COUNTR

UNDERSTAND YOUR FLAWS, IMPROVE YOUR PERFORMANCE

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ABSTRACT

Boxing. It's one of the most exhausting sports out there, due to the rapid and powerful movements the entire body exerts over extended periods of time. Especially beginners don't know how to pace themselves and fatigue after a few minutes of going full speed during their first sessions. By physicalizing data of sparring activity, boxers can easily understand what pace they are fighting at, allowing them to improve their timing, cardio and motivation. A number of novice boxers were tested by using the visualization tool over 3 rounds of sparring.

1. INTRODUCTION

Boxing is a sport that requires a combination of strength, technique, IQ and endurance. It is often seen as one of the most physically and mentally challenging sports there is [9]. Especially newcomers that are just starting to pick up the sport, often find themselves quickly exhausted during their first sessions, leading to a decrease in motivation since they don't believe they are fit enough for the sport [10].

However, what novices often don't realize is the fact that boxing is a marathon and a sprint at the same time. Although the sport requires a high level of endurance, it is advised to use a combination of bursts of explosiveness with moments of low intensity in between [11]. The ability to maintain the ideal pace in boxing, involves striking a balance between a moderate rhythm and the sudden bursts of intensity.

To address this issue, Countr seeks to improve the way that beginners perceive and approach their boxing training. By gathering data about movement patterns of novice boxers during sparring sessions, and transforming that data into an interactive visualization tool, this project enables novice boxers to gain a deep understanding of their performance, pacing and strategy during their sparring sessions.

To collect this movement data a depth camera is situated above the ring, which can be used to track object from above, in this case the fighters. The camera uses algorithms to create a heatmap that displays the positioning and movement of the fighters at every moment of the round. In addition to this, a graph is created that showcases high moments of intensity during the round. These visualizations can be combined to create a rich visualization tool that can be used by boxers to reflect on their performance, and therefore improve on their strategy, cardio and motivation. This project aims to answer the following question:

How can a visualized dataset of sparring activity help a novice boxer reflect on their flaws in cardio/pacing and strategy, and therefore show improvement and increased motivation?

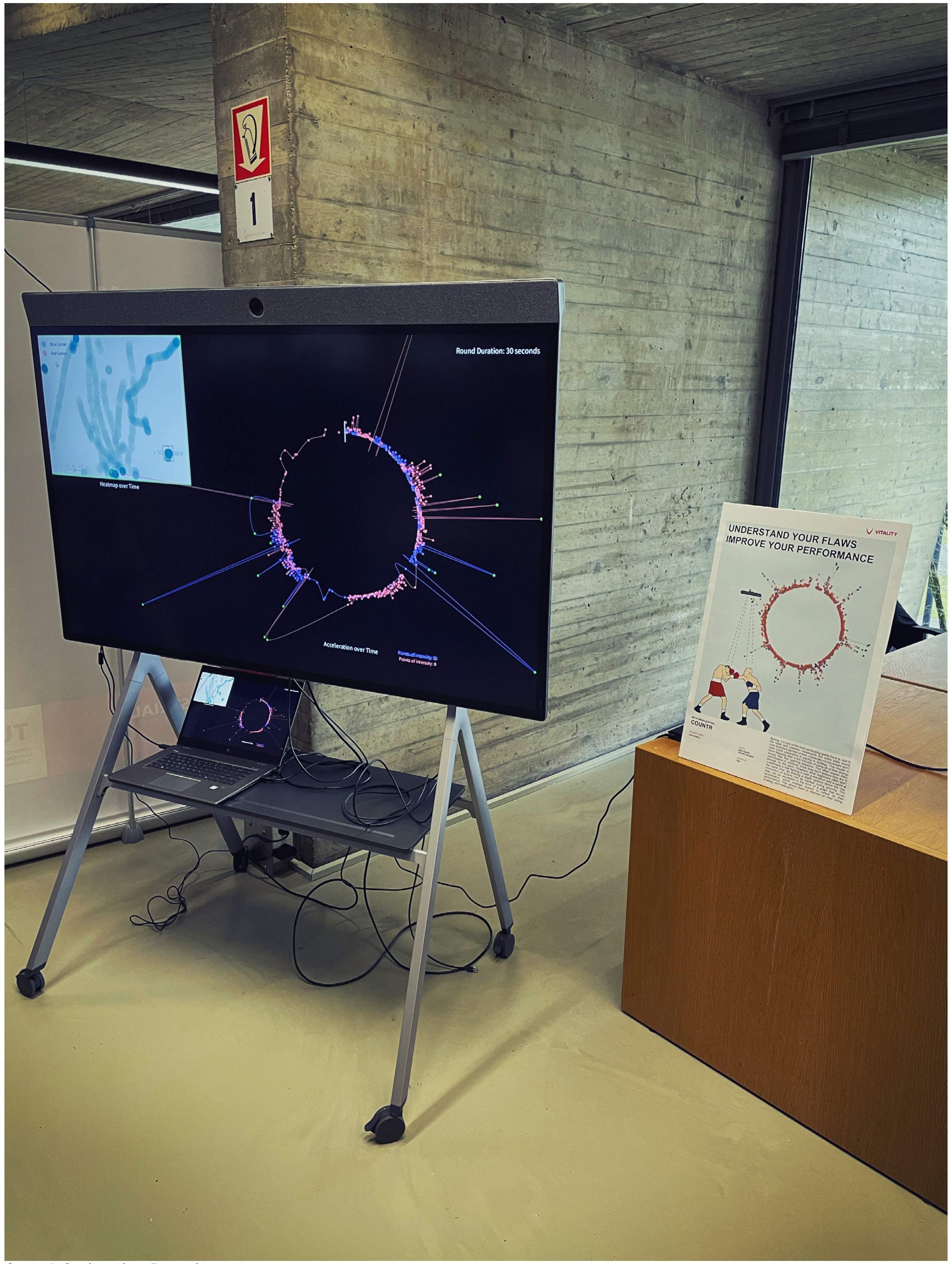


figure 1: final product Demoday

2. RELATED WORK

Body tracking and sensory feedback

In the evolving landscape of body tracking and motion capture, multiple projects across different fields have provided Countr with useful insights. Similar to Countr, EagleSense (figure 2) uses a Kinect depth camera positioned to capture data from a top-view perspective [31]. However, in contrast to Countr, this project uses the Kinect for real-time human posture and activity recognition in an office setting. EagleSense serves as a precedent for Countr, showcasing the potential of the Kinect camera as a non-intrusive tracking device to monitor the movement of users. This aligns with Countr's goal of providing feedback immediately after boxing performances. Apart from top-view tracking or motion capture in sports, the Kinect camera can also be used in different environments, such as the kitchen. Panger, G. (2012) explores the application of the Microsoft Kinect in real-life kitchens [19]. While the context differs from sports applications, the insights gained from this articles can inform Countr's design considerations. It highlights challenges such as preventing unwanted results when completing tasks and troubleshooting, providing valuable information in terms of avoiding unintended interactions and enhancing the effectiveness of capturing data and providing feedback (figure 3). Another project that dives into motion capture and that is focused more on boxing is Lightron [6], a wearable sensor system that aims to enhance punching accuracy during shadowboxing. By using accelerometers and sensors that register flexing and stretching, Lightron offers real-time LED light feedback to its users and thus improves motion detection and analysis, which is crucial for assessing punching accuracy (figure 4). Using light as a real-time feedback mechanism allows for immediate application of the provided data, however it must be taken into consideration that Countr provides feedback on sparring sessions and not on shadowboxing. Since these are two different methods of training, the effectiveness of real time LED light feedback may have different outcomes. Moving on to another method of body tracking, Seuter et al. (2020) have connected a sports watch with intertial measurement units via Bluetooth [20]. This innovative approach enables extremely accurate movement tracking, which could be useful during motion capture in boxing training. However, a potential drawback that comes with using this method is the increased complexity and budget associated with integrating multiple IMUs. Furthermore, Kos et al. (2018) explore the role of science and technology in sports in an article that underscores the recent evolution of sports technology and highlights the role of data backed-up feedback [14]. The integration of sensors and other technology is explored, accentuating the rising influence of technology in the sports landscape.

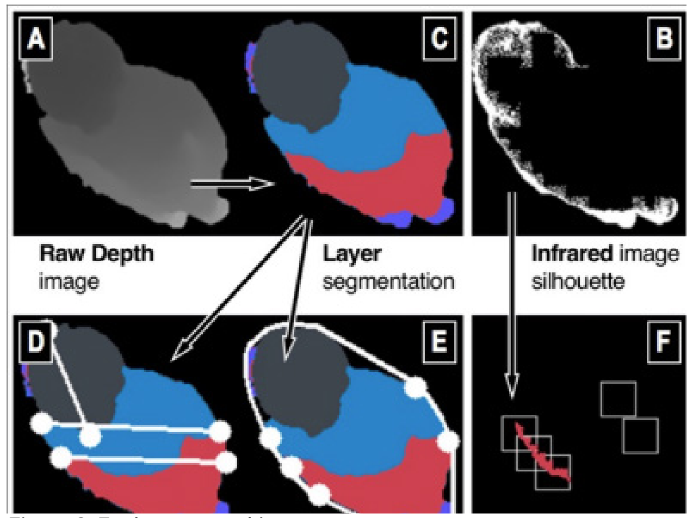


Figure 2: Eaglesense tracking

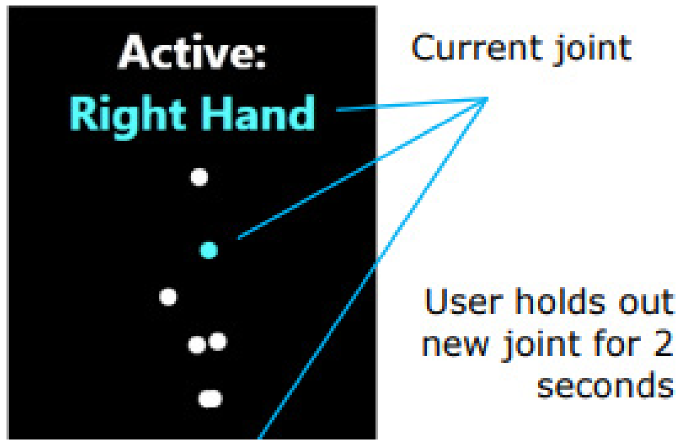


Figure 3: Kinect in the kitchen tracking

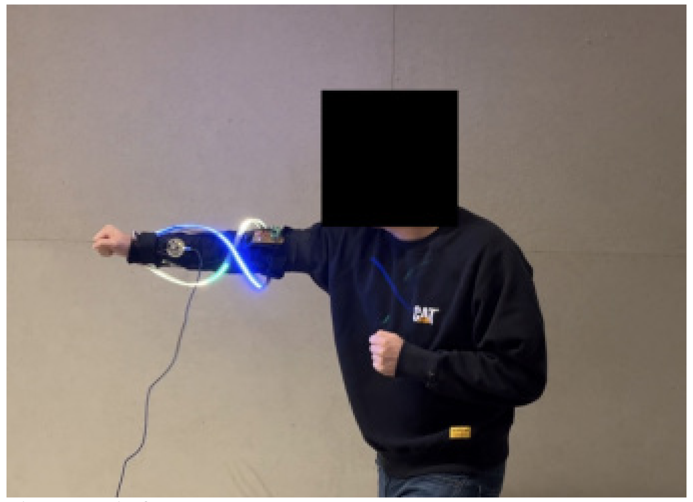


Figure 4: Ligthron

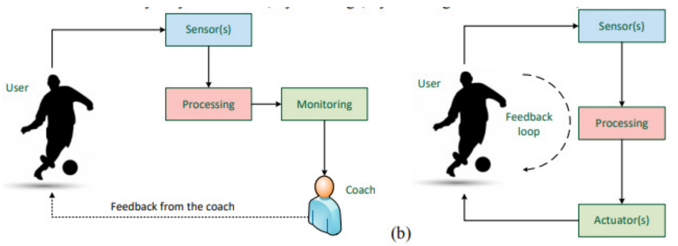


Figure 5: feedback of sensors in sports

In addition to this, Kos et al. (2018) make comparisons between coaching and sensory feedback (figure 5) and state that technical equipment has the ability to obtain information that is out of reach of human senses , aligning with Countrs goal of providing objective performance data to its users.

Data visualization/physicalization in the world of sports and physical activity

In the realm of data visualization and physicalization withing sports and physical activity, several projects and articles provide opportunities for Countrs development. For instance, Clever Franke has recently developed a visualization method that aims to enhance fan experience and engagement during Freestyle BMX [2]. By quantifying performance through sensory data, BMX rider data is visualized and displayed live on-screen, presenting the route the riders take and the specific tricks they perform (figure 6). The process and techniques used to realize this project can inspire and assist Countr during visualizing captured data. Moving away from BMX and looking into visualization tools as a approach to analyze physical activity in a broader scope, Tong et al. (2019) introduces a sensor-based interactive visualization tool to analyze physical activity [27]. This tool uses the parallel coördinates technique (figure 7), which is beneficial for analyzing high dimensional data sets. This approach shows advantages in user-centered exploration and data interpretation, however adaptability to different types of data sets such as sparring activity may prove to be unsuitable. Delving into a more specific area of visualizations, tools to enhance boxing performance have already been explored. SkillVis proposes a tool to assess boxers' motions and skill levels [21]. Through horizontal motion capture data, a representation in the form of a graph is displayed in a 3D space (figure 8). SkillVis is able to visualize punch dynamics, combinations and overall boxing behavior. Although these visualizations enable users to improve their technique and skill level, it doesn't give insights on pacing and movement, which is Countr's goal. Moving away from visualizations and looking into physical representations of data, Alexander et al. (2015) explore the challenges that come with making data physical [3]. Attention is brought to the evolution of data physicalizations, categorizing examples from static bar charts to dynamic objects. The article addresses the need for effectivity, construction and evaluation of data. A workshop was organized to assess challenges on making physical representations of data. A similar approach was taken by Countr in the form of a co-creation session, to determine and discuss what type of visual or physical feedback is most beneficial for Countr's purpose. Physical representations of data can be applied in a multitude of environments. For Instance, Stusak et al. (2014) delve into data sculptures focusing on running activity. The article Activity Sculptures explores the impact of physical rewards generated from personal data [23]. This approach shows possibilities within the broader field of data physicalizations, highlighting potential benefits of tangible elements of digital ones (figure 9). A similar approach is taken by Menheere et al. (2021) with Laina, which offers a unique

Figure 6: BMX visualization Clever Franke

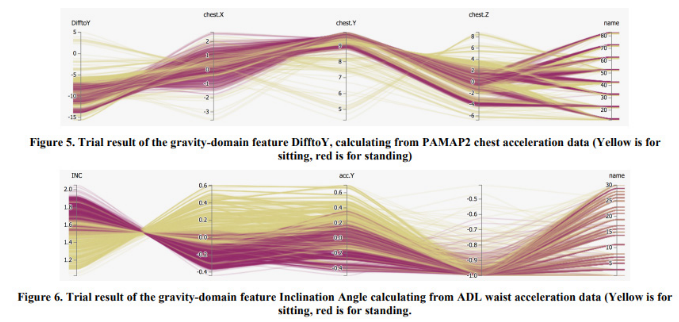


Figure 7: Parrallel coordinates visualization

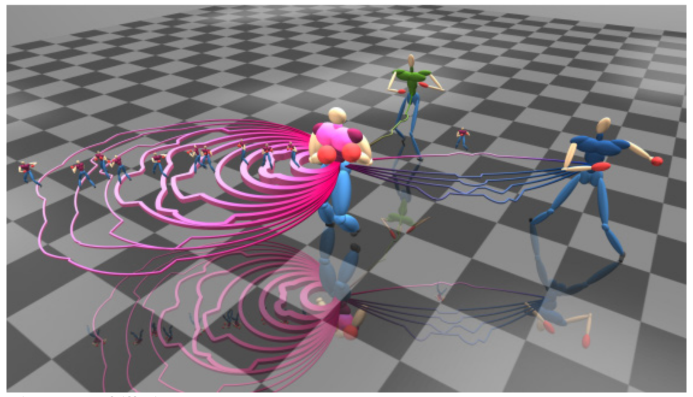


Figure 8: SkillVis

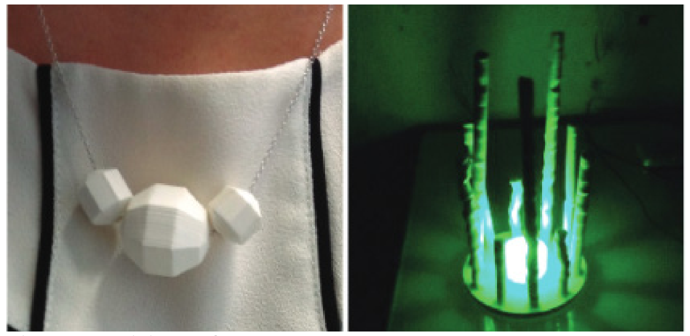


Figure 9: Activity Sculptures

approach to providing feedback on running routes [15]. Laina is a shape changing art piece, that uses pins that transform slowly over time based on effort related metrics (figure 10). By doing this it provide an aesthetic representation of personal running data. Because users can interact with Laina by changing pins to create their own artwork, connectivity and engagement with personal data is encouraged. Countr relates to Laina by having a similar goal in encouraging users to engage with their own data. However, long term feedback may increase difficulty in analyzing performances due to sparring being a more complex and high focus activity compared to running.

Figure 10: LAINA

Promoting physical activity

various approaches are taken in the realm of promoting physical activity through technology. Tajadura-Jiménez et al. (2018) have designed a wearable concept that alters body perception through sound (figure 11) [24]. With this system the project aims to overcome psychological barriers to physical activity. A different approach is taken by "The Journey", an augmented reality mobile game [18]. The Journey targets young adult in promoting physical activity, by enabling users to explore touristic attractions and other interesting locations via a virtual tour (figure 12). This happens while their steps are tracked by their smartphone. Next to sound and Augmented Reality, narrative based feedback is another tool to promote physical activity [17]. This is explored in the WhoIsZuki health platform, which uses visual and textual storytelling to create positive psychological shifts for the and therefore motivates the user to perform more physical activity. Lastly, Kocielnik et al. (2018) use a conversational system called Reflection Companion for engaging users in reflection regarding their physical activity [13]. The system provided daily mini-dialogues and graphs to promote reflection on captured fitness data, leading to increased motivation and behavioral change. To conclude, many different approaches arise when addressing the promotion of physical activity through technology. Options range from sound to augmented reality and even storytelling, each with their own benefits and drawbacks. Aspects such as accessibility, adaptability and engagement should be taken into account when considering to integrate these options into other designs. Integrating elements from these projects could contribute to Countr's development as a visualization tool to encourage reflection and

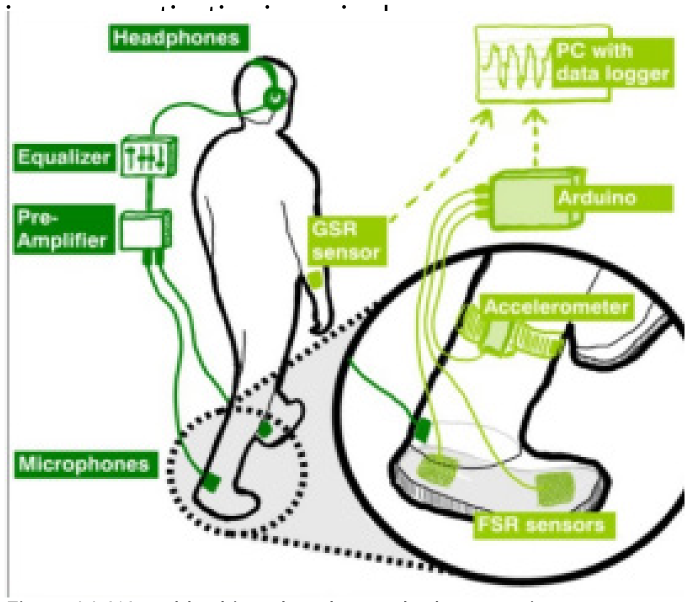
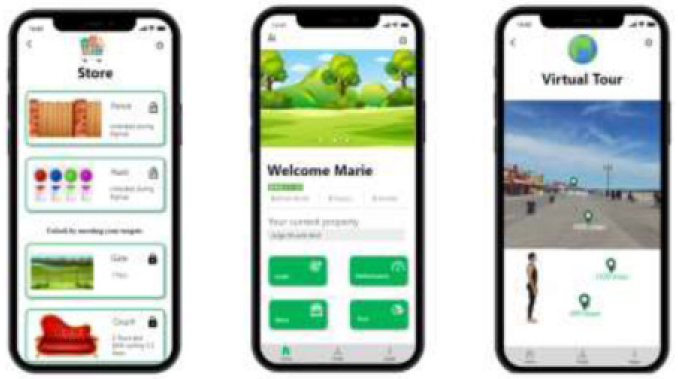


Figure 11: Wearable object that changes body perception



a) Store House b) Dashboard c) Virtual Tour

Figure 12: The Journey

PROCESS - 3.1.1 DISCOVER

During the development of Countr, an early focal point was identifying the target group and user needs. Since Countrs overarching goal is to enhance performance and motivation in physical activity through visualizing data, one of the key aspects was the determination of which physical activity would be designed for. After considering multiple sports, boxing was determined as the ideal physical activity to visualize for a number of reasons:

Physical fitness - Boxing is a sport that uses the entire body and enhances cardiovascular health, strength, endurance and agility. The sport involves a combination of aerobic and anaerobic exercises, which contributes to physical well-being [5][8][12].

Mental health - Aside from physical well-being, boxing can provide multiple benefits that boost mental health such as stress relief, confidence, discipline and focus.

Rising popularity - Boxing and martial arts in general have seen a rise in popularity over recent years [22]. When looking at boxing and kickboxing at the TU/e, the amount of members of the boxing/kickboxing association Impact has grown from 108 to 161 over the last year, which is a 67% increase.

Moving forward, identifying which type of data within boxing training is most beneficial for visualization and analysis must be determined. After consulting boxing coaches regarding the metrics that could be useful for performance analysis, the insights about different metrics and how they could be measured can be found in the table below (see appendix C for more information):

Technique	**Measurable data**
Footwork	pressure sensors on shoes/ mat.
Weight shift	pressure sensors on shoes/ mat.
Jab and cross - Arm extension	extension speed and elbow lockout
Arm retraction	extension vs retraction speed
Stance width	relative proximity sensors
Hip/shoulder rotation	rotary encoder or gyroscope on hips and shoulders

Sparring	**Measurable data**
Distance/range	distance sensors
Movement	Pressure sensors on shoes/ mat
Switching between power shots and setup shots	measuring impact of every strike
Keeping the guard up	accelerometers
Standing your ground	distance sensors
Going to the body	Impact sensors in clothing
Angles	gyroscope

When looking at discovered metrics, the focal point is determining the most beneficial factor that can be visualized for enhance performance for the target group. Since the goal is to increase motivation in physical activity, the target group is kept broad and consists of novice boxers. Novices, who don't have experience in pacing or strategy, often fatigue after a few minutes of using all of their energy during their first sparring sessions. This often leaves them unmotivated to continue, since they are exhausted and don't believe they are fit enough for the sport. While boxing is a sport that relies heavily on cardio, what beginners often don't understand is that fighting is both a marathon and a sprint at the same time. By visualizing movement data during sparring activity, novice boxers are given the ability to reflect on their performance, allowing them to improve their timing, strategy, cardio and motivation. The following section regards the research question:

How can a visualized dataset of sparring activity help a novice boxer reflect on their flaws in cardio/pacing and strategy, and therefore show improvement?

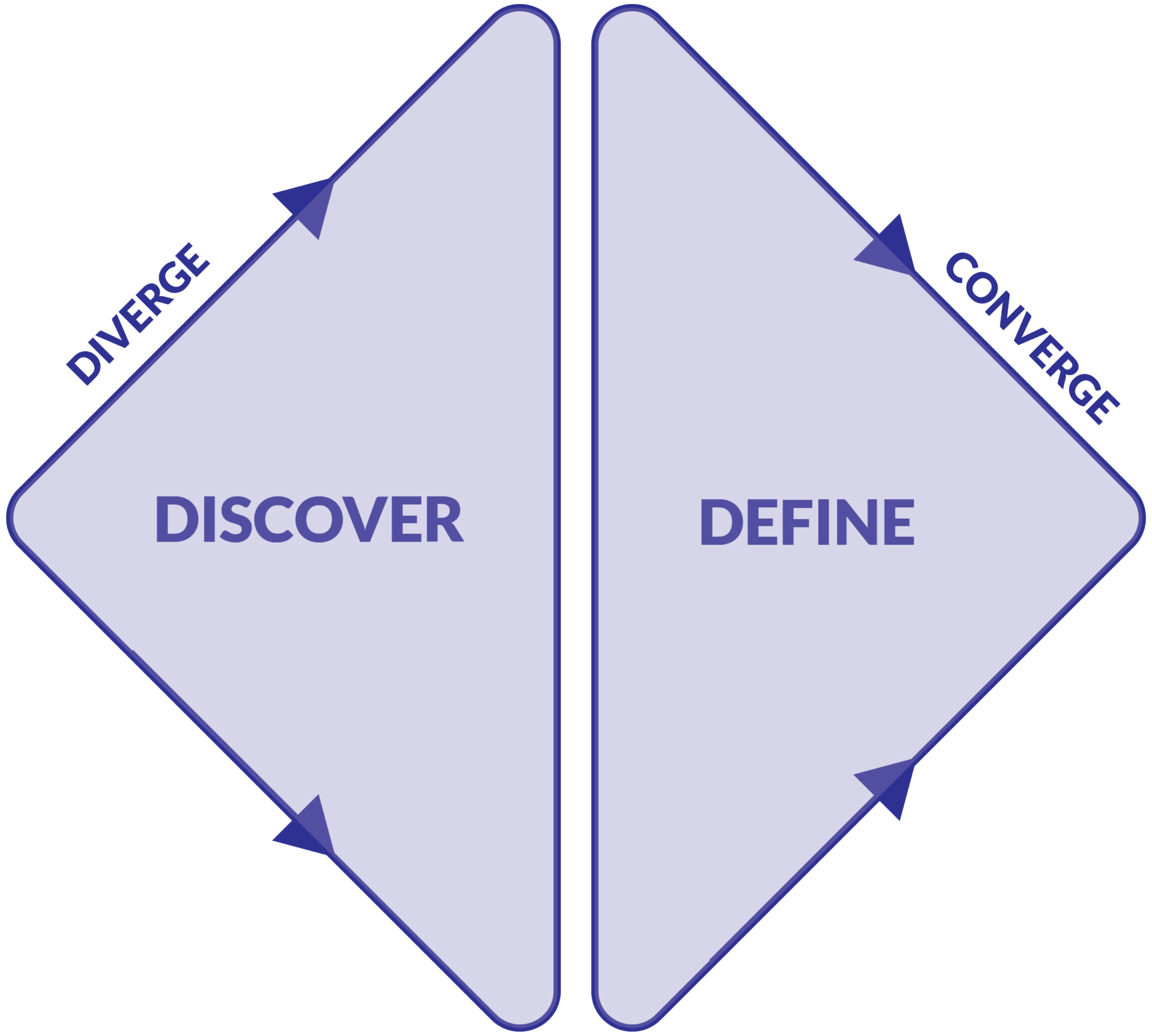


Figure 13: Process visual first half

3.1.2 DEFINE

Countrs method of capturing data is arguably its most essential element. An accurate, but cost-effective and user-friendly way of capturing data needs to be developed to visualize personal performance. The initial concept evolved around the integration of pressure and coordinate sensors in the soles of the user's shoes. This way, each step the user takes could be mapped and visualized to show their movement around the ring. However, to use this method, small wireless sensors would need to be used to create a smooth user experience. In addition to this, the sensors would need to be implemented inside the user's shoe to avoid discomfort or damage in electronics. These factors could increase production cost significantly since every user would need a pair of boxing shoes integrated with these sensors. After background research and meeting with coaches, the use of a depth camera positioned above the sparring area deemed to provide more benefits. Specifically the Microsoft Kinect used in projects such as EagleSense proved to have success in top-view body tracking. By using a depth camera, body tracking can be performed to easily and accurately track boxers' movement around the ring. Compared to using integrated sensors, a depth camera is more cost effective and requires less effort in technology and realization, while still keeping the benefit of accurate movement tracking. Before creating prototypes of the visualization tool, an algorithm to accurately track the data needed to be developed. The body tracking consisted of three iterations.

Iteration 1
In the initial iteration, the most important step was capturing depth values with the Kinect camera using the processing library called SimpleOpenNI [28]. By following a tutorial on capturing data with Kinect, the first steps could be made [25][26]. The goal was to capture values within a specific distance range by setting minimum and maximum values. Then the average point within the threshold could be calculated to create a trackable object (figure 14). This option worked reasonably well, apart from one significant drawback. This method only allowed for single object tracking, since every registered data point was being averaged. Therefore, this option wouldn't suffice since two opponents are present in the camera field simultaneously and need to be tracked individually.

Iteration 2
Iterating on the lessons learned from the iteration one, the second iteration aimed to remove the limitation of tracking only one object. This algorithm involved the use of blob detection. In contrast to the previous iteration of calculating the averages point, blob detection calculates the distance between values, and registers values within a certain distance of one another as part of the same 'blob.' However, if a value exceeds a specified distance from the previously measured value, it is registered as a new blob (figure 15). This algorithm introduced the possibility of tracking multiple objects at once.

Iteration 3
To finalize the system for accurately tracking two opponents, several improvements were implemented in the third iteration. First, blobs below a certain size were deleted, preventing the Kinect from registering insignificant objects such as a raised arm as individual objects. The number of blobs that could be tracked simultaneously was limited to two, limiting the body tracking to two opponents and preventing malfunctions in case an unintended object or person entered the ring. Furthermore, The introduction of IDs in form of numbers to the blobs was an important feature, allowing the camera to distinguish between different objects and keep track of which opponent is which. Lastly, a lifespan was added to the objects to prevent errors in the camera or the algorithm from disrupting the tracking. This ensured that blobs wouldn't be immediately deleted and replaced in situations where the Kinect momentarily lost tracking or opponents moved out of the threshold (figure 16).

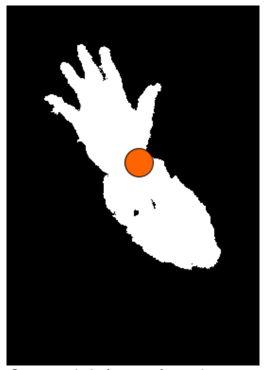


figure 14: iteration 1

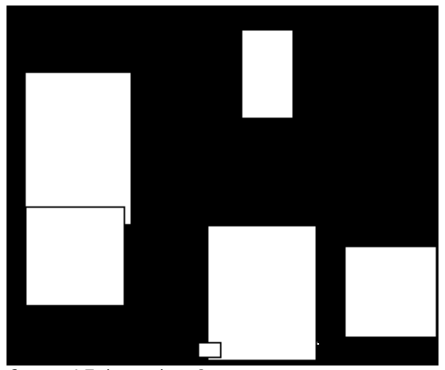


figure 15: iteration 2

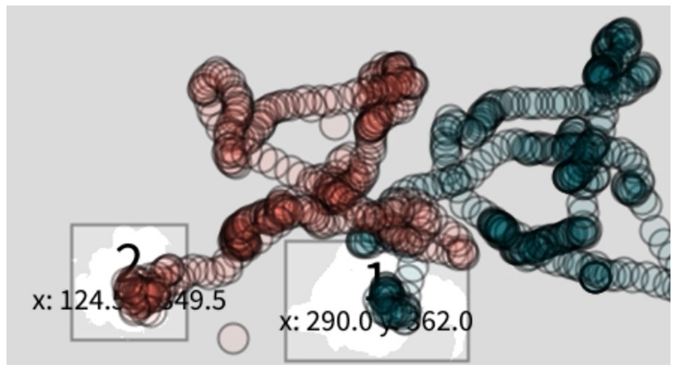


figure 16: iteration 3

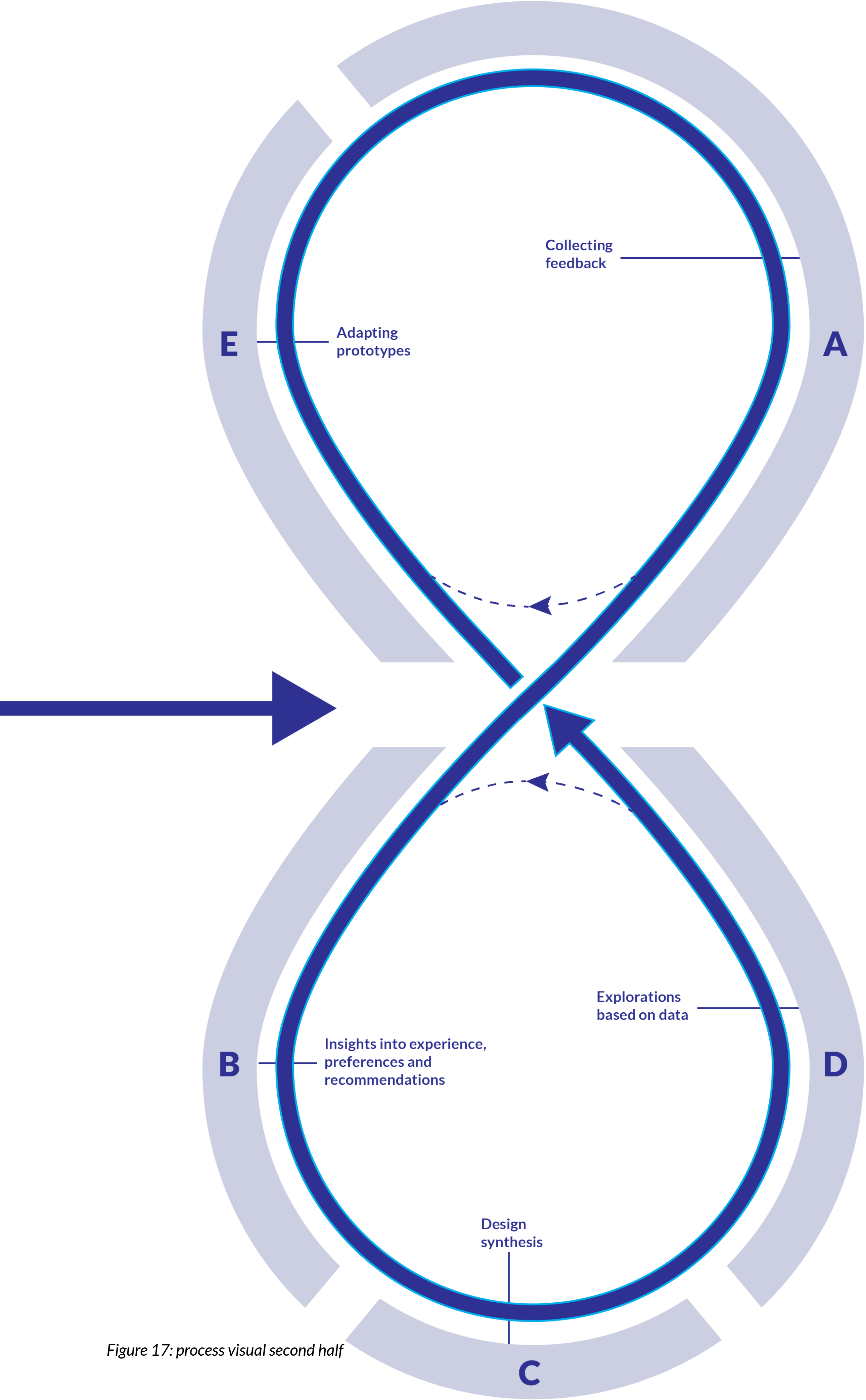


Figure 17: process visual second half

3.2 DATA ENABLED DESIGN

This section employs a data-enabled design approach [29], utilizing data in the form of qualitative feedback during meetings and co-creation sessions as creative materials for refining and enhancing previous iterations. This part of the process is divided into 5 segments.

A – Collecting Feedback

During the process of developing Countr, feedback has been provided in a multitude of ways. One of those ways was during midterm Demoday. To receive feedback on the visualization/physicalisation, an exploration was done with different aesthetics prior to midterm Demoday (figure 18). The samples were displayed during the day to receive insights on the aesthetic qualities as well as the ability to understand the visualization/physicalisation. Another way of receiving feedback was talking to coaches and experts. Opinions and preferences were discussed regarding data capture, usability and clarity regarding user interfaces. These points of discussion allowed new ideas and concepts to emerge.Finally, To explore the potential benefits and pitfalls of different types of feedback methods, multiple co-creation sessions were conducted [30]. In these sessions different examples, visualizations and physicalizations were displayed and asked to discuss and iterate on (find more information regarding the procedure in the methodology section and appendix B). The different types of feedback that were discussed are real-time, post-hoc and long-term feedback. The key insights from these sessions can be found in segment C

B. Insights into experience, preferences and recommendations

During midterm Demoday, most individuals were positively affected by the aesthetic properties of the physical artifacts. However, questions arose regarding the benefits of physicalizations compared of visualizations. Since interactivity and additional textual information or instructions are difficult to integrate in physical data representations, nearly every person needed additional explanation about the function of the artifacts. Furthermore, recommendations regarding the feedback system were discussed, such as stacking the data of multiple sparring rounds on top of each other and altering the system based on different styles of boxing. Coach and expert meetings provided insights about the pros and cons of each iteration. Insights that were discussed during meetings explored usability, interface, readability and clarity. In addition to this, communication from visualization to user deemed a key element. Especially when analyzing personal performance, the user needs to be able to understand exactly what data is being communicated before reflection and improvement can take place. Below the main insights regarding the co creation sessions can be found. The insights are grouped into the three feedback types, each stating positive feedback and concerns. At the end, preferences and recommendations are stated.

Real time

Positive feedback
It is beneficial to receive extra information about your opponent during sparring.
Adjustments can be immediately made when using real time feedback
Concerns
Potential distraction and difficulty in focusing on data because sparring is already a high focus activity
Sensory overload because of extra data

Post hoc
Positive feedback
Allows for more concentration on the data than with real time feedback
Valuable insights about personal performance
Concerns
Graph was challenging to understand, extra information was needed (possibly in the form of on screen text or symbols)

Long term
Positive feedback
Physical object is visually pleasing, seems like a personal prize
Concerns
Questions about whether a physical representation is worth the extra time before receiving feedback.
Doubts about whether a physical representation increases the engagement/ability to reflect ('It is my personal data so I am already interested in it').

Preferences
In terms of ability to reflect on the personal data, participants generally preferred the post hoc feedback over real-time and long-term feedback
Reasons for preference include the ability to focus on sparring and then analyse performance immediately afterward.

Suggestions for Improvement
On their own the visualizations and physicalizations can be difficult to understand. Provide extra information in the form of symbols or text. Provide extra features to create a richer visualization that provides more insights.

C. Design synthesis

Based on the insights from the midterm Demoday, coach/expert meetings and the co-creation sessions, improvements on iterations could be made. The decision was made to move away from physical artifacts and focus on the development of a visualization tool. When analyzing the feedback, visualization tools are preferred because of the ability to immediately reflect on performance after training. In addition to this, digital data representations can be made interactive and can provide additional information if necessary. Over the course of multiple iterations, the following statements were discovered for the optimal visualization tool for performance enhancement in boxing:

The communicated data needs to be understandable.
The interface needs to be user friendly.
The visualization tool needs to be interactive to encourage. engagement and provide additional information.
The visualization tool needs to be able to show progress over time.

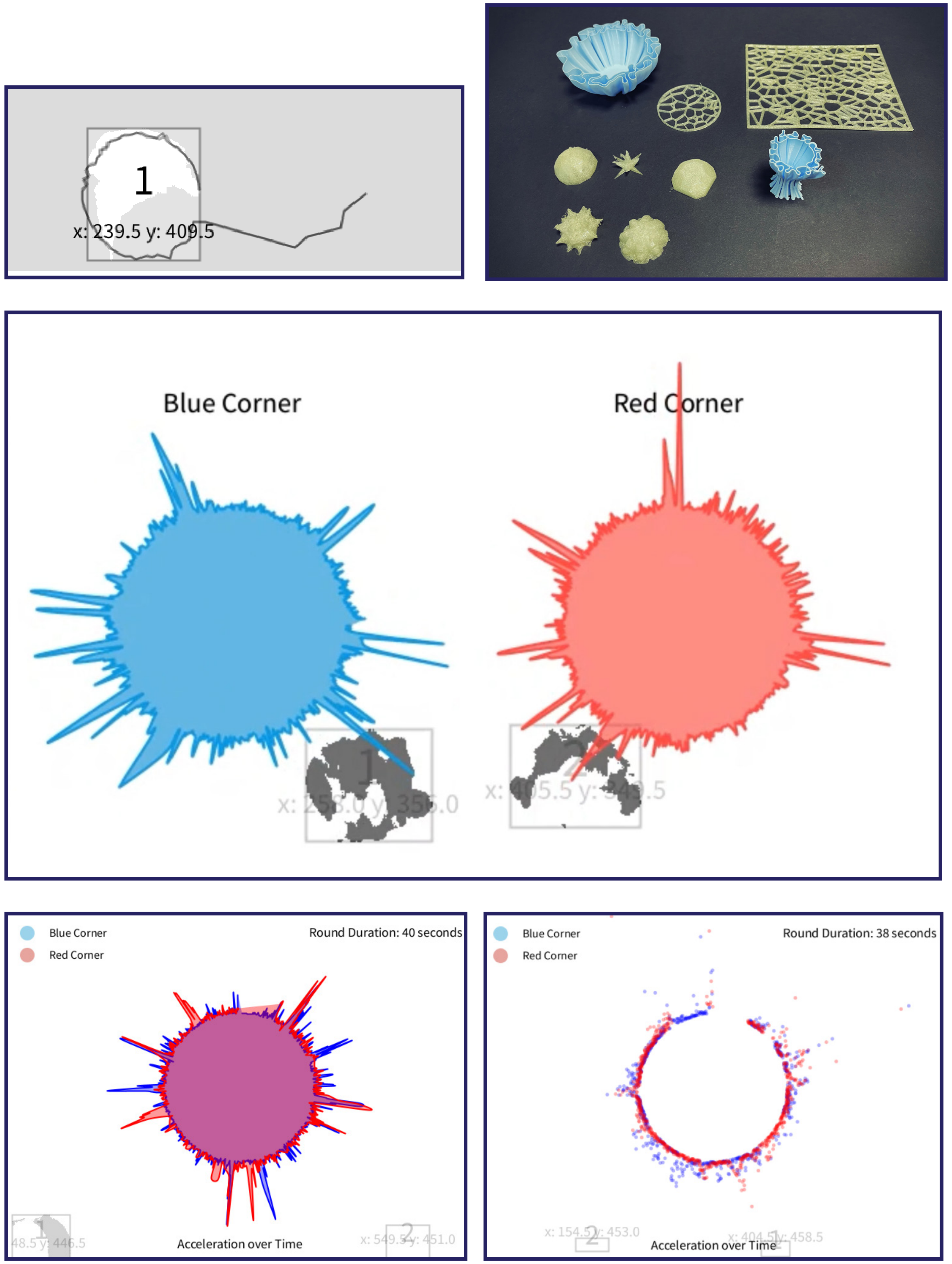
D. Explorations based on data

To explore with the provided insights about previous iterations, wizard of oz methods were used. Examples of visualizations were created that were not based on actual data. These examples included explorations in aesthetics, interactivity and interface. To create these examples, graphs were either coded without any input of body tracking data, or used hand tracking instead of full body tracking to allow for easy adaptation without the need of a boxing environment to function.

E. Adapting prototypes

After exploring new possibilities and features in phase E, implementations could be made into the visualization tool to develop the next iteration. A range of iterations can be seen in figure 18. After creating each iteration, the process loop restarts at phase A.

ITERATIONS



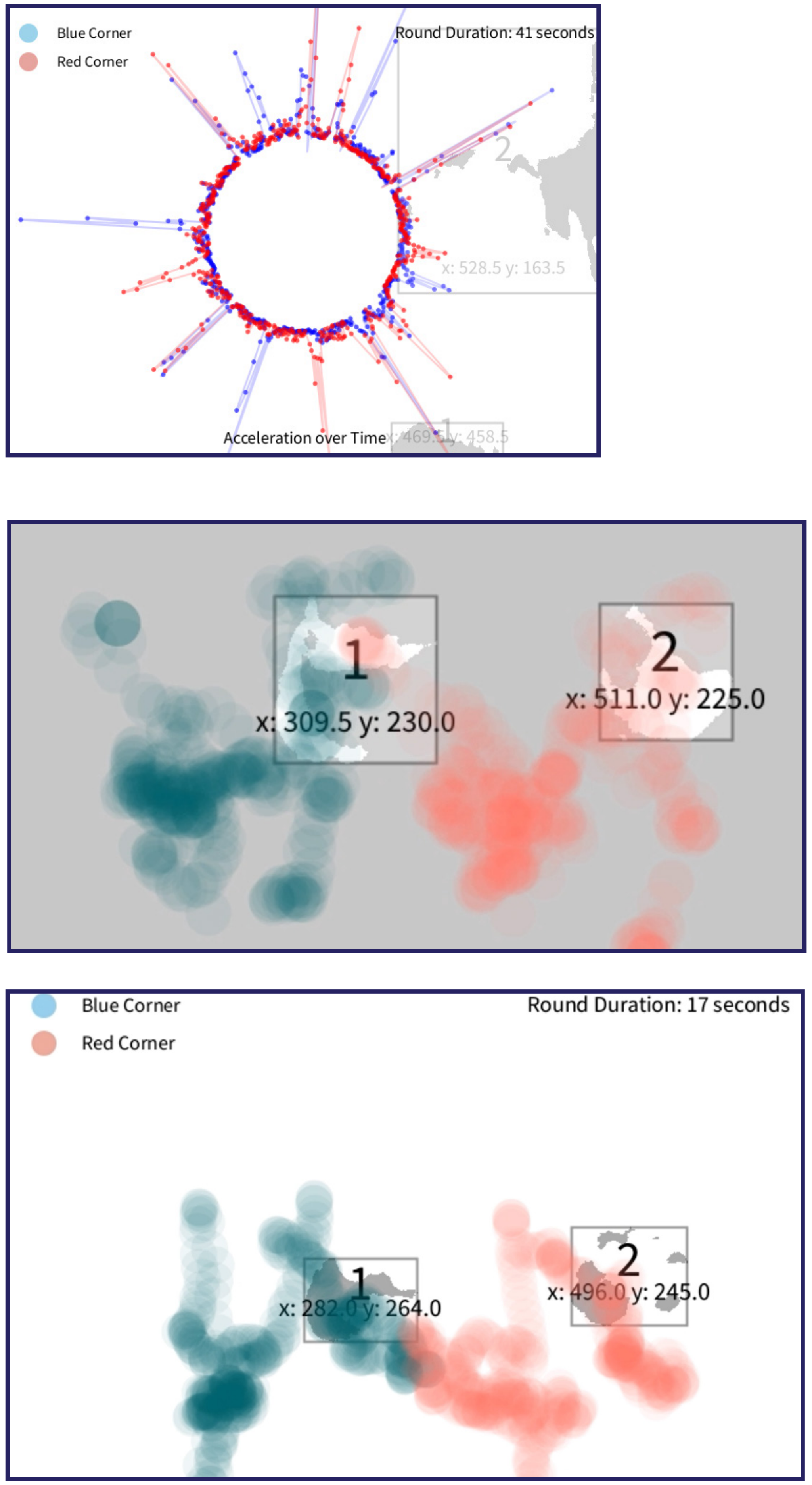


Figure 18: visualazation iterations

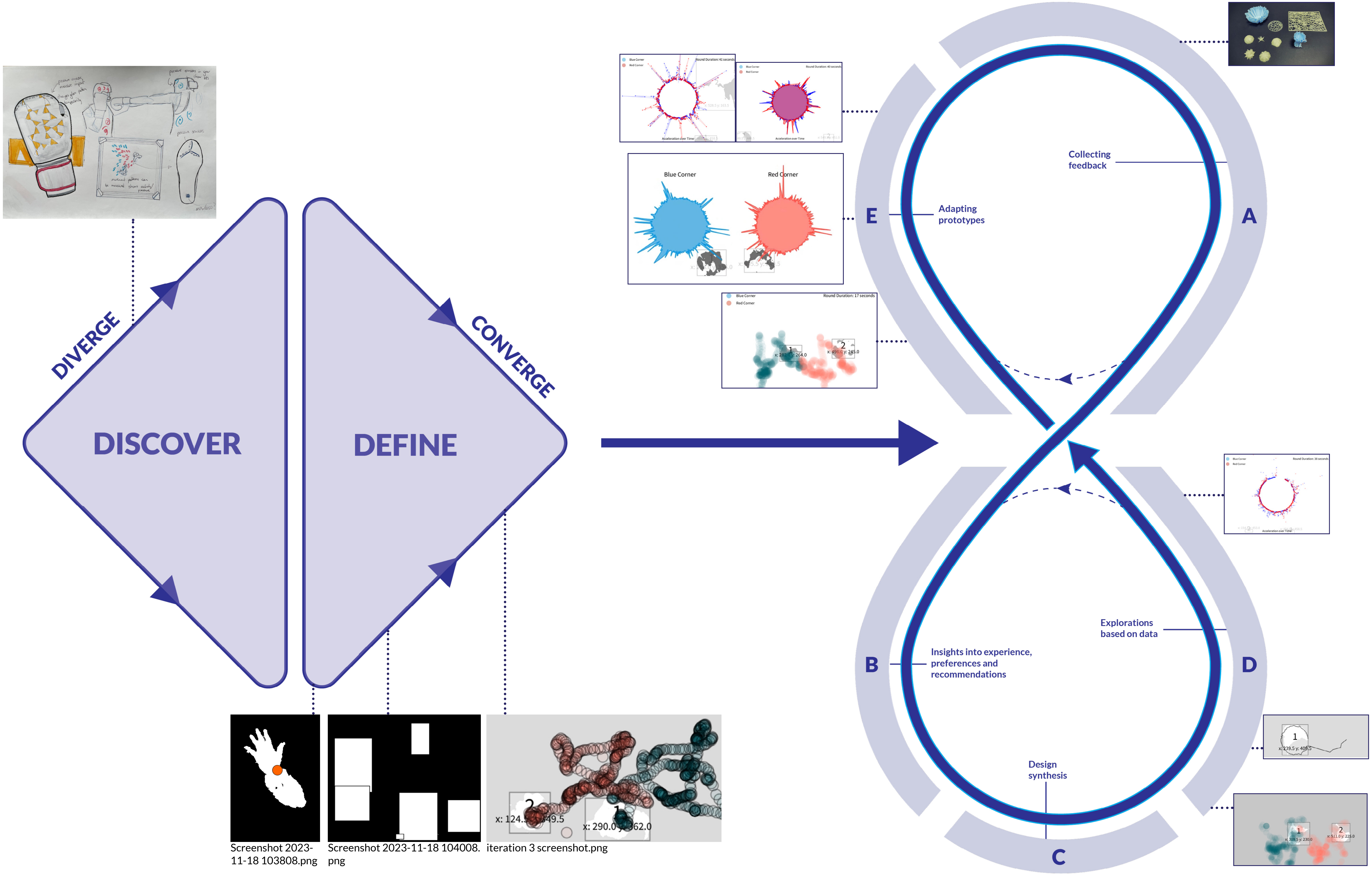


Figure 19: Process visual

4. FINAL DESIGN - COUNTR

COUNTR is a visualization tool that helps novice boxers reflect on their performance by gaining a deep understanding of their movement and explosiveness in the ring. By using a depth camera situated above the boxing ring, COUNTR creates an interactive heatmap that showcases movement around the ring, and a dynamic graph that displays moments of intensity. COUNTR aims to solve the issue of novice boxers having a limited understanding of the pacing and strategy that is most optimal for the sport.

Components

Depth camera

By using a depth camera (Microsoft Kinect), movement of individual objects (in this case the fighters) can be tracked accurately around the boxing ring. A depth camera is used instead of a regular camera to enable the use of raw depth values instead of a variable that can be measured by a regular camera such as colour. This allows for the smoothest use of the product since different colours in the environment won't disrupt the accuracy of the collected data.

Software algorithms

The algorithms that allow for accurate data collection are created in Processing and form the backbone of Countr. Processing Kinect libraries are used to gather raw depth values, after which blob detection is used track individual objects based on clustered depth data points. Further additions to the code allow for persistence in the tracking (numbering objects and keeping track of their positioning) and also include the minimization of potential errors such as camera inconsistencies. To gather the values that are used to display the moments of intensity, calculations are continuously made to determine the acceleration between positions in the ring.

Visualizations

To create a deep understanding of pacing and strategy in the ring, two main aspects can be displayed, movement/positioning and intensity over time. The visualization tool consists of a heatmap that shows the positioning and movement of each fighter from a birds-eye view, and a graph that displays the moments of intensity. Users have the flexibility to select either their individual graph or view both graphs simultaneously. Moreover, to enhance readability, moments of high intensity are visually highlighted in green. This feature not only provides a clearer representation but also allows users to pinpoint the specific instances when these high-intensity moments occurred. The detailed timestamps associated with these moments serve as a reference, enabling users to seamlessly navigate back to the heatmap. This allows users to revisit the corresponding heatmap data and delve into the specifics of each recorded moment.

Interface

The interface of Countr is designed with a user-centric approach, prioritizing simplicity and readability. A user-friendly interface allows novice boxers and trainers to understand the provided data without much effort or external help. Making the interface interactive provides an extra layer of engagement and encourages the user to understand and reflect.

Design principles

1. User-Centered design

The design decisions are based on a user-centered approach, making sure that Countr remains accessible and beneficial to its target group – novice boxers and their trainers. By keeping their preferences and needs as the number one priority and including them in design decisions, Countr aims to provide an engaging and user-friendly experience.

2. Iterative Development

The iterative nature of the design process allows for continuous improvement and refinement based on collected data, user feedback and technological advancements. This ensures that Countr can keep making strides towards an even more advanced visualization tool.

3. Data-driven Insights

Data-driven insights are the backbone of Countr's transformative approach to boxing training. By including objective data in feedback during training sessions, users gain unbiased insights regarding their performance. These insights can be used to identify patterns, allowing users to recognize their possible flaws and improve on them.

4. Usability and Engagement

Countr's interface is intentionally designed for usability and engagement, including interactive qualities in the visualizations to encourage active participation. This aspect aims to enhance to ability to gain a deeper understanding of the users performance.

5. Motivation and Ownership

Countr's interactive nature and post-hoc feedback is purposefully designed to create a sense of ownership and motivation for novice boxers. By providing immediate objective feedback, the design aims to create a positive and empowering training experience.

Figure 20: final design

4.1 INTERFACE

Users are able to track their pacing over the course of multiple rounds to recognize patterns and improvements

Data from previous session is stored to track long-term progress over time

Mircosoft Kinect depth camera is used to capture the data

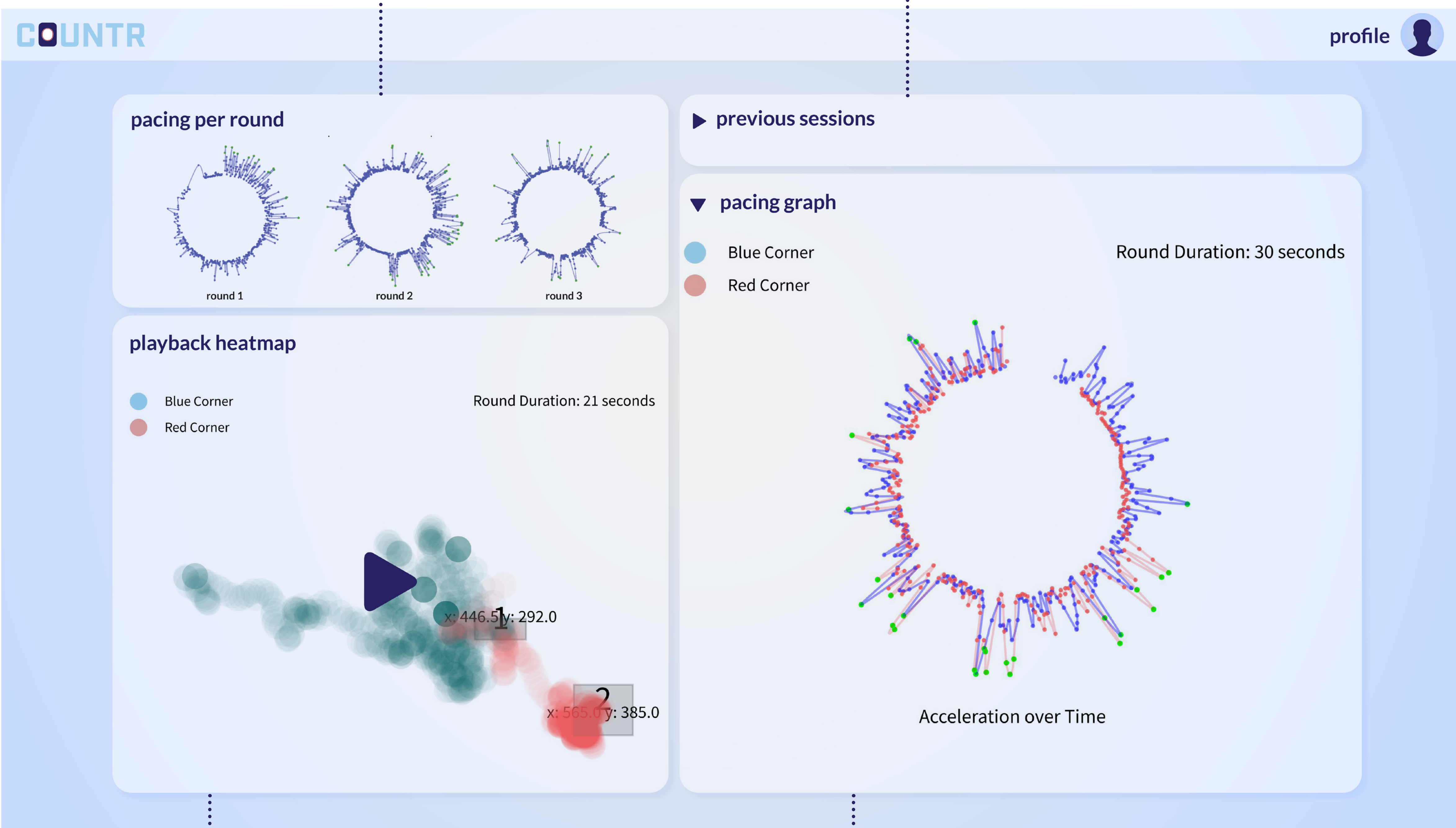


figure 1Countr interface.png

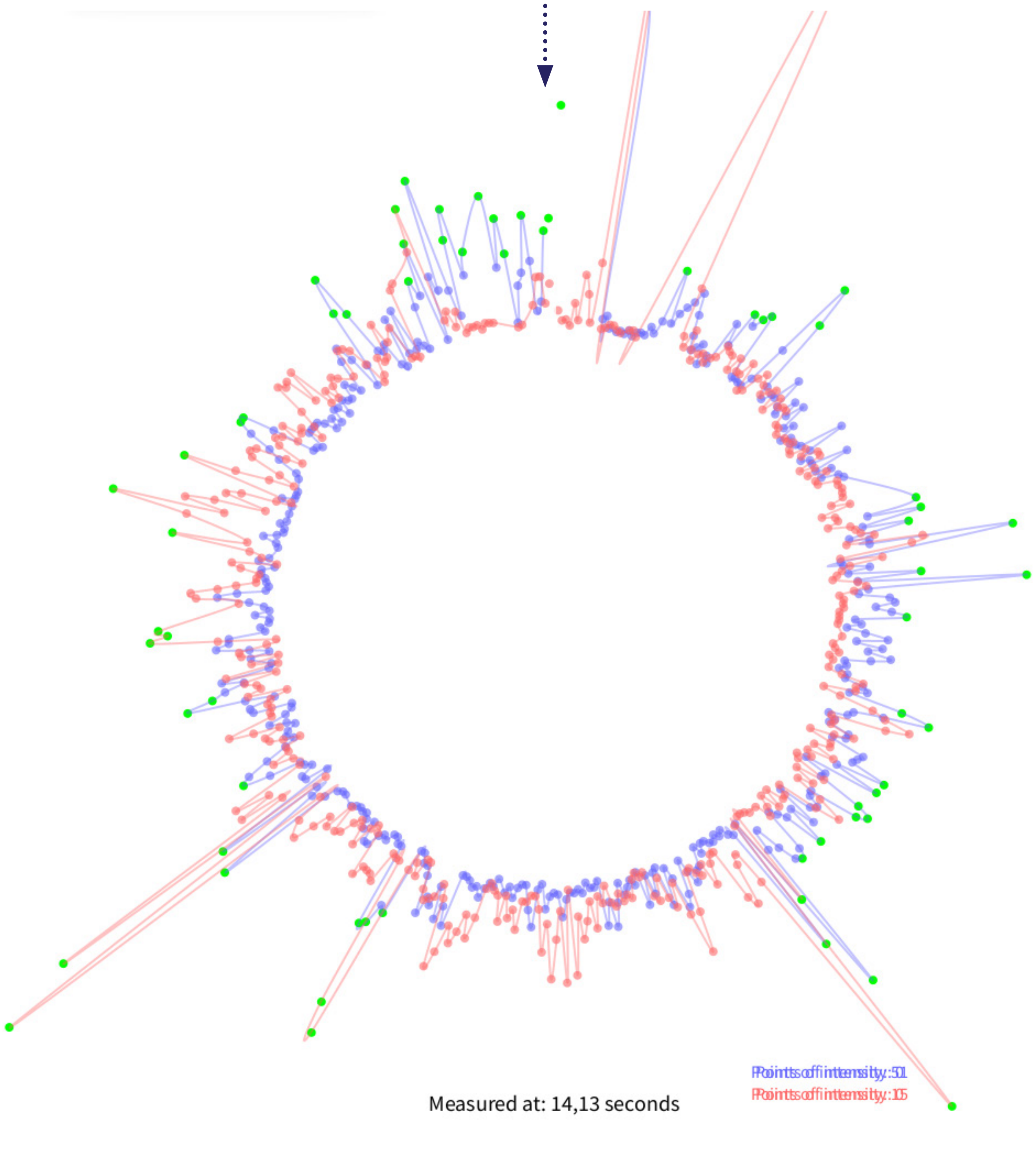
Heatmaps can be played back to delve into specific situations and key moments that happenend during the round

The pacing graph captures moments of intensity (acceleration between positions). It can be used to analyze pacing, or to recognize key moments during the round be comparing your own graph to the opponents'.

Figure 21: interface

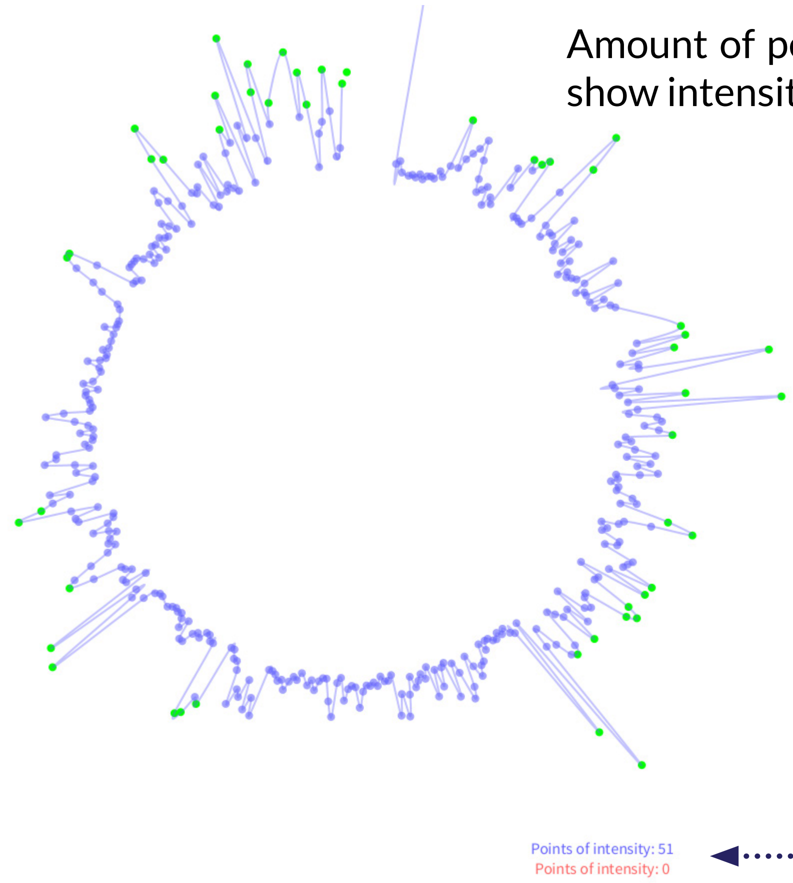
4.2 INTERACTIVITY

The graphs can either be displayed at the same time or separate.



Users can hover over data points to see at what point they were measured

Amount of peaks are displayed to show intensity of the round



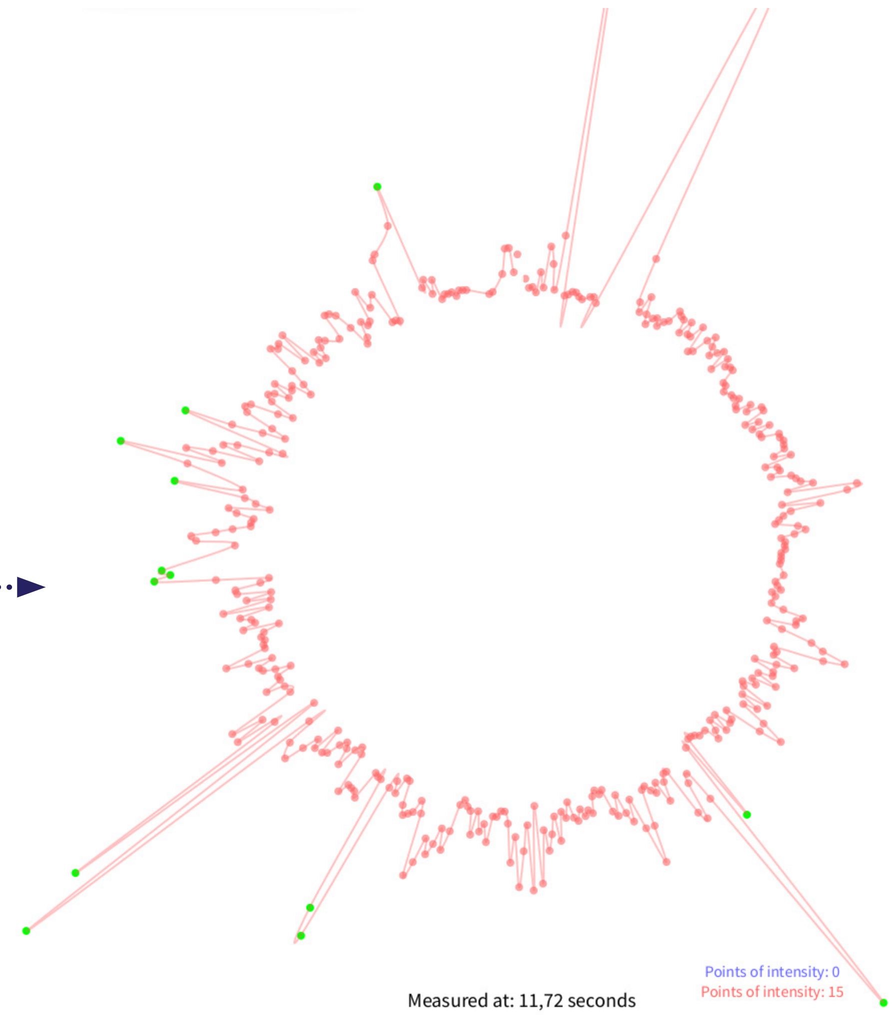
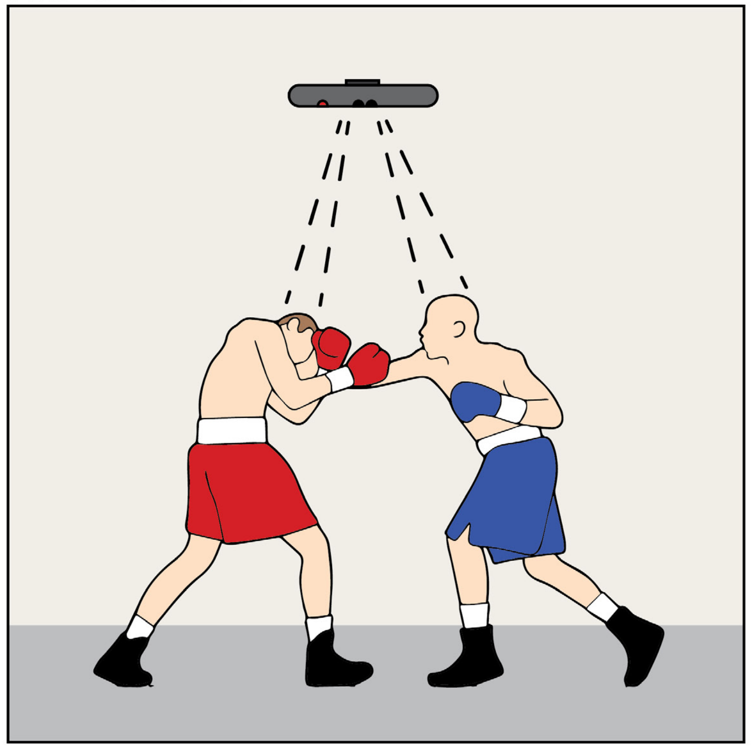
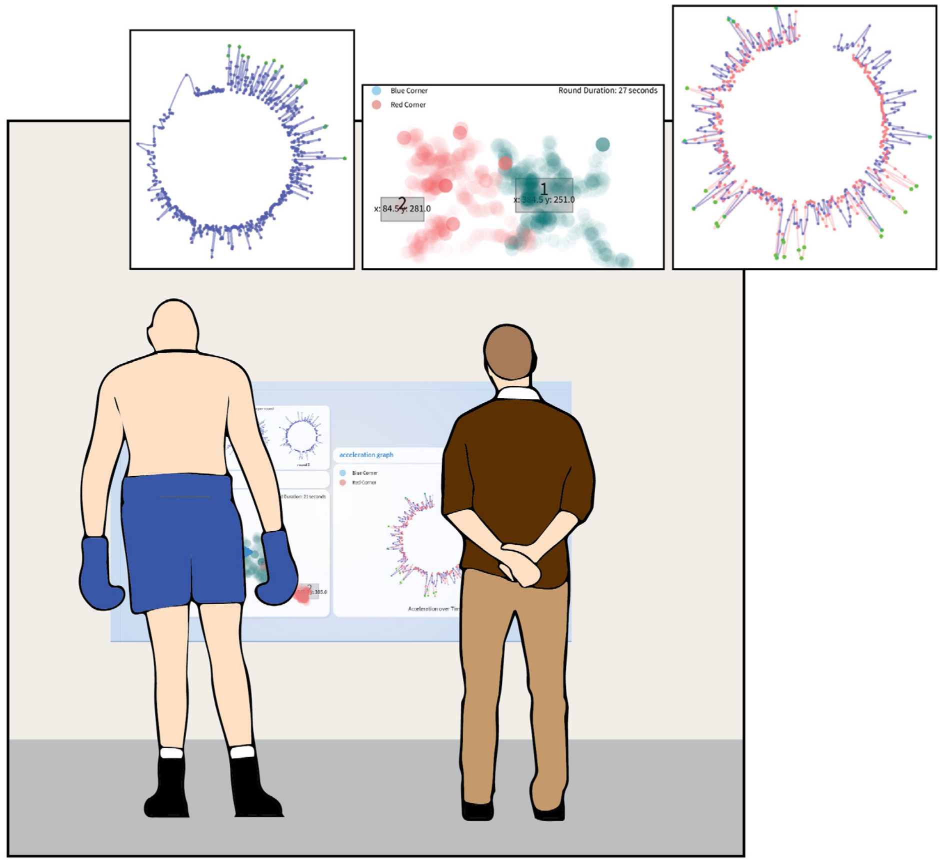


Figure 22: interactivity explanation

ROUND 1

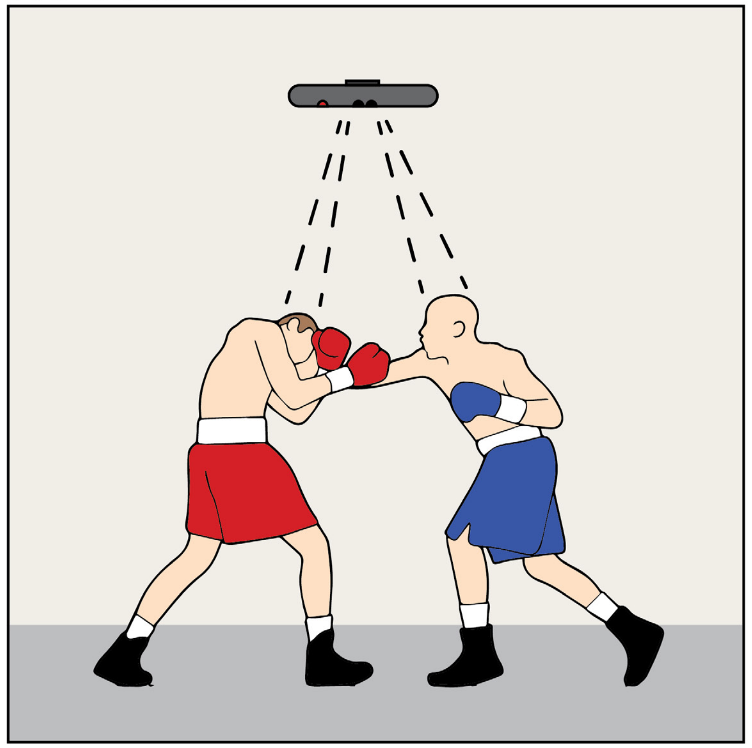


During a round of sparring, a depth camera captures movement data. Processing software transforms the data into a visualization tool.

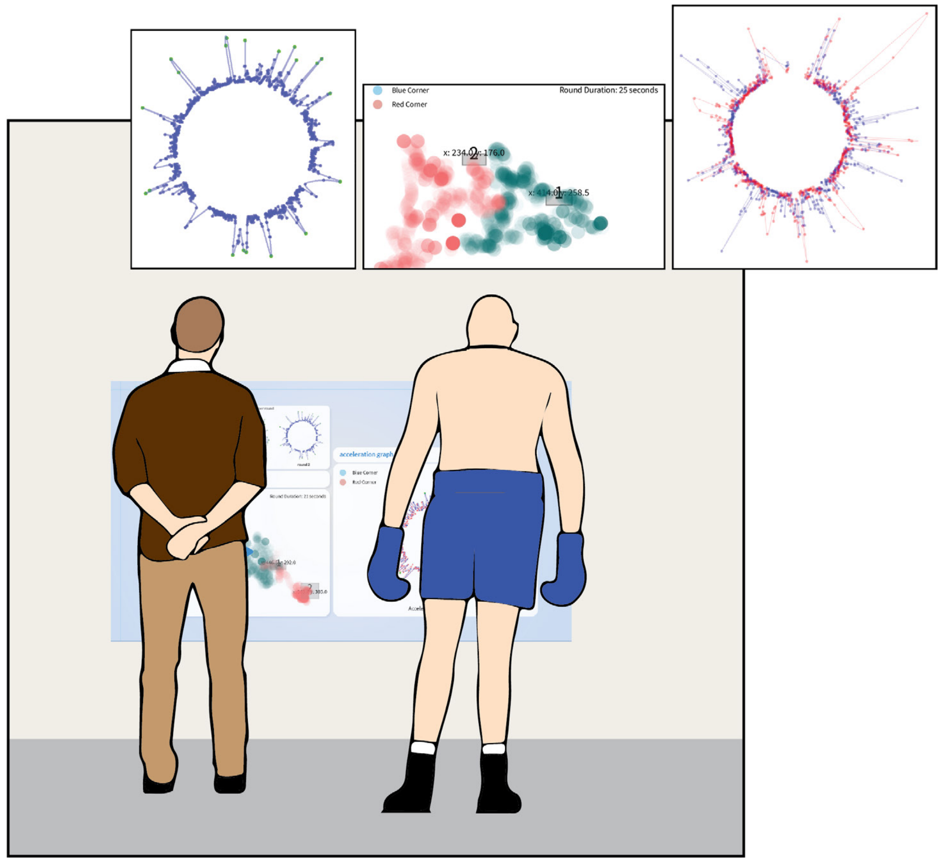


The data of the boxer in the blue corner gets analyzed. Insights are provided on pacing, moments of intensity and specific situations during the round.

ROUND 2



The boxer spars another round and tries to implement the provided feedback.



Again, the performance is analyzed to reflect on any possible improvements in pacing or new interesting situations. This process can be repeated for continuous progress and reflection.

Figure 23: Storyboad Countr

5. VALUE PROPOSITION

Countr emerges as a valuable solution for personalized training, extending its boundaries even beyond boxing through its innovative approach to performance analysis. This section explores the transformative impact Countr could bring to various stakeholders such as boxers, trainers and the world of sports technology.

Empowering Boxers: Elevating performance through personal data

Starting with the product's main target group, Countr aims to create a journey that focuses on progress through reflection on personal data. By using a depth camera to capture movement and explosiveness, users are enabled to gain a deep understanding of their pacing and positioning at each moment during sparring. The system's ability to visualize their performance allows novice boxers to recognize patterns, strengths and weaknesses, which provides a unique lens through which boxers can enhance their performance and therefore motivation.

Enabling Trainers: Extra layer to coaching approach

Another key stakeholder are the trainers that work in a boxing gym. The visualizations that are created by Countr provide an added layer to performance analysis. By analyzing the captured data, boxing coaches can either discover new insights about their students that they may have not recognized before, or they can use the data to communicate certain improvements that can be made during training. This in-depth form of coaching not only enhances training effectiveness, but also strengthens the relationship between coach and athlete, encouraging a collaborative journey for development.

A gateway for sports technology innovation

When looking beyond training sessions during boxing, Countr opens doors to new opportunities in the world of sports technology. The use of visualization methods positions Countr as a product that offers possibilities in higher level performance analysis and even commercial purposes. In an environment where fans are increasingly captivated by sports data, Countr can provide a deeper level of engagement by displaying visualizations between rounds. This sets the stage for partnerships, collaborations and exploration for additional revenue streams within the evolving sports technology ecosystem.

Subscription models

When looking at Countr as a finished product on the market, the introduction of a subscription model would be ideal as the product primarily relies on software and depth cameras are relatively cheap. This approach allows users to receive continuous updates and ongoing support, ensuring a smooth and sustainable revenue stream while offering affordability and flexibility to its customers.

Bridging gaps in traditional training approaches

Countr has the ability to transcend traditional methods of boxing training by making advanced performance analysis tools accessible to a broad audience at an affordable price point. This democratization not only enhances individual performance but boosts innovation in training methodologies.

Long term progress tracking

By storing data of previous sparring sessions, Countr enables users to track their progress over time. This provides insight into improvements in pacing and strategy, giving the user a feeling of accomplishment, gratification and motivation.

6. ETHICAL CONSIDERATIONS

Designer's intention

Countr aims to create an enhanced training environment for novice boxers to help them understand their pacing, positioning and strategy and therefore increase their motivation to continue and improve in the sport. The design intention stems from a desire to use objective personal data as a mean to give the user the ability to gain a deep understanding of their performance and encourages to reflect on that data. The goal is to enhance individual performance and contribute to the evolution of training methodologies in the sports innovation landscape.

Potential unethical situations

While Countr's goal is to make a positive impact on performance development, ethical considerations can be made to examine potential negative consequences and pitfalls. Stakeholders such as novice boxers and their coaches, may face privacy concerns since every movement during their training is being captured by a camera. If Countr would be used on a higher level of boxing in the future, a data breach could result in the potential leak of a fighter's gameplan for an upcoming fight. Another negative consequence might occur if users start relying too much on the data visualizations. Users might start depending on the provided data too much and therefore neglect other important training aspects such as qualitative feedback from coaches and listening to their own bodies. In addition to this, continuous data tracking and comparisons based on earlier sessions could lead to constant increased pressure to improve all the time. This may have negative effects such as stress and anxiety. Usability is a crucial feature to avoid negative consequences

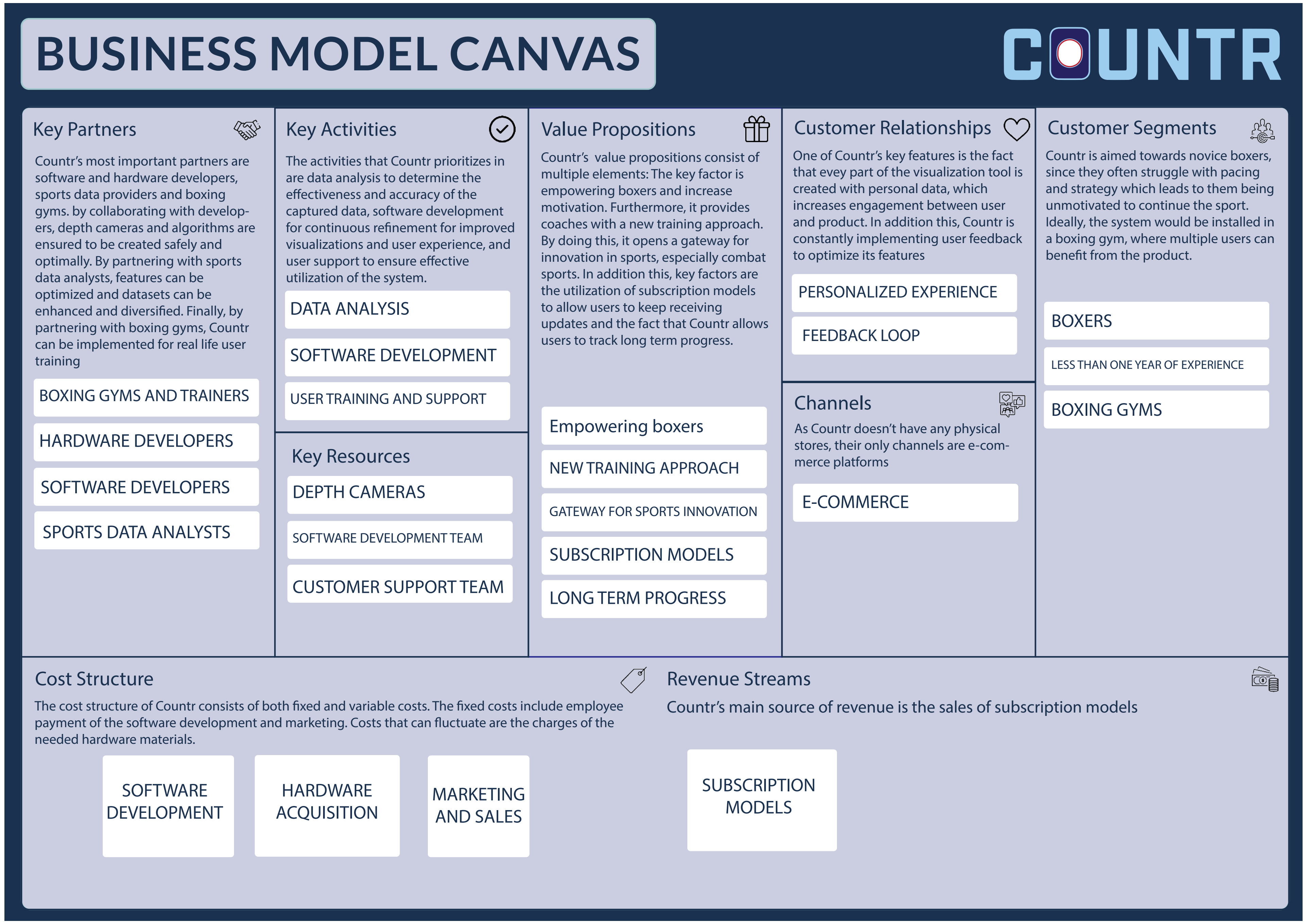


Figure 24: Business model canvas Countr

such as data misinterpretation. While long term use is encouraged to benefit from Countrs goal to serve as a tool for continuous progress over an extended period of time, this also increases privacy concerns as personal data is stored over a longer time period. Ensuring accessibility is not exploited over time is necessary to uphold ethical standards.

Since Countr is a mainly software based product, the potential of hacking must be taken into consideration. This could result in undesired outcomes such as a data breach as mentioned before, or the manipulation of training data. Altering personal data would lead to distorted performance insights. Boxers may receive inaccurate feedback, which would either negatively impact the effectiveness of their training, or lower Countrs credibility.

7. METHODOLOGY

Part 1: Interviews and Co-Creation Session

Participants

Participants that were chosen were healthy adults that have less than one year of boxing experience, since this is the user group that the concept is aimed towards. This user group aligns with Countr's focus on revolutionizing the way novice boxers approach boxing training.

Sample size: 12-20 participants

Participants will provide their input once. After 12- 20 different perspectives enough data will be collected to draw a conclusion. Co creation sessions will be done in groups of 3-5 people at a time, taking around 20-30 minutes per group.

Material

Images of visualizations and 3D printing physicalizations were used during the co-creation session. An iPhone was used to record the interview audio.

Procedure

In this phase, participants will engage with various types of physicalizations and visualizations that represent a boxer's movement and pacing during a sparring session. These representations fall into three categories: real-time, post hoc, and long-term. First examples will be given regarding real time feedback, then visualizations will be shown regarding post-hoc feedback and finally physicalizations will be shown regarding long term feedback. After each type of feedback, participants will be asked to answer the following questions in a semi structured interview:

Understanding Levels: Participants will explain their level of comprehension of each version.

Preference: Participants will identify which versions prefer to engage with the most and the least, stating reasons. They will also contemplate whether they would use any of these versions and explain why.

Comparative Analysis: Participants will consider if they favour any of these options over conventional feedback methods like coaching, explaining their preferences.

During the session, participants will be encouraged to engage in discussions, propose alternatives, and contribute their ideas to enhance the presented concepts.

Data analysis

Interview transcriptions:

Audio recordings from the conducted interviews were transcribed into written text. The participants' responses could then be analyzed to discover qualitative insights such as understanding levels, preferences and comparisons between different feedback methods.

Thematic Analysis:

Thematic analysis was then applied to the transcriptions, aiming to identify recurring themes, patterns and meaningful insights.

Part 2: Monitoring and Semi-Structured Interviews

Participants

Participants that were chosen were healthy adults that have less than one year of boxing experience, since this is the user group that the concept is aimed towards. This user group aligns with Countr's focus on revolutionizing the way novice boxers approach boxing training.

Sample size: 5 participants

Participants will be monitored for 3 rounds of 2 minutes each, after which a short interview will be conducted. Due to the time constrain of the project, 5 participants will suffice.

Material

A Kinect Camera connected to a laptop was used to gather the body tracking data.

Procedure

In this segment, a Microsoft Kinect depth camera will be positioned above a boxing ring to monitor users' movements, pacing and moments of intensity during sparring. After each sparring round (3-5 rounds in total), the visualization tool will display the captured data in the form of a heatmap and a graph that displays moments of intensity.

Participants will be asked to analyse the data and therefore their performance, enabling them to compare multiple sparring sessions. In addition to this, their behaviour during and after the sessions will be observed. Extra explanation regarding any of the visualizations will be provided if necessary. Interviews will be conducted regarding their experiences, understanding, and their ability to reflect on the data. This approach aims to gain insights into the effectiveness and user perceptions of the implemented monitoring and visualization techniques in the context of boxing training.

Monitoring performance data:

The depth camera recorded participants' movements, pacing, and moments of intensity during sparring sessions. The captured data, visualized through heatmaps and graphs, formed the basis for the analysis. Performance metrics, such as time spent in specific areas of the ring and fluctuations in intensity, were assessed to determine the impact of the monitoring tool on participants' performance.

Thematic Analysis:

Thematic analysis was then applied to the collected data and interview answers, aiming to identify recurring themes, patterns and meaningful insights.

8. RESULTS

Central findings

The main objective of the user study was to test the impact of the developed visualization tool on novice boxers in a real life setting. Multiple aspects were analyzed, such as pacing, strategy and ultimately improvement. The findings are centered around the graphs that displayed moments of intensity, the heatmap results and the participants' behavior and responses in the interviews. For co-creation insights see the process section and appendix B.

Intensity graphs

Among the participants, #P1 and #P4 showed a significant improvement in pacing over the three rounds, showcasing more consistent levels of intensity in round three compared to round 1. However, #P2, #P3 and #P5 displayed either minimal changes in pacing, or showed different consistencies over the three rounds.

Heatmap insights

The integration of the heatmap, developed to showcase movement insights into specific situations during a round, was used to discover multiple flaws and habits between the participants. For instance, #P5 noticed a recurring habit of circling into the opponent's power hand, resulting in unnecessary hits. In addition to this, #P3 remained in a disadvantageous position by staying in one of the corners of the ring for too long, causing restricted movement and allowing their opponent to move in and out of range freely.

Undertanding visualizations

A reoccurring challenge deemed to be the understandability of the graphs that displayed moments of intensity. 4 out of 5 participants needed extra explanation to fully understand and therefore reflect on that part of the data. This further emphasizes the importance of a user friendly interface when designing tools of this

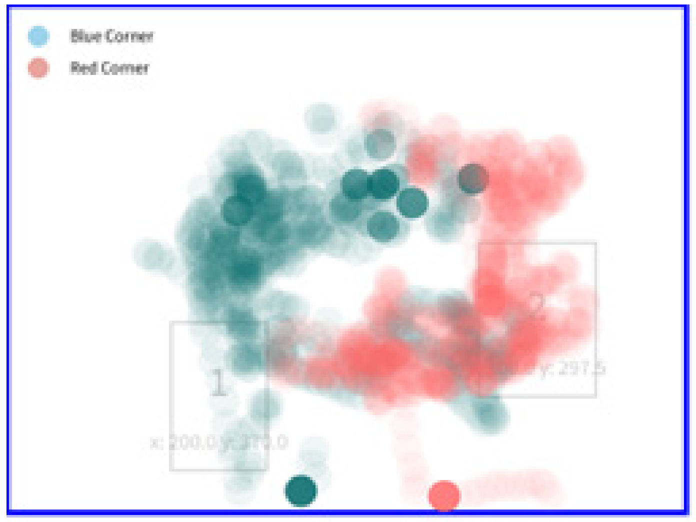


figure 25: heatmap circling insights

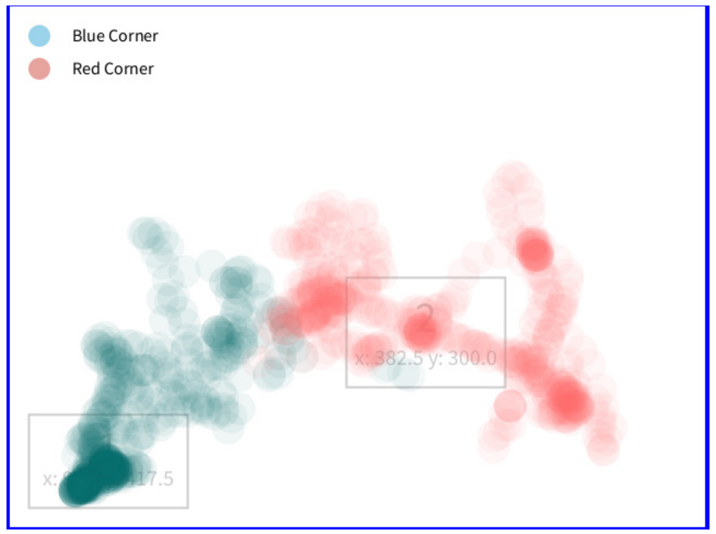


figure 26: heatmap corner disadvantage insights

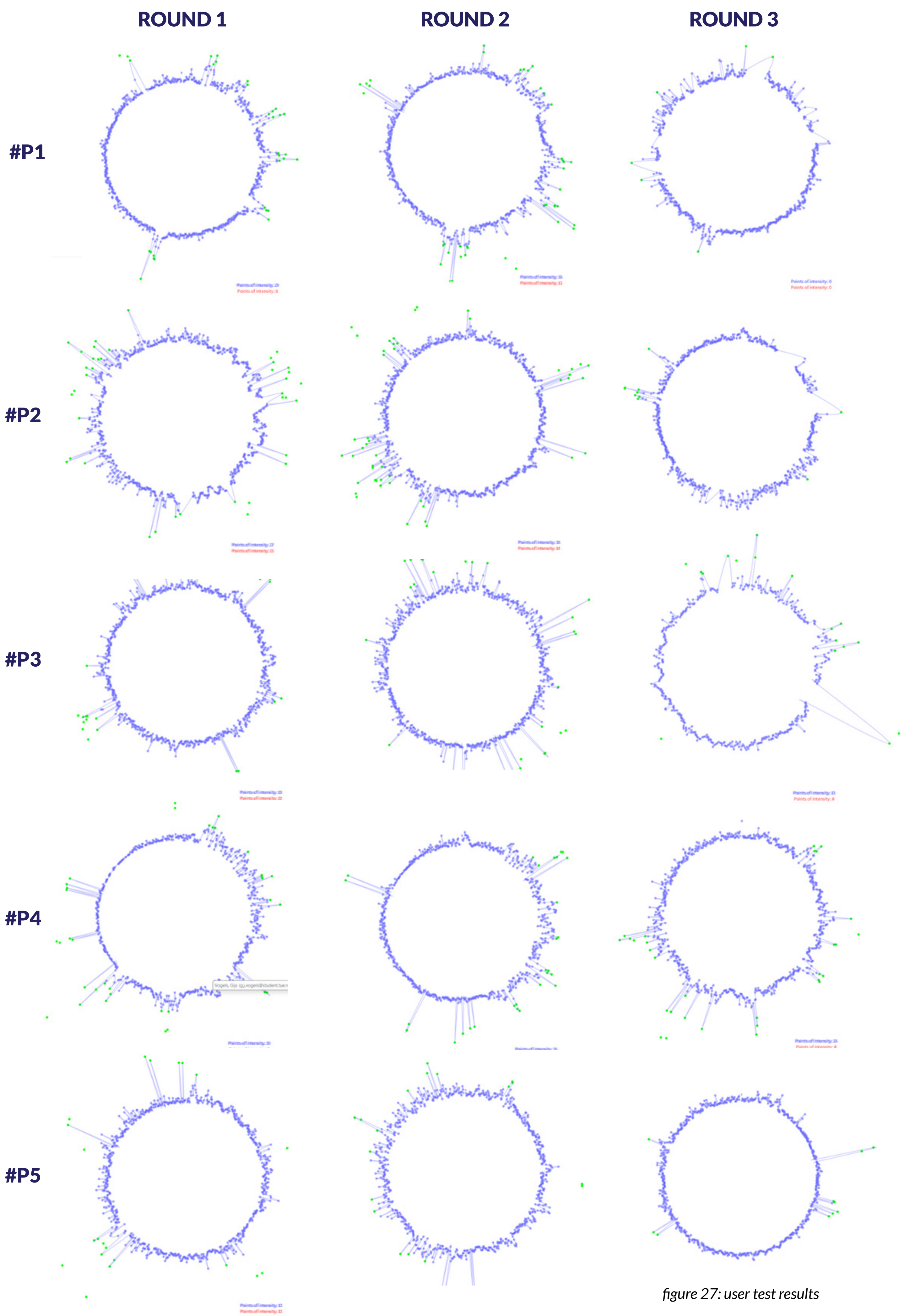


figure 27: user test results

9. DISCUSSION

Key findings
The results showed a dichotomy between the participants regarding the graphs that shows moments of intensity, with participants #P1 and #P4 showing a more consistent pace in the third round compared to the first, whereas the other three participants showed minimal change in pacing. 4 out of 5 Participants needed extra explanation regarding the visualizations before they were able to understand their personal data. Regarding strategy, the heatmap proved to contain valuable information regarding specific situations during a round. For instance, in round 1 of participant #P5 recognized that there was a case of a lot of circling around each other. With the help of some coaching it was revealed that participant #P5 was circling into the power hand of his opponent and therefore getting hit more than necessary. After understanding this he started standing his ground more and even circling the other way, and therefore getting hit much less. Another situation was recognized from the graph that displays moments of intensity. The person in the blue corner happened to have minimal movement at the end of the round, whereas the person in the red corner showed a high amount of intensity. When going back to the heatmap, it was revealed that #P3 was stuck in the corner of the ring and #P1 was able to move in and out of range without restrictions. After discovering this, #P3 understood that staying in the corner restricts movement and causes a big disadvantage during a fight.

Explanation of results
Participants #P1 and #P4 showed improvements in pacing by having moments of intensity distributed across the whole round after reflecting on their data during the first rounds Minimal change in pacing or strategy between participants #P2, #P3 and #P5 can be caused by several aspects. One explanation is the fact that the study only consists of three rounds per individual. Countr is a product that is intended for long term progress and having only two rounds to reflect before going into the final round may be insufficient for some individuals to reveal significant progress. Another explanation is that participants may have different boxing styles. Countr provides objective information and while a consistent pace is typically seen as the most effective, there are instances where this is not the case.

References to previous research
Although there are visualization tools for boxing, most of these tools, such as SkillVis, focus on posture and strikes that are thrown instead of movement and moments of intensity. While these visualization tools offer useful insights regarding technique and combinations, they lack the ability to provide information about positioning and pacing. Countr enables boxers to understand where they should position themselves in relation to their opponent and when they can and should be explosive. However, visualizations such as SkillVis give more insights about the way punches and combinations are thrown, which is a key aspect in boxing that Countr is not able to showcase.

Deduction
Countr provides multiple insights that can be implemented in projects beyond boxing, offering valuable information for technology in sports and training methods. The project focuses on enabling users to assess their own personal performance rather than using a one-size-fits-all strategy. Reflecting directly on objective data instead of being told what the best approach to certain situations is has revealed promising opportunities in personal progress. An iterative development process that includes the user's needs and preferences proves to be essential for optimally refining tools over time. Clear communication and the ability to understand provided data deem crucial in an immersive learning environment.

Limitations and weaknesses
Even though Countr offers valuable insights into personal boxing performance, the product faces certain challenges and limitations that have to be taken into consideration. Countr focuses on capturing movement data to recognize patterns and explosiveness, but can't provide information about thrown punches. Where the system excels in offering feedback regarding positioning and movement, it lacks the ability to give an understanding of aspects like amount of punches thrown or the impact that certain punches have. The absence of punch-related data restricts Countr from creating a visualization that tells the whole story of a fight.
Furthermore, the study shows that without extra assistance, the provided data can be difficult to understand and therefore reflect on. Especially the graph that displays moments of intensity required additional explanation before users understood what data was being shown. At the time when the study was conducted, a finalized interface was not yet fully developed, which may have caused unnecessary confusion. If the final interface was used during the study, extra information wouldn't have been necessary and different results may have occurred. Another challenge rises when the product has to be used in a different environment. Since Countr uses a Depth camera that has to be placed above a ring or any other environment that is used for sparring, it has to be calibrated based on ceiling and ring height. When the system is not well calibrated, it may detect too many or not enough depth values, resulting in errors or inaccuracies in the captured data.

Principal Implications and Recommendations
to summarize, Countr can have a significant contribution to the intersection of sports technology and training methodologies. The results highlight the benefits of post-hoc feedback, user-friendly interfaces, and objective personal data when it comes to analyzing performance. Countr is only the beginning of a range of possibilities in the world of boxing visualization and serves as a building block for future work and improvements. Recommendations for further development and research include exploring the integration of additional components such as pressure sensors to register punches or side view cameras that can track skeletal data to give insights into technique. In addition to this, longitudinal studies can provide information regarding the long-term impact of data-driven feedback on personal development and motivation.

10. FUTURE WORK AND ENVISIONING

This project has explored and provided a rich dataset that allows for an in-depth visualization of sparring activity. However, as mentioned before, Countr serves as a building block for future work and improvements. Multiple steps can be taken to further expand the ability to capture data and therefore improve the visualization beyond its current capabilities.

Pressure sensors
One method that would create a more comprehensive understanding of boxing dynamics during sparring sessions is the integration of pressure sensors within the gloves or gear of the fighters. If sensors would be put into the gear, they would likely be positioned on the body's most vulnerable areas, such as the jaw and liver—frequent targets for their opponents' punches [16]. The ability to capture additional data with this integration would enable the capture and visualization of the impact and amount of landed punches, adding another layer of data to the analysis. Combining this with the already existing heatmap, an impact map could be displayed that not only shows movement, but also when and where fighters get hit. This added feature introduces the possibility to analyze the correlation between movement, timing of their punches and intensity of impacts. This would result in new insights into both defensive and offensive strategies.

Second depth camera
Another feature that could be implemented to add an extra layer to performance analysis is the incorporation of an additional depth camera positioned for horizontal data capture. Multiple depth cameras that are originally intended for gaming purposes have already been implemented with horizontal skeletal tracking, which would smoothen the integration into the Countr project. The inclusion of a second camera that captures skeletal data offers a detailed and nuanced understanding of movement during sparring, as insights into the biomechanics of the boxers can be showcased. By displaying skeletal data in addition to the already existing visualizations, assessments can be made on multiple aspects such as posture, balance and technique.

In summary, the incorporation of a camera capturing skeletal data and pressure sensors measuring punching dynamics represents many opportunities for Countr to improve as a visualization tool. This augmentation enhances the platform's analytical depth, precision, and practical applicability, positioning Countr as a promising product in the evolution of boxing training and performance analysis.

11. CONCLUSION

In addressing the challenge of increasing motivation of novice boxers by providing a deep understanding and reflection tool regarding their performance, Countr has successfully created a visualization tool that displays insights in pacing and strategy. The approach to achieve this goal centered on using a depth camera to capture and analyze movement and explosiveness during sparring sessions. By providing novice boxers with personal objective data, they can use the visualizations to either reflect on their performance on their own or in collaboration with their coach. Countr proves to achieve its goal successfully in certain situations, although having its limitations in recognizing different boxing styles or giving insights on punching dynamics. The graph that displays moments of intensity needed extra explanation for the users to fully understand what data was being showcased, but proved to be a beneficial tool for recognizing patterns in pacing during each round of sparring. The heatmap proved valuable in revealing strategic insights during specific moments of the round, such as identifying circling patterns and recognizing the impact of corner positioning. Combining these two visualizations highlighted certain flaws and keys to improvement, and encouraged participants to use their own data to reflect on their sparring session. A key aspect in understanding the visualizations is an interface that prioritizes usability and communication. To explore the impact on performance after long term use, longitudinal studies have to be conducted.

In conclusion, Countr has emerged as a promising visualization tool that can be used by novice boxers to gain a deep understanding into pacing and strategy, which can increase their motivation to continue on their boxing journey. Countr is only the beginning of a new methodology of boxing training and performance analysis, and provides a wide range of possibilities for future implications in the sports technology landscape.

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ChatGPT was used to resolve errors in the code

```
//1: import libraries:: -> sketch ->Import Library
import SimpleOpenNI.*;
//2: make a variable to to hold the SimpleOpenNI
object (to be able to access data from the kinect)
SimpleOpenNI kinect;

//3: declare PImage variable to hold and display the
pixel data from the kinect
PImage depthCam;
//4: declare PImage variable to hold only the pixel
data in range ...
PImage result;


int blobCounter = 1;
int maxLife = 10000;
int prevBlobCount = 0;
int startTime;
int maxRunTime = 20000;
float distThreshold = 75;
boolean showAllGraphs = true;
boolean showBlob1Graph = false;
boolean showOtherBlobsGraph = false;

ArrayList<Blob> blobs = new ArrayList<Blob>();




void setup() {
  fullScreen();
startTime = millis();
  // make the sketch size a that of kinect sample
  size(640, 480);
  // set a background color
  background(0);
  // instantatiate the SimpleOpenNI object
  //paremeter : is the current context
  kinect  = new SimpleOpenNI(this);
  //invoke the method from the lib to allow access to
the depth camera
  kinect.enableDepth();
  // create an empty PImage container
  result = createImage(width,height,RGB);
}


//4: our drawing loop
void draw() {
  int passedTime = millis() - startTime;
```

```
//if 'r' key is pressed, reset sketch
  if (keyPressed && key == 'r') {
    reset();
  }
  //reset the background
 background(0);

  ArrayList<Blob> currentBlobs = new Array-
List<Blob>();


  // get the next frame from the kinect
  kinect.update();
  // get the depth image and assign to the PImage var
(using the lib)
  depthCam = kinect.depthImage();

  // get the depthMap (mm) values
  int[] depthVals = kinect.depthMap();

  // load the pixel array of the result image
  result.loadPixels();



  //go through the matrix - for each row go through
every column
  for (int y=0; y<depthCam.height; y+=5)
  {
    //go through each col
    for (int x =0; x<depthCam.width; x+=5)
    {
      // get the location in the depthVals array
      int loc = x+(y*depthCam.width);
      // if the depth values of the sampled image are in
range
      if (depthVals[loc] > 2000 && depthVals[loc]<
2700 )
      {
        //let the pixel value in the result image be white
       result.pixels[loc] = color(0);



       boolean found = false;
       for (Blob b : currentBlobs) {
         if (b.isNear (x,y)) {
           b.add(x,y);
           found = true;
           break;
         }
```

```
         }

          if (!found) {
          Blob b = new Blob(x,y);
          currentBlobs.add(b);
            }


          }

        else
         // otherwise let the pixel value in the result image
be black
        result.pixels[loc] = color(0);



       }
     }

result.updatePixels();
image(result, 0, 0);

fill(255);
  strokeWeight(5);
  stroke(100,255,100,200);
  rect(0,0,640,480);

for (int i = currentBlobs.size()-1; i >=0; i--) {
        if (currentBlobs.get(i).size() < 800) {
  currentBlobs.remove(i);
      }
}



if (blobs.isEmpty() && currentBlobs.size() > 0) {
  for ( Blob b: currentBlobs) {
    b.id = blobCounter;
    blobs.add(b);
    blobCounter++;
  }

} else if (blobs.size() <= currentBlobs.size()) {

  for (Blob b : blobs) {
    float recordD = 1000;
    Blob matched = null;
    for (Blob cb: currentBlobs) {
      PVector centerB = b.getCenter();
      PVector centerCB = cb.getCenter();
      float d = PVector.dist(centerB, centerCB);
      if (d < recordD && !cb.taken) {
        recordD = d;
```

```
        matched = cb;
      }
    }
    matched.taken = true;
    b.become(matched);
    }


for (Blob b : currentBlobs) {
  if (!b.taken) {
    b.id = blobCounter;
    blobs.add(b);
    blobCounter++;
  }
}
} else if (blobs.size() > currentBlobs.size()) {
  for (Blob b: blobs) {
    b.taken = false;
  }


  for (Blob cb : currentBlobs) {
    float recordD = 1000;
    Blob matched = null;
    for (Blob b: blobs) {
      PVector centerB = b.getCenter();
      PVector centerCB = cb.getCenter();
      float d = PVector.dist(centerB, centerCB);
      if (d < recordD && !b.taken) {
        recordD = d;
        matched = b;
      }
    }
    if (matched != null) {
    matched.taken = true;
    matched.lifespan = maxLife;
    matched.become(cb);
    }
    }

    for (int i = blobs.size() - 1; i >= 0; i--) {
      Blob b = blobs.get(i);
      if (!b.taken) {
        if (b.checkLife()) {
          blobs.remove(i);
      }
    }
    }

}

for (int i = blobs.size() - 1; i >= 0; i--) {
```

```
  Blob b = blobs.get(i);
  if (b.id > 2) {
    blobs.remove(i);
  }
}

 if (keyPressed) {
   if (key == '1') {
     showAllGraphs = true;
     showBlob1Graph = false;
     showOtherBlobsGraph = false;
   } else if (key == '2') {
     showAllGraphs = false;
     showBlob1Graph = true;
     showOtherBlobsGraph = false;
   } else if (key == '3') {
     showAllGraphs = false;
     showBlob1Graph = false;
     showOtherBlobsGraph = true;
   }
  }

  // Display graphs based on visibility variables
  if (showAllGraphs) {
   // Display all graphs
   for (Blob b : blobs) {
     b.show();
     b.update();
     b.drawAccelerationGraph();
   }
  } else if (showBlob1Graph) {
   // Display only blob 1 graph (blue)
   for (Blob b : blobs) {
     if (b.id == 1) {
       b.show();
       b.update();
       b.drawAccelerationGraph();
     }
   }
  } else if (showOtherBlobsGraph) {
   // Display only other blobs graphs (red)
   for (Blob b : blobs) {
     if (b.id != 1) {
       b.show();
       b.update();
       b.drawAccelerationGraph();
     }
   }
  }


  noStroke();
  fill(0,142,204,100); // Blue color
  ellipse(30, 30, 20, 20); // Blue circle
  textAlign(LEFT);
  textSize(16);
  fill(0);
  text("Blue Corner", 60, 35); // 'Blue Corner' text

  // Display 'red corner' text with red circle
  noStroke();
  fill(194,24,7 , 100); // Red color
  ellipse(30, 60, 20, 20); // Red circle
  fill(0);
  text("Red Corner", 60, 65); // 'Red Corner' text

  strokeWeight(3);
  stroke(255,200);
  line(width/2 + 300, height/2 - 230, width/2 + 300,
height/2 - 290);

 textAlign(CENTER);
  textSize(22);
  fill(255);
  text("Acceleration over Time", width / 2 + 300,
height - 100);
  text("Heatmap over Time", 320, 510);

  if (passedTime < 30000) {
  String timeText = "Round Duration: " + nf(passed-
Time / 1000, 2) + " seconds"; // Format time in
seconds
  textAlign(CENTER);
  textSize(22);
  fill(255);
  text(timeText, width - 150, 50);
  } else {
   // After 10 seconds, display the frozen timer
   String frozenTimeText = "Round Duration: " +
nf(30, 2) + " seconds";
   textAlign(CENTER);
   textSize(22);
   fill(255);
   text(frozenTimeText, width - 150, 50);
  }
}

void reset() {
blobs.clear();
  blobCounter = 1;
  maxLife = 10000;
  prevBlobCount = 0;
  startTime = millis();
  showAllGraphs = true;
  showBlob1Graph = false;
  showOtherBlobsGraph = false;
  depthCam = kinect.depthImage();
  result = createImage(width, height, RGB);
}


  float distSq(float x1, float y1, float x2, float y2) {
  float d = (x2-x1)*(x2-x1) + (y2-y1)*(y2-y1);
  return d;
  }

class Blob {
 float minx;
 float miny;
 float maxx;
 float maxy;

 ArrayList<PVector> points;
 ArrayList<PVector> history;

 int id = 0;
 int lifespan = maxLife;

 boolean taken = false;
 boolean creationTimeDisplayed = false;

 Blob(float x, float y) {
   minx = x;
   miny = y;
   maxx = x;
   maxy = y;
   points = new ArrayList<PVector>();
   points.add(new PVector(x, y));
   history = new ArrayList<PVector>();
 }

 boolean checkLife() {
   lifespan--;
   return lifespan < 0;
 }

 void show() {
   stroke(0, 50);
   fill(255, 50);
   strokeWeight(2);
   rectMode(CORNERS);
   rect(minx, miny, maxx, maxy);

   textAlign(CENTER);
   textSize(40);
   fill(0, 50);
   text(id, minx + (maxx - minx) * 0.5, miny + (maxy
- miny) * 0.5);
   textSize(20);
   text("x: " + (minx + maxx) / 2 + " y: " + (miny +
maxy) / 2, minx + (maxx - minx) * 0.5, maxy - 20);

   for (PVector current : history) {
     fill(map(id, 1, blobCounter - 1, 0, 255), 100, 100,
15);
     noStroke();
     ellipse(current.x, current.y, 30, 30);
   }
 }

 void add(float x, float y) {
   points.add(new PVector(x, y));
   minx = min(minx, x);
   miny = min(miny, y);
   maxx = max(maxx, x);
   maxy = max(maxy, y);
 }

 void become(Blob other) {
   minx = other.minx;
   maxx = other.maxx;
   miny = other.miny;
   maxy = other.maxy;
 }

 void drawAccelerationGraph() {
   // (Same as before, no changes made here)
 }

 void update() {
   if (millis() - startTime < 30000) {
     PVector v = new PVector((minx + maxx) / 2,
(miny + maxy) / 2);
     history.add(v);
   }
 }

 float size() {
   return (maxx - minx) * (maxy - miny);
 }

 PVector getCenter() {
   float x = (maxx - minx) * 0.5 + minx;
   float y = (maxy - miny) * 0.5 + miny;
   return new PVector(x, y);
 }

 boolean isNear(float x, float y) {
```

```
  float d = 100000;
  for (PVector v : points) {
    float tempD = distSq(x, y, v.x, v.y);
    if (tempD < d) {
      d = tempD;
    }
  }

  return d < distThreshold * distThreshold;
}

float distSq(float x1, float y1, float x2, float y2) {
  return (x2 - x1) * (x2 - x1) + (y2 - y1) * (y2 - y1);
}
}
```

APPENDIX B

Co creation transcript

1.
Greeting
Hey everyone, thanks for coming.
Hi
Hey
So as you know you are here to do a user test about boxing visualization.
Before you start, can you all fill out the consent form please.

Explaining test + first ideas
Great, let's start.
Sure.
Before I am going to show you some different examples about boxing visualizations I would like you to discuss what visualizations you think would be helpful for your training.
Okay.
It could be anything, just speak your mind.
Maybe some kind of thing that shows how hard you punch or what punches you throw.
Yeah or something that shows where you get hit.
Okay nice.
Anything else.
You could like measure how people throw a punch and visualize their technique.
Oh yeah that would be cool.
Nice.
Anything that focuses on something other than only punches for example movement.
You can visualize how people move around the ring.
And how would you do that.
Maybe use sensors on their body and track the location and make like a graph or something.
Oh yes that would be cool.
Or you could see like how many steps they take during a fight.

Okay thank you for your input.
So now we are going to the next part of the test which consists of three parts.
So I am going to show you three different types of visual feedback and I want you to give me your opinion on which version you prefer.
So the three types of feedback are real time, post hoc and long term.
Real time basically means that you would receive real time feedback while you are sparring.
Okay
Post hoc means that you spar one round and then afterwards you see the feedback.
And long term means that you spar a round and after one day or more you receive your feedback.
Clear
Yes
Yes
Okay lets start with real time feedback

Real time
So this is the only type of feedback that I don't have a physical example of so I am going to describe a situation what I would think it would look like.
Oh okay
Okay
Okay
So I think it would be interesting if you could see on the other person where their guard is open or where they get punched the most in the form of colour changing gear.
Or you could show on the ground where the opponent will likely move based on previous collected data
What do you think about these options and would you like to use them
I think it's really cool to see extra things and information about your opponent
Yeah exactly
I like that you can adjust immediately because it is in real time
Me too
Yeah
Any negatives or things that you don't like
I think it will be hard to focus on the data since sparring is very like stressful already
Or not stressful but you need to focus
Yeah yeah
And maybe the extra things on the body or the floor will be distracting and it confuses you or something like that
Yeah good point
Okay anything else
I think if you keep it simple it could work
So like focus on one thing and show that to like keep it simple
Okay
Anything else
No
Okay
Then let's move on the next part which is the post hoc
Feedback
Okay Sure

Post hoc
Okay so for this part I have a couple visualizations on a screen that I am going to show you
And again you can show me or tell me what you think
Oh very cool
Did you make this
Yes I did
What are those square things that are moving around
I'll tell you after the second thing
Oh okay
Okay so the first thing I showed was a heatmap that shows where the fighters are moving over time and the second thing was a graph that shows the activity of fighters during the round
It looks cool
I don't really understand the second part
The graph
Yes
Yeah me too
Okay so I will play it again
So when a fighter has a burst of acceleration in any direction the graph shows a peak

Okay

I like the heatmap thing because you can see every step that you made but I think the graph is a little difficult to understand
How would you improve the graph

I would maybe explain how it works before using it or like put extra information on the screen
Yeah I agree

Okay thank you

Anything else

Not really

I like that it is after the round because you can focus on just that thing instead of fighting and looking at information at the same time

So you like it better than the real time feedback

Yes I think so

Do you agree

Yes yeah

Okay thank you

Let's move on to the next iteration

Long term

So this is something similar to the graph but it is a physical object.

Would you prefer to receive this a day after your sparring session or look at the visualisation immediately.

Why would we receive this a day afterwards
Because it takes time to make it

Oh okay

Okay makes sense

How did you make this

It is 3D printed

It looks very cool

Thank you

Yes it looks cool but why would you make it physical and not just on a screen

What do you think

I don't know

Do you prefer it over the visualisation

It looks better

But if it takes more time to make it I don't really see the point

I like that it looks like a sort of of personal prize that you can take home

Yes that's true

But does it help you reflect better

Not really

Would you be more motivated to interact with the data if it has a physical form

Or would you be more interested in it

Not really because it is data about me so I am already interested in it

Good point thank you

Okay any more feedback

No not really

No

Preferences

Okay so overall which one do you like the most

The visualisation

The post hoc

Yes

Yes me too

Why did you like it better than the other ones

Because I can focus on sparring and then after that I can look at how I did immediately

Yes true

Do you have any improvements for the visualisation

Maybe you can make the overall concept more clear

So give more information

Yes you can tell what it is about and how it can be used

Okay thank you

Any more feedback

No not really

No

Okay that was the session

Thank you all for participating

[End]

2.
Greeting
Hello everyone, thanks for joining the session.
Hey.
So you are here to do a user test and discuss about boxing visualizations. Before we start, can you all fill out the consent form please?

Explaining test + first ideas
Thank you
Before we start the test I would like you to think of how you would use data to visualize boxing performance.
Like anything?
Yes anything just say what comes to mind
Okay
Okay
Maybe like a scoreboard that shows the amount of punches.
Yes exactly
Okay, nice.
Anything else?
How about showing the impact of punches, like the force or power behind each punch?
Oh yeah, that sounds interesting.
You could have like a bunch of graphs that show stats.
Nice.
Maybe something that gives insights into defensive moves, like blocking or dodging?
You can have a visualization of successful defensive moves or areas where you're most vulnerable.
Or vice versa to show like attacking things that have success.
Yeah, that would be helpful.
Okay, anything else?
Not really I think that's it

So now let's look at how you would communicate these things. How do you think you can create visualizations for these aspects?
I think for tracking movement, we could use sensors on the body and track the location to create a graph or heatmap.
Oh, yes, that would be cool. You mean like a full-body motion capture?
Yes like a bit the same how they use those suits to make videogames.
Exactly, you get like a the exact movement of the whole body.
Okay great.
And how would you show things that are punch related?
maybe something with colors would be cool.
kind of color system on the opponent to indicate the force of the punch.
Nice. And for defensive moves, maybe a slow-motion playback of successful blocks and dodges with text or information or something.
Or even a virtual training partner showing different attack moves for learning how to defend.

Okay, thank you for all the input. Now, I'm going to show you three different types of visual feedback, and I want you to discuss on which version you like the most or which one you would use. The three types of feedback are real-time, post hoc, and long term.
Do you have any questions?
No
Okay, let's start with real-time.

Real-time
This is the only type of feedback that I don't have a prototype of, so I am going to describe some options that could be made.
Sure.
Okay.
So, imagine you can see on the other person where they are lacking defensively or where they get punched a lot, in the form of color-changing gear.
You already said something about this.
Yeah that's nice.
Or you could have virtual markers on the ground predicting where your opponent might move based on previous data.
What do you think about these options, and do you think they would help?
Its nice to get extra information while you're sparring.
Yeah
You can try to like predict what they are going to do next.
Yeah.
Any negatives or things that you don't like?
Maybe its difficult to see since you are trying to dodge punches.
Yeah, yeah.
Maybe when you have sensors or light or something it can be uncomfortable.
How would you show light during a sparring session. Don't you need like batteries or something.
That doesn't really matter for now.
Oh okay.
Maybe you can use sound as well.
Like you could wear an earpiece that makes noise when you make a mistake.
Oh yeah good idea.
Anything else?
No
Okay lets move on to post-hoc feedback

Post-hoc
Okay so for this part I have some visualizations on

my laptop.
Again you can tell me what you think about it.
So this is a heatmap that shows movement around the ring
Cool
It looks nice
And this is a graph that shows moments of intensity
Okay
What does intensity mean
It means how much a fighter moves around the ring
Ah okay
So when the graph shows a peak you move a lot
Yeah that's right
Ah okay cool.
So what do you think.
Yeah it looks nice.
Why did you use a circle.
I chose a circle because every circle represents one round and you can compare them easier.
Ah okay
Yeah I like it
Maybe you could change the colors of the heatmap so you show what direction they are moving in.
Yeah I was thinking the same thing
Yeah because now you cant see how they are moving just where.
Okay good idea thank you
I like the activity graph.
It shows really well when you are active
Okay

Long-term
Okay for the last option I am going to show you some physical objects and again let me know what you think.
So you would get these about a day after the session because 3D printing takes some time.
You can touch it or hold it
Okay
Sure
It looks really cool.
Yeah
Would you like to use it
Well I don't really know what it means
It is the same as the intensity graph.
So the peaks would show moments of intensity.
Ah okay
Yeah it looks very cool but I don't know what I would use it for
Can you think of you would make the data physical that you would use
I cant think of anything right now
It could use LED's to make it interactive
Oh yes that would be nice
Then it gives some extra information yeah
Or you could make it different pieces so that you can build something
Would that make it worth waiting
Well if it helps me with training it would
Okay thank you

Preferences
So out of the three options, what option would help you with training the most
The second one
Post-hoc
Yeah
Yes me too
Why
It just gives the clearest data.
Like you just see everything in one screen .
Okay anything to improve this part
Yeah like we said maybe make different movements different colors
And make sure the things are explained.
I would not understand it if you didn't explain it
Okay thank you
Anything else
Okay thank you all for your participation

3.
Greeting
Hey everyone thanks for coming. Before we start can you fill in the consent forms.
Great thank you.

Explaining test + first ideas
So before we start I would like to ask you what data you can think of that can be visualized in boxing.
Just anything think out loud.

I think anything that has to do with punches
Yeah
So what for example
Like how many punches you land.
Or where you hit people, how hard you hit people.
Or when you land or the glove or on the head.
And how would you show that.
maybe a color code for successful and unsuccessful strikes.
Great idea.
What do you think.
What about a virtual trainer that checks how you punch or how you defend.
Nice
Lets get one more, any thoughts?
If you are sparring, you could visualize something like hard rate or where you breathe.
Oh yes nice.
Okay and how would you show all those things.
Maybe something with light.
Yeah like something that the color changes based on where you punch or how hard you punch.
You can also make like a bar that slowly goes down to see how tired you are.

Okay all great ideas.
Lets move on to the next part of the session.
we're discussing three types of visual feedback.
real-time, post hoc, and long term.
Ready
Yes
Yes
Okay lets go

Real-time
So for this type of feedback I don't have a prototype so I am going to describe a situation of how I think it could look like.
So I think it would be cool if you saw where the other person is lacking in defense or where they get punched the most in the form of color changing gear.
Oh cool
or you could show movement patterns on the ground
nice
so what do you think and do you have any positive of negative opinions
I really like it
Yeah you feel like the terminator if you could see things like that about your opponent
Anything you might dislike about it
You have to be really quick
True
Yeah
Well you cant really react when you see a different color and then immediately get punched
Like you have to focus on your opponent
And the opponent can also see what feedback you are getting
Oh yeah I didn't think of that
Good point
Thank you
Anything else

Post hoc
Okay lets move on to the next type of feedback which is post-hoc.
I will give you some visualizations that I made that shows a heatmap of movement and then a graph that shows intensity.
So the graph shows a peak when make quick attacking or defensive movements.
Okay cool
Sure
I really like the heatmap
Yeah you can exactly see where you were
Is this from a real person
No I did it with my hands like
Ah okay
But if you put the camera above a ring it would work the same
Yeah okay cool nice
What do you think about the graph
I think it would be cool if you also could see punches
Yeah me too
Because now you see intensity as movement but you punch without moving
Yes good point
But for the rest I like it
Do you like it more than real-time
Yes because you can take your time to look at the data
Okay anything else
Not from me
No
What about you
Not really
Okay let's move on to the last one

Long term
So this is a physical version of the graph that shows moments of intensity. You can put this at home as like a trophy or set multiple versions next to each other or on top of each other to show progress. What do you think

I like that you can put them on top of each other for the progress
You can see like how you have become better over time
Yes, it would take about a day to get because it has to be 3D printed
Yes that is a bad thing
Yeah this looks more like you use it to look back on how you did but you can't really see that well what you did exactly
Any other thoughts
It feels very personal because it is a real object
But like #participant said it doesn't give a lot of detail

Preferences
So which option do you prefer or would you use to improve your pacing and strategy
I like the post hoc the most
I agree
I like the real time actually
Why
I don't know I just think it would feel really cool to see extra information in light or something
And if the ground changes it looks like you are on a dance floor or something
Yeah that is true
And you
I like the graphs the most
Okay anything else that you want to say
Okay thank you for your time
[End]

Appendix C

Boxing coach feedback 190923

Technique
Footwork
Focusing on footwork means stepping with every punch and rotating your feet. This makes sure that you are keeping your legs under you when punches, avoiding reaching with your upper body and making sure that your shots are powerful.
Measurable data: pressure sensors on shoes/mat.
Infrarood en diepte camera neerzetten voor een top down view.
Weight shift
In relation to footwork, shifting your weight means placing your weight from one foot to the other. This sets your body up in a solid position to throw a power shot.
Measurable data: pressure sensors on shoes/mat.
Jab and cross - Arm extension
When throwing straight strikes, it is important to extend the arm fully, to be able to throw from as much distance as possible, as well as getting the most power out of the strike.
Measurable data: Elbow lockout?
Arm retraction
After throwing a strike, it is crucial to bring back the arm as fast as possible to avoid getting countered.
Measurable data: extension vs retraction speed
Stance width
Keeping your feet at a 45 degree angle at a little wider than shoulder width keeps you balanced while still being quick on your feet.
Measurable data: relative proximity sensors?
Hip/shoulder rotation
Avoid throwing arm punches by making sure to fully rotate your hips and shoulders during every strike you throw.
Measurable data: rotary encoder on hips and shoulders.

Sparring
Distance/range
When you are not preparing to throw a strike, make sure to stay out of range of your opponent to avoid taking unnecessary damage. When throwing a strike, throw a setup shot (e.g. jab to get into range).
Measurable data: distance sensors
Switching between power shots and setup shots
It is extremely exhausting to make every punch a power shot. In addition to this, single power shots are predictable and easy to defend. This makes it important to mix it up. Throw combinations with feints/setup shots to have more success with landing that power punch.
Measurable data: measuring impact on every strike
Keeping the guard up
Even when you are tired, try keeping up your guard at all times when you are in range of getting hit. This prevents you from relying only on head movement and can prevent unnecessary damage.
Standing your ground
Stepping back is a good practice when defending, however avoid backing up so much that you end up in the ropes or get cornered.
Measurable data: distance sensors
Going to the body
Avoid headhunting too much, it becomes predictable and easy to defend. Throw combinations to the body and to the head
Angles
Try to get off your opponent's center line to avoid shots and create opportunities of your own.
Measurable data: gyroscope?