the only thing that suffices the needs of impared users. Areas which lack accessibility range from entertainment and food preparation to medication intake and computers. The technical portion of this project will focus on the entertainment section, narrowing down into board game convenience, but the recognition and movement system could be repurposed for other tasks, such as sorting medicine and kitchen utensils.

Out of the five senses, only two are required to play a game of chess - touch and vision (Gustafsson, 2017). Even a simple task, such as rearranging a chessboard can be difficult with the absence of one of these senses (Gustafsson, 2017). The ReChess is an artifact that aims to solve this problem. At its core, the ReChess is capable of recognizing and autonomously moving objects around a flat, playing area. Although its only built-in function is to rearrange chess pieces back to their original position, the hardware engine of ReChess provides a fundamental detect-and-move framework that allows for easy implementation for different features, such as player vs machine matches and voice commands. The system is meant to be a general building block for autonomously playing board games, with chess rearrangement as one of its first subfeatures. The brain of ReChess is a Raspberry Pi, which "enables people of all ages to explore computing, and to learn how to program in languages" ("What is a Raspberry Pi?", 2021). This microprocessor's vision goes hand in hand with ReChess, allowing users of all sorts to interface with the code. The robot poses little to no safety threat, as it hides most of its electronics, PCB, and actuators are hidden inside a wooden frame. The problem with the majority of the current smart-boards is that the movement system is attached to the top of the board, being obstructive for the user and playing areas. In contrast, the ReChess is able to move the pieces from underneath the playing area using a CoreXY cartesian motion platform with electromagnet payload. CoreXY provides a parallel belt-driven mechanism that has an ability to reduce the moving load of the system (Yin et al., 2018). The electromagnet picks up pieces (which must have a metal base) using the CoreXY. To recognize the piece, the robot has a small camera attached to the top of the board, which uses the fiducial markers on the pieces and image processing algorithms to identify an object. While machine vs human playing capabilities are outside of the scope of the project, they could be implemented using the StockFish chess-playing AI. Figure 2 shows the prototype of the ReChess.

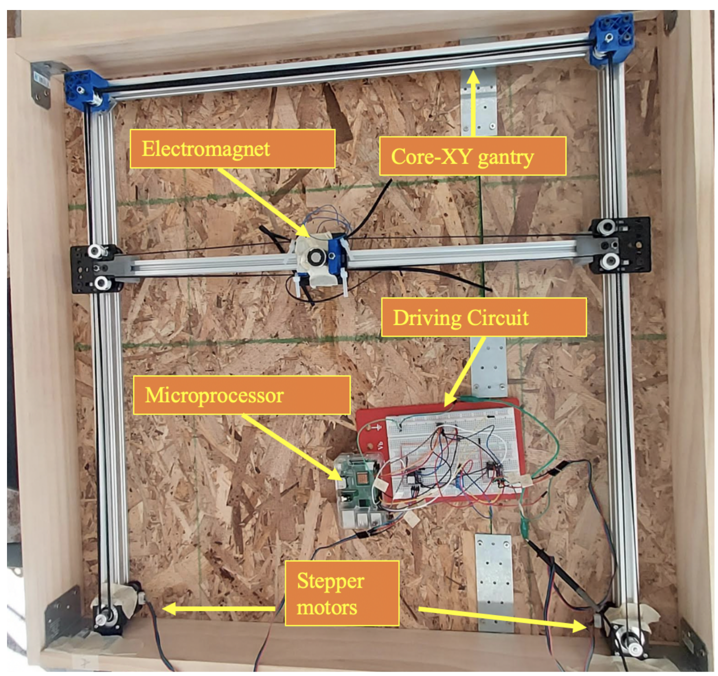

Figure 2: Anatomy of the movement mechanics of ReChess. All the components are embedded in the coreXY frame for reference (Ayvar, 2022).

