An Attempt to Develop a Real-time Analysis Program: Research and Development of the Match Analysis Program for Water Polo in 2017

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Toho Junior High School, second year (eighth grade)

*This research papers and all raw data have already sent by FedEx in December directly to Undergraduate Admission Office.

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Abstract

The purpose of this study was to create a computer program beneficial for my water polo team through my analyses of the data gained from all the games of Japan National Water Polo Team in 2016, and to put it to actual use. As I was a true beginner of programming, I needed support from a professional programmer, Mr. Teramoto, who received an award from SOUMUSHOU （Ministry of Internal Affairs and Communications） by making games to help elementary and junior high school children to learn programming. I contacted him directly for the support. I learned programming while simultaneously creating this real time analysis program. Since this project was a huge one, I decided to learn basic skills on programing and do all the research for the game analysis for water polo during eighth grade and then start on the development of the real program during ninth grade. The biggest challenge in this research was how to measure total the swimming distance for each player as I always had a hypothesis that the correlation between winning and losing and total swimming length. For the attempt to measure the swimming distance, I used UMA TRACKER software and tried to use it in water polo games for a couple of times, which ended up unsuccessful. I wrote the main reasons why the software was not right for it. Therefore, in this report, one-fourth of it is investigated and reviewed with the preceding research papers, while the other part is a couple of attempts of experimental research and another part of it is about the process on how I learned to make my program from scratch, and the rest is the final result image of completion of my real-time analysis program. The real-time analysis program will continue to be developed for one more year, and it should be launched in year of 2018.

*This research paper was first written in Japanese as an individual summer project in the eighth grade at Toho Junior School, with which I won the first prize. I then translated into English when I was in the 11th grade and proofread and modified in the 12th grade.

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Ⅰ. Introduction.

On January 8, 2017, the Toho Water Polo Middle School team was eliminated from the Spring Junior Olympics Qualifier.　It was also the day I started thinking about how I could contribute to the

team to make us stronger besides improving my skills through hard work and practice.

It is often said that the levels in water polo at junior high schools in Japan are very similar from one school to another. In the qualifying round of the Summer Junior Olympics, we had 0 wins, 2 losses, 2 draws, and not much difference in scores. There were many games where we were so close to winning.

Last summer, in trying to analyze all of Japan's games in the Rio de Janeiro Olympics, I learned that data has a lot to say. If we could make our own games data-driven, we might be able to notice things that we otherwise would not.

However, the data analysis procedure we did last year was quite time-consuming: recording the game on video, replaying the video over and over again, checking where the shots were taken and where the goals were scored, inputting the data manually, calculating the data again, and then diagramming it. It was unrealistic for us to actually use the data. Even if we were to use that method to convert the data, the data would be too old by then, and if our memory of the details of the game had faded, we would not be able to compare it with the data and use it to look back.

If there was an analysis program that allowed players to easily input data from their own games and from those of the opposing teams, and immediately see the results of the data, they could look at the game objectively and notice things that they had not noticed before.

With this motivation in mind, I searched for books and articles on sports in general and data analysis in particular, and found that each sport has its own program called "Real-Time Game Analysis" that is utilized in each sport.

Using this as a reference, I began to explore the possibility of developing a real-time analysis program for water polo matches where we could easily use and share data with others. Since my team had lost in the qualifying round of the Junior Olympics, we decided to devote our free time to research.

I noted that even I were to try and make a basic and simple real-time analysis program, the development and implementation time required for such a program would be too important, so I aimed to put it to practical use in the summer of 2017, our third year.

1）In Carrying Out This Research

In order to conduct this research, I need to have knowledge and skills in programming. However, I am a complete beginner when it comes to programming. Therefore, even though I had a desire to develop a program, I had no idea where to start. Therefore, after my team was eliminated from the Junior Olympics, I looked through some introductory books on programming, but even after reading the books, I was still lost. There was a brief moment when I felt stuck and dejected at the thought that I was not able to realize my project.