The self-rearranging chessboard will be designed and built during a semester-long capstone project, with a final demo deadline on December 12, 2022. During this time, the robot would be capable of rearranging the pieces on command, either by push-button or voice recognition. The bot is intended to be able to rearrange pieces even as users place other pieces within the chessboard. It is currently being developed under the guidance of Harry Powell, a professor in the Charles L. Brown Department of Computer and Electrical Engineering at the University of Virginia. The design process follows the general Engineering and Scientific method, which has the process of (1) Identify the problem and target audience (2) come up with a solution (3) Prototype the solution (4) Test the solution and obtain feedback (4) Come up with an improved model and repeat. This design process is depicted in Figure 3.

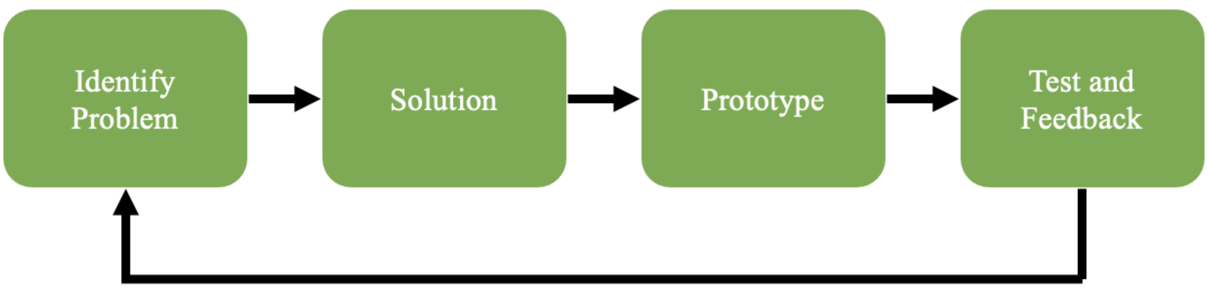

Figure 3: ReChess Development Process. Depictions of the Engineering process applied to the development of the technical portion of the project, ReChess (Ayvar, 2022) .

The development of the ReChess playing robot is spearheaded by four students at the University of Virginia: Selena Pham, Bruce Bui, Marshall McIlyar, and Bryam Ayvar. Each team-member is studying Electrical or Computer Engineering at the University of Virginia School of Engineering and Applied Sciences. The embedded code is written in the Python programming language running under the Raspbian Operating System, and it interfaces with stepper motors through a custom printed circuit board (PCB). The PCB was designed by the team members and manufactured and assembled by advanced circuits. The expected product setting of the project is for commercial use to be used at home or at a general public event.

THE EFFECT OF THE CONSTRUCTION OF TECHNOLOGICAL ARTIFACTS ON THE MARGINALIZED MEMBERS OF SOCIETY

The design space and test users are a vital part when it comes to technological development, as the social groups can have a pertinent impact on what the final product would be (Wastell, & White, 2014) . As an example, one of the very first face-detection algorithms, written by Google, was only able to detect light-skinned users because all of the preliminary testing and machine learning algorithms were fed only datasets of light-skinned people (Mandal et al., 2015). There were several complaints of dark-skinned users being unable to interact with this new software (Razzaq, Ghazali, El Abbadi & Dosh, 2022). Therefore, the artifact limited the use of the technology to a certain group due to the engineers' initial encompassed design space. Whether intentional or not, the example showcases that the final end product and audience is highly dependent on who is being considered during the development process. There are many hidden members in the design world that inventors should account for, in fact, some would argue that they should account for almost all human beings (Detweiler, Pommeranz & Stark, 2012). However, what the exact percentage of people should be aimed for that the technology caters to is the problem. Similar to this situation, if stakeholders are not integrated early on, particularly in the design and prototyping phase of the project, they become "ghosts" who are marginalized from the technology's use. This is what is happening in the handicapped world. There are multiple users who have not been able to interact with even old tech, such as keyboards and mouses, and they are often left to fend for themselves (Perrin & Atske, 2021). However, there should be a legal standard in the engineering world that allows for usage of people in this social group, similar to the ADA standard imposed for architects and civil engineers.

The barriers behind technological development are primarily chosen during the beginning stages of development (Petralia, Balland, & Morrison, 2017). In order to analyze the pathway of the game of chess, the research will investigate the different variations of the chess game and the social groups that contributed to the most current version of the game. Chess was born in India, and it was originally known as Chaturanga, which translated to “four-division”, as there were only four special pieces and each piece represented a division of the military (History of chess, September 7, 2022). Then, Chess moved from India to Persia, there were major changes to the pieces (History of chess, September 7, 2022). Most notably, the elephant piece was replaced by a bishop (Bishop(chess), October 13, 2022). This modification was done because some users were unfamiliar with elephants and educators wanted to introduce the idea of social groups with the game of chess (McClain, November 17, 2011). This change meant that there were some cultural influences on the development of the game even this early on.

Nearing the 15th century, due to the rise of female monarchs, the game of chess replaced the advisor piece with a new piece, the queen, and additionally, she was given the amalgamated powers of the rook and the bishop (McCrary, 2021). As chess became more popular, every-day players had the problem of pawns being too slow, and the king being too weak, and artists wanted more bold and dramatic plays to be added (Promotion (chess), 2022). These social groups propelled the addition of special moves, such as castling, en-passant, and pawn-to-queen upgrading. Finally, one of the most recent features added to chess was simply standardization, and it was introduced by chess theorists, programmers, and chess organizations, who needed a grade to study, program, and host games of chess, respectively (Newborn, 1975).

Figure 4 describes the major social groups that had an effect on a feature of the game of chess as discussed before, in the form of a Social Construction Of Technology graph (Bijker & Pinch, 1984).

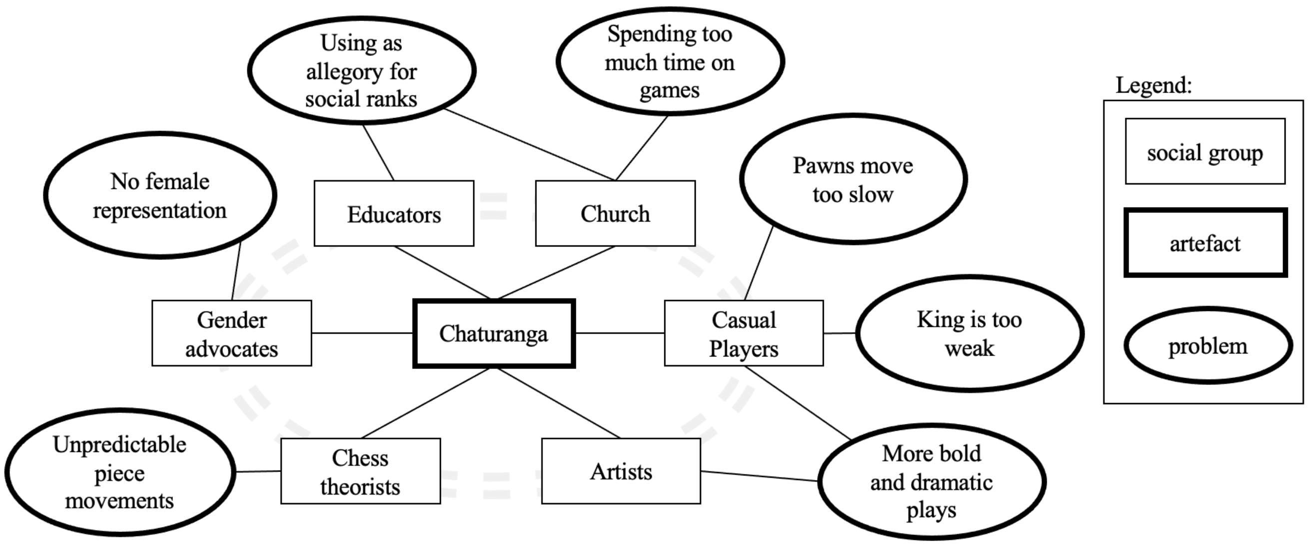

Figure 4: Social-construct graph of the original game of chess, Chaturanga. Depictions of the major social group's effect on a feature of the game of chess as discussed (Ayvar, 2022).

The development path that the game of chess has taken has been dependent on how relevant the social group has been to the game (Spoerer, Sirivichayakul & Iida, 2013). In other words, as it moved from culture to culture, the values that a certain group carried were embedded in the game. Due to events at certain points in time or the uniqueness of a particular culture, the pieces and their movements reflected the requirements of the contemporary social groups. Each new change to the game of chess can be marketed as a new feature for a certain group, attracting more players.

Chess and many other technologies have stayed relevant for their ability to follow the most popular paths with the most advantageous opportunities. However, the main pattern that can be seen from the evolution of chess is the fact that larger social groups have a greater influence than smaller ones. While advantageous for the development of the technology, this leaves less popular social groups to be marginalized and unable to benefit from the changes. For example, religion, government, and human expression (art) steered the major changes, whereas smaller social groups, such as handicapped users have been left to feel marginalized (Marjoram, 1987). Figure 3 fails to showcase this phenomenon, as it is missing an essential component which is the weights of the social construction graph. The weight of a path in the graph can be a representation of cost and reward for the artifact or developer. Figure 5 depicts the proposed update to the social construct graph of Chaturanga, including weights connecting each social group, representing incentives that the designer or artifact may be persuaded to follow. Impaired users, shown in red, are often unaccounted for in this representation because they pose the least benefits for the designer or artifact.

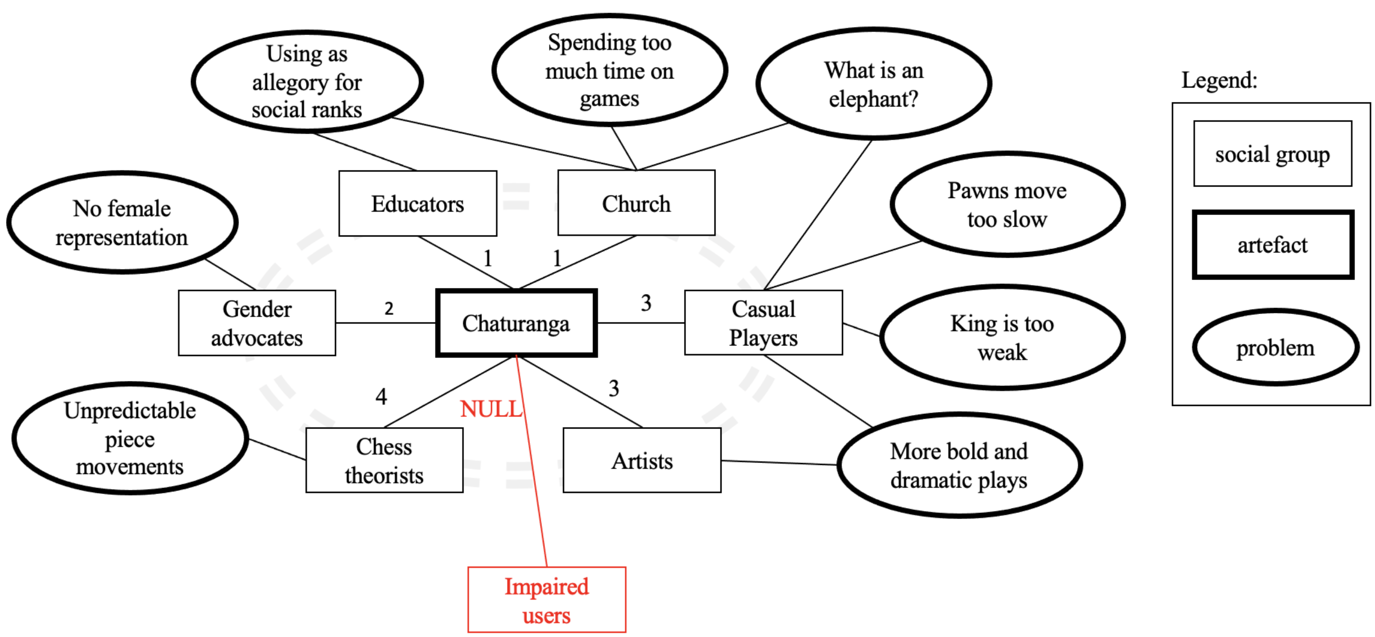

Figure 5: Updated social construct graph of the game of Chaturanga. Weights represent incentives that the artifact may benefit from catering to a specific social group. (Ayvar, 2022)

The new era of chess has begun to shift towards a more computer-generated approach (Greer, 2000). The number of online chess players have reached around 20 million active users (Ginsburg & Weisband, 2002). Computer scientists have built stronger chess-playing AIs that can take inputs such as voice commands, capacitive touch buttons, and smart sensors; and outputs such as automatic movement, sound, and visual imagery allow users to account for members of society who do not have the required senses to play a game of chess. This computer technology provides the opportunity to fix the problems of the handicapped social group.

Through analysis of artifact case studies in which sought features have neglected or even harmed marginalized social groups, the effect of the construction of technological artifacts on the marginalized members of society can be investigated. This will be done via the social construction of technology (SCOT) framework pioneered by Trevor Pinch and Wiebe Bijker (Bijker, Hughes, & Pinch, 1987; Bijker & Pinch, 1984; Kline & Pinch, 1999). In the SCOT framework, the designer is in charge of absorbing all of the requirements from all the social groups and choosing a path to move forward in the form of a feature (Bijker & Pinch, 1984). Through an understanding behind the decision-making process of the engineer, the results and expected outcomes of the product can be better understood. When the design process is repeated multiple times the product reaches a "stabilized" state, in which the relevant social groups accept the design.

This research will be in the form of a scholarly article analyzing technological decisions which let a social group to be favored over others, and understanding the reasoning, benefits and drawbacks of the implemented features. It will attempt to demonstrate how technological decisions impact marginalized social groups and whether the technology we offer is enough for them. By understanding the source of the problem and the development of a technology, the field of social engineering can be better equipped to encompass the needs of all stakeholders. Possible outcomes include motivating a set of rules for engineers to consider when integrating a new feature of characteristic to a certain artifact, such as prioritizing safety and inclusivity over other attributes of an addition.

REFERENCES

Ayvar, B. (2022). Anatomy of the movement mechanics of ReChess [Figure 2]. Prospectus (Unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, VA.

Ayvar, B. (2022). ReChess Development Process [Figure 3]. Prospectus (Unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, VA.

Ayvar, B. (2022). Social-construct graph of the original game of chess, Chaturanga. [Figure 4]. Prospectus (Unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, VA.

Ayvar, B. (2022). Updated social construct graph of the game of Chaturanga. [Figure 5]. Prospectus (Unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, VA.

Bijker, W. E., Hughes, T. P., & Pinch, T. J. (1984) The social construction of technological systems. Zeitschrift für Wissenschaftsforschung, 2, 39-52.

Bijker, W. E., & Pinch, T. J. (1984). The social construction of facts and artifacts. Social Studies of Science, 14, 399–441. https://doi.org/10.1177/030631284014003004

Bishop(chess). (2022, October 13). In Wikipedia. Retrieved October 24, 2022, from https://en.wikipedia.org/wiki/Bishop_(chess)

Burgstahler, S. (2003). The role of technology in preparing youth with disabilities for postsecondary education and employment. *Journal of Special Education Technology*, *18*(4), 7–19.

Church, R. L., & Marston, J. R. (2003). Measuring accessibility for people with a disability. *Geographical Analysis*, *35*(1), 83–96. https://doi.org/10.1111/j.1538-4632.2003.tb01102.x

Detweiler, C., Pommeranz, A., & Stark, L. (2012). Methods to account for values in human-centered computing. *CHI '12 Extended Abstracts on Human Factors in Computing Systems*. https://doi.org/10.1145/2212776.2212708

Foley, A., & Ferri, B. A. (2012). Technology for people, not disabilities: Ensuring Access and Inclusion. *Journal of Research in Special Educational Needs*, *12*(4), 192–200.

Ginsburg, M., & Weisband, S. (2002). Social Capital and volunteerism in virtual communities: The case of the internet chess club. *Proceedings of the 35th Annual Hawaii International Conference on System Sciences*, 2225-2234. https://doi.org/10.1109/hicss.2002.994152

Golladay, S. (1996). Playing the queen: Historical perspectives on gender and chess. *Journal of Women in Culture and Society, 22*(2), 439-461.

Gustafsson, M. (2017). Wittgenstein, language, and chess. *Finding One's Way Through Wittgenstein's Philosophical Investigations*, 79–93. https://doi.org/10.1007/978-3-319-63507-1_5

Greer, K. (2000). Computer chess move-ordering schemes using move influence. *Artificial Intelligence*, *120*(2), 235–250. https://doi.org/10.1016/s0004-3702(00)00026-6

Heron, M. J., et al., (2018). Eighteen months of meeple like us: An exploration into the state of Board Game Accessibility. *The Computer Games Journal*, *7*(2), 75–95. https://doi.org/10.1007/s40869-018-0056-9

History of chess. (2022, September 7). In *Wikipedia*. Retrieved October 24, 2022 from https://en.wikipedia.org/wiki/History_of_chess

Kline, R., & Pinch, T. J. (1999). The social construction of technology. The Social Shaping of Technology, 2.

Lintz, J. (2004). CNC Technology brings out hidden talents in disabled children. *Tech Directions*, 64(4), 19 - 21.

Mandal, B., et al., (2015). A wearable face recognition system on Google Glass for assisting social interactions. *Computer Vision - ACCV 2014 Workshops*, 419–433. https://doi.org/10.1007/978-3-319-16634-6_31

Marjoram, D. T. E. (1987). Chess and gifted children. *Gifted Education International*, *5*(1), 48–51. https://doi.org/10.1177/026142948700500112

McClain, D.L. (2011, November 17). Elephants and Bishops. *The New York Times*. Retrieved from https://www.nytimes.com/2011/11/18/arts/elephants-and-bishops.html

McCrary, J. (2021, July 2). The evolution of Modern Chess Rules: Enter the Queen and Bishop. Retrieved October 24, 2022, from US Chess website: https://new.uschess.org/news/evolution-modern-chess-rules-enter-queen-and-bishop

Newborn, M. (1975). The history and basic ideas of Computer Chess. Computer Chess, 5–29.

Petralia, S., Balland, P.A. & Morrison, A. (2017). Climbing the ladder of Technological Development. *Research Policy*, *46*(5), 956–969. https://doi.org/10.1016/j.respol.2017.03.012

Perrin, A. & Atske, S. (2021). Americans with disabilities less likely than those without to own some digital devices. Retrieved October 22, 2022, from Pew Research Center website: https://www.pewresearch.org/fact-tank/2021/09/10/americans-with-disabilities-less-likely-than-those-without-to-own-some-digital-devices/

Pham, S. (2022). Gantt chart Self-rearrangement Chess. [Figure 1]. Prospectus (Unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, VA.

Razzaq, A. N., Ghazali, R., El Abbadi, N. K., & Dosh, M. (2022). A comprehensive survey on Face Detection Techniques. *Webology*, *19*(1), 613–628. https://doi.org/10.14704/web/v19i1/web19044

Shin, M. (2020). A growth of accessibility in video games. Retrieved October 22, 2022, from Do It website: https://www.washington.edu/doit/growth-accessibility-video-games

Spoerer, K., Sirivichayakul, T., & Iida, H. (2013). Homogeneous Group Performance in chess. *Procedia Technology*, *11*, 1272–1276. https://doi.org/10.1016/j.protcy.2013.12.324

Titchkosky, T. (2003). Governing embodiment: Technologies of constituting citizens with disabilities. *Canadian Journal of Sociology / Cahiers Canadiens De Sociologie*, *28*(4), 517.

Promotion (chess). (2022, October 29). In *Wikipedia*. Retrieved October 24, 2022, from https://en.wikipedia.org/wiki/Promotion_(chess)

Wastell, D., & White, S. (2014). Making sense of complex electronic records: Socio-Technical Design in social care. *Applied Ergonomics*, *45*(2), 143–149. https://doi.org/10.1016/j.apergo.2013.02.002

What is a Raspberry Pi? (2021). Retrieved October 22, 2022, from Open Source website: https://opensource.com/resources/raspberry-pi

Yin, M., et al., (2018). Dynamic Modeling and Characterization of the Core- XyCartesian Motion System. *2018 IEEE International Conference on Real-time Computing and Robotics (RCAR)*, 206-211. doi: 10.1109/RCAR.2018.8621684.