One day, on my way home from water polo practice, I suddenly thought that, given the nature of programming, there might be more information on the Internet than in books, so I did some

research to see if there was a way to learn programming on the Internet. As I searched for information on the Internet, I gradually came to realize that many people are confused when they start from books to learn programming.

I thought about attending a seminar to learn programming for junior high school students, but as a water polo player with only a few days off from full-day practice during the summer vacation, I could not commit to concentrating and attending an outside seminar.

Then I had the thought that, “if programming is going to be taught in elementary schools from 2020, there must be someone who can teach it.” I came across the name of Daiki Teramoto, who won the Grand Prize of the Minister of Internal Affairs and Communications Award at the IT Entrepreneur Koshien (This is very famous place known as where selected Universities baseball teams compete each other in the Spring and Summer. I assumed that this Entrepreneur competition was used the name of “Koshien” is to let people see this is a big and important competition) in 2014. He has developed software that allows elementary and junior high school students to learn programming by making and playing games, which were tested in classes at several junior high schools in Tokyo.

I wondered if there was any way I could get some guidance from him, but I was reluctant to contact such a prestigious person myself. First, I asked my parents to get in touch with Mr. Teramoto. He replied that he would like to have a one-on-one teleconference with me. My parents coordinated the schedule for the videoconference with Mr. Teramoto, but I did all the preparations for the videoconference myself, including downloading the app called "Appear In" that Mr. Teramoto had specified for the videoconference.

At the meeting, Mr. Teramoto told us that he does not usually offer tutoring, but he was impressed by my motivation to create something for others through my desire to “learn programming in order to develop software for my team," and to "develop a program or application for real-time analysis of water polo matches” which had never been done before in Japan. He appreciated the fact that I was trying to develop something that didn't exist in Japan yet, and he offered to help me learn the basics of programming so that as I, even as a beginner, could learn it on my own from there.

Mr. Teramoto emphasized that programming development is like muscle training, and that basically I have to think about everything and practice everything myself to learn it. Incidentally, the biggest obstacle in learning programming is that during the learning process, the screen might suddenly get still, and even if you follow the instructions, you will not be able to progress at all. If the inability to progress continues for more than 20 minutes, people often get fed up and give up, and as a result, there is a problem that keeps them away from programming. In fact, when learning to program in a limited amount of time, many problems can occur, such as images suddenly freezing, the computer not starting up properly, failing to save and having to start all over again, or not being able to play back all the content in the middle of writing the HTML code. I know this to be true, because I have had many experiences that made me want to give up.

In order to avoid these issues, Mr. Teramoto decided to help me in the following ways. 1) Making sure to send him questions when the situation does not improve for more than 20 minutes, or when the language is not clear even after looking it up. 2) Holding a video conference when I am not sure what to do next, or when I have a lot of questions, or when I want advice on how to put my ideas into concrete form, so that I can work together to find a solution. Mr. Teramoto created this support system, which made it possible for my team to proceed with this research.

2）Purpose of This Research

The purpose of this research is to develop a real-time analysis program for water polo matches that can be used in real life, and record the process of how I, a programming amateur achieved it

In addition, the video of the results of the behavior analysis using the UMATRACKER software, which was actually performed in the course of this research, could not be saved as a file, so it was saved on USB along with the video recording and other videos that could be saved. For details, please refer to the USB file submitted with this paper. As for the website I created, I have only included a part of the screen in this paper, so please check the URL for the website itself

II. Outline of this Study

1. Purpose of the Study

The first attempt to introduce real-time analysis in water polo was made by Frank Paterson in 1986, but its usefulness at the time was overlooked (Takagi et al. 1986). In Japan, Takagi tried real-time processing in the same year, but it was not enough to make practical use of it. Since then, the development of computer laptops has increased the processing power, and in 1989, Takagi and his colleagues again reviewed the analysis items and used them in actual games, and their effectiveness was recognized (Takagi etc. 1989). Since then, however, a search of the National Diet Library's NDL search for papers on real-time analysis of water polo has turned up no new papers.

In the case of basketball, soccer, and rugby, several papers can be found. According to the available papers, in rugby, it is common to "capture game footage, delineate and mark plays" as performance analysis (Miyao et al. 2001). In addition, game analysis in other ball games is practiced to quantify the various events that occur in a game, and to use this information for training, technical practice, and strategizing (Okuda et al. 2005). The effectiveness of this method has been studied.

Currently, the Toho Junior High School Swimming (water polo) Club Team records video of each official match and plays it back immediately after each match, and the OB and managers watch the video to point out any problems and give advice on how to improve for the next match. For practice games, when we are able to video record the game, we play the video back at the meeting on the next practice day and share issues and improvements with other members.

The current method is still effective. The problem, however, is that when I have a number of matches, I can remember when someone points out something I need to work on or something I need to improve on, but as time goes by, my memory becomes hazy. Also, when I play a game, I try to imitate the good points of the strong players on the opposing team, but I have trouble remembering all the details or keeping track of them.
I thought it would be desirable to make more use of the useful suggestions from the members, OB and managers and the issues that are shared among the team members on a daily basis, to be able to notice the good points of our own fighting style that we are not fully aware of, and to have data that allows us to study our opponents.

2. The Main Objective of the Study:

(1) While playing back the recorded video during or immediately after each match, data can be entered for each player's key movements (shooting tendencies, number of assists, missed passes, counters*, etc.) and total distance swum.

(2) The data in (1) above can be viewed by the players and officials after the game, and the data can be compared with the actual game when playing back the video.

(3)All official games are recorded, and after the game, you can play back the video of the opposing team and analyze the data of each of their players, which can be used to plan strategies for the next game.

(4) In practice games, if it is difficult to input information at the same time, make sure to record the video and input each player's movements while playing back the video during the meeting, so that each player can use it as objective material to notice their own tendencies and areas for improvement.

(5) The program will be able to input data that shows not only the movements and shooting tendencies of each player, but also the overall composition of the game, and as data from each game is accumulated, analysis of game tendencies can be conducted to understand game performance trends as a team.

(6) The game structure of opposing teams can also be studied more objectively by accumulating data.

(7) The program will be improved as needed to meet the needs of the team and will be available for use.

(8) Make it available to Toho Water Polo Team Club members and related parties.

*Water polo is a 7-on-7 game of offense and defense, with the goal being to score a goal. 4 to 8 minutes is one period for junior high school students (the official time is 8miniute) , and the game may be played in two or four periods. In some cases, junior high school students play only one period in the preliminary round. Counter-attacking is when you attack faster than your opponent to gain a numerical advantage over the opposing team.

3． Preliminary Research Study

The following steps were taken to find out what kind of research has been done so far.

(1) Investigate existing real-time analysis programs.

(2) Survey existing research papers on real-time analysis.

(3) Summary of 1) and 2) and discussion of what was learned

4． Basic Procedures for Program Development

In parallel with the preliminary research, the acquisition of basic programming skills necessary for actual program development was promoted in the following order.

1)Procedures for acquiring basic skills

(1) Learning basic programming skills: Learn HTML with “Dot install”

(2) Research on analysis software for swimming distance measurement

(3) Learning and skill mastery

(4) Learning about task progress management software such as Trello

(5) Creating output images for program software

(6) Creating an image of the input screen

(7) Create an image of the output screen.

(8) Create GITHUB repositories

(9) Create HTML with VSCodeSetup

(10) Apropos to GITHUB

(11) Creating CSS and components (to improve the look and feel of the site)

(12) Learn JavaScript at “Dot install”

5． Real-time Game Analysis Program Research and Development Procedures

1)Real-time game analysis Web site research and development procedures

<Review of data items>

(1) Review of data items required for players

(2) Review of data item content required by the entire team

(3) Extraction of data items for real-time analysis from (1) and (2)

(4) Journaling of what can and cannot be automated data quantification and analysis processes

(5) Examining the output image of a real-time analysis program

(6) Create images of each screen for real-time analysis

2)Actual website development

(1) Create a real-time game analysis login screen in HTML

(2) Creating a real-time game analysis input screen in HTML

(3) Create a real-time game output screen in HTML

(4) Using JavaScript, make it possible to perform calculations, and display the results of the calculations on the output screen when they are entered on the input screen.

3） Real-time game behavior analysis Web site research and development procedures

<Trial run analysis with UMATracker>

(1) Killifish Image Download

(2) Trajectory analysis trial of killifish

(3) Trajectory analysis graphing trial of killifish

(4) Challenges in the analysis of killifish

４）Trial analysis for total swim distance analysis

(1) Game recording for analysis

(2) Video editing for analysis prototypes

(3) Picture drag and drop to UMATRACKER

(4) Analysis by UMATRACKER

(5) Graphing of analysis results

(6) Extraction of issues in (5)

（７）Investigating ways to integrate real-time analysis with websites

III. Preliminary Research Findings

1． Preliminary Research

As I did last year, I borrowed my parent's number and password to search for existing papers on real-time analysis on the NDL search system of the National Diet Library, which allows me to search from my home computer, printed out those that could be found on the Internet, and made arrangements to order those that had to be ordered.

Since none of the papers on real-time analysis of water polo were published after 2000, the recent status of real-time analysis in other ball sports was also investigated and used as a reference for this research and development.

The following is a summary of the water polo-specific papers, what I was able to learn from their research, and the challenges I face in developing my own program.

1) ” *Game Analysis of Water Polo: Game Structure and Winning Factors from the Attacking Point of View* ”(Sakata, Takahashi, Takagi, Tsubakimoto, Matsui, Tatenami, Mehto University Physical Education Research 1987)

<The purpose of this paper's research>

Conventional game analysis of water polo is from the perspective of swimming, swimming distance, and movement trajectory during the game. Most of them were related to passing, shooting, outside water shots, and the flow of the game. On the other hand, in basketball, handball, etc., no analysis on "game composition" has been conducted. Therefore, this study takes a look at the water polo game from an offensive perspective and clarifies what kind of offensive phases the game consists of and how these offensive phases are related to winning and losing.

＜Research Outline＞

Water Polo Phrases: Breaking down the entire game of water polo, not just the shooting. Analyzed the relationship between the 15 items broken down into the following categories and their relationship to wins and losses in the games in question:

(1) Center ball (CB)
(2) Neutral throw (NT)
(3) Goalie save (GS)
(4) Defensive save (DS)
(5) Goal throw (GT)
(6) defensive rebound ball (DF, RB)
(7) offensive ordinary foul (OF)
(8) offensive major foul (OF)
(9) pass cut (PC)
(10) Ball Cut (BC)
(11) Offense Out of Bounds (OB)
(12) Corner Throws (CT)
(13) Defensive Major Fouls Discharged (E)
(14) Penalty Throws (PT)
(15) Game Resumption (H)

<What I learned from this paper>

It is difficult to grasp the entire composition of a game if the analysis is only focused on shooting or passing analysis. It is an advantage to have a record of all the plays in a game, but

manually inputting each play while watching the game is a waste of time and effort. Also, there is no analysis of the entire game.

2) ” A Study on Game Analysis of Water Polo Games Using Real-Time Processing”
(Takagi, Takahashi, Sakata University Science Bulletin 1989)
<The purpose of this paper's research.>

It can be very effective if coaches and players can get the information they need immediately during the game, analyze it quickly, and respond to it. For this reason, many sports use scorebooks to analyze the battle situation. However, the data in the scorebook is only raw data, such as the number of shots, the players who shot, and the success or failure of scoring, so it cannot be used immediately in games. To date, there have been many methods of video recording and analyzing games. I am also examining the effectiveness of using computers to analyze games in real time.

＜Summary of Research＞
Game Analysis Methods

(1) Data entry: Operators enter data with keyboard on laptop PC based on data from recorders.

(2) Classification items: I analyzed information related to shooting, such as the player who shot, the type of shot, the position of the shot, and whether it was a success or failure.

(3) Data processing method: Input data was processed by a program developed for this analysis.

(4) Data output method: The text display shows the type of shot taken by each player, the coordinates of the shooting position, the success or failure of scoring, the attacking pattern, the shooting percentage, and the cause of shooting failure. In the graphic display, the coordinates of the shooting position of each player and team are shown on the monitor screen.

From the above, the following analysis results are reported;

(1) Number of shots, shot success rate
(2) Shooting position and shot success rate
(3) Type of shoot
(4) Attacking patterns and causes of missed shots

In addition, he also wrote about the study of real-time processing methods.

(1) By comparing the data with the score sheet, I was able to obtain information on the above four items that could not be obtained with the score sheet. Visualization of information and accurate statistical processing, such as graphing the data, are possible only with the real-time processing method.

(2) Consideration of data processing speed.
As a result of analyzing the actual game, it was demonstrated that the processing method used in this study can be used for immediate analysis of the progress of the game.

(3) Consideration of analysis item selection.
I was able to fully grasp the actual situation during the game regarding the information about shooting, which was the information we wanted most.

However, there were some shots, attack patterns, and shooting positions that could not be analyzed in this analysis. For these problems, it is necessary to determine more appropriate categories in the future.

In addition, if you have valid information such as identifying the player who assisted you, you can determine key players.

As for improvements to invest in, the practicality of the real-time processing method was recognized, but problems remain, such as how to read the shooting position coordinates and reviewing the categories of options in the analysis items. In addition, since this analysis was based on shooting, there is a need to analyze assisted players and jar fouls in the future.

<What I learned from this paper.>

The real-time processing method was found to provide analysis data on new categories such as the location and type of shots, in addition to the conventional data such as the number of shots.

Also, by visualizing the data, such as graphing it, an easy-to-understand sharing method can be applied.

By understanding the weaknesses of the opposing team during the actual game, rather than analyzing them afterwards via the video recording, you can find any number of possibilities to turn the score around.

3) "Analysis of a Water Polo Game: On Swimming Distance, Moving Trajectory and Swimming Velocity" (Tsubakimoto, Takagi, Sakata and Takahashi, Journal of the College of Liberal Arts, Ibaraki University 1987)

<The purpose of this paper's research.>

Not many studies have been reported on the analysis of the game of water polo. (As of 1987). The DLT (Direct Line Transformation) method using VTR provides information on speed and distance, such as swimming speed, movement trajectory, and swimming distance. In this study, they used this method to analyze the game of water polo.

<Summary of Research>

Two VTRs were set up, and the coordinate axes on the monitor screen were read by the VTR motion analyzer every second, and the obtained coordinate values were input to a PC to calculate the secondary coordinate axes on the real plane by the DLT method. The swimming distance, travel distance, and swimming speed were calculated based on these data.

(1) Swimming distance: The average swimming distance of the players in the surveyed match (University Championship semifinal between Nihon University and Tsukuba University) was 1,907 meters, or 476 meters per period. For the forward type, the swimming distance

increased from the first period to the second period. It decreased in the third and fourth periods. For the Backs type, the swimming distance increased from the first to the second and third periods. It decreased in the fourth period.

(2) Tracking the movement of each member; The half backs are often seen moving in front of their own goal. More participation in the attack by the backs is required, so it is necessary for the backs to work on improving their swimming and shooting skills.

(3) Swimming speed: The overall swimming speed of the game is 0.72m/S, with a maximum of 2.4m/S. Since such instantaneous speed is required, instantaneous stirrups and hand strokes are necessary, and it is suggested to incorporate treading practice and front crawl practice.

*It is not called a half-type at present.

<What I learned from this paper.>

As the swimming distance, trajectory, and speed are represented by numbers and visually appealing graphs, it is possible to understand the tendency of each position in the game and to think about what kind of practice is required by the data. It can reinforce the strengths and weaknesses of each athlete.

2. Survey Results on Existing Real-Time Analytics Programs and Apps.

Based on Mr. Teramoto's advice that it is important to apply already existing applications and programs, we first researched existing applications related to water polo game analysis. A search of “Water Polo (in Japanese)”, produced zero results.

Next, we search for “Water Polo” in English which yielded a search result of a few games. Additionally, I was able to find several apps in English and other languages. However, since most of them were developed for coaches, many of them specialized in game scheduling and goal analysis, and many of them were not free. The only one I found was "Water Polo Statistics," which seemed to be close to what I wanted to develop, so I asked my parents' permission and downloaded it for a fee. However, when I went to check out the contents, I found that I could not actually use it unless I sent my personal information by e-mail, and the billing system was difficult to understand, so I gave up on using it as a reference.

I also researched other programs available on the Internet, and found SPORTSEASY, an overseas game analysis program, to be helpful, so I tried to join for free. However, the scope of the free program was limited to the management of game schedules, and in order to actually use it, all members of the club had to be invited.

At least at this stage, there are no existing applications or programs that can be used in Japan or in Japanese, and there are some foreign ones that could be used, but none that players can use.

IV. Learn basic programming

The basics of programming were learned through the use of several programs and tools. The following are some of the typical ones used in learning the basics for this research and development.

1)What is Dot Install?

Summary: Dot install is a video site that allows beginners to learn programming in an easy-to-understand way by actually trying it out. 3-minute videos are easy to watch, and even if you start from zero, you can make considerable progress. Each video is 3 minutes long and easy to watch. There are about 20 3-minute videos per programming language, and when you watch one video, the achievement rate is displayed on the screen. For reference, some of the content titles included in the Introduction to HTML are shown in the following videos below.

2)Introduction to HTML

(1) What is HTML?
(2)Get the tools you need.
(3)Understand tags and attributes.
(4)My first time with HTML
(5)Let's try to use meta and link tags.
(6)Let's use the style tag.
(7)Let's try to use id, class, and style attributes.
(8)Let's understand sections
(9)Try to be aware of the outline.
(10) Use h1-h6 tags to create headings.
(11)Use p, hr, pre, blockquote, div
(12)Let's make a list with ol,ul,li,di,dt,dd.
(13)Let's try using strong, span, and br.
(14)Let's set up links with a tags.
(15)Use the img (image display) tag to display the image.
(16)Let's create a table with table tag.
(17)Let's create a form with the from tag.
(18)Let's create input components with input tags.
(19)Let's try to create a Textarea, buttun tag.
(20)Let's try using checkbox, radio, and label.
(21)Create a select box with the Select tag.
(22) Let's use the attributes available in HTML5.
(23) Let's try using character references.
(24) Understand the content model.

There are 315 sections in total, Each section has more than 20 points to be cleared as shown above, and the system is designed so that you can create your own HTML by clearing them one by one. Currently, 100,000 people are learning programming on this video site. I also learned JavaScript through dot install.

＊HTML stands for Hyper Text Markup Language, which is one of the most basic markup languages used to create web pages. Most of the web pages that you usually see in your browser are made with HTML.

3)What is ATOM?

Summary: ATOM is an application for creating web sites and websites by programming. You can create HTML by watching the DOTINSGTALL video described above, and proceeding through the ATOM screens. It is a fairly easy to use text editor,

and is said to be a good choice for beginners starting out. However, it stopped functioning properly on my computer, so in the end, I used VS Code Setup. It has the same functions as Atom.

4)What is JavaScript?

Summary: JavaScript is used to calculate numbers and create graphs, which cannot be created with HTML alone. It can also be used to create passwords, and is essential for creating websites.

5)What is a Bootstrap ?

Summary: Bootstrap is a whole site that displays the CSS and Components that are needed to write HTML. It shows a lot of tags that can be effectively used in the site.

6)What is CSS and Components?

Summary: This site contains about 100 designs that can be used as a reference for the look and design of sites created with HTML.

7)What is GITHUB?

Summary: GitHub is a source code management service for software development projects, and is an indispensable service for developers, with functions such as viewing s-code, easy bug management, and social media features. A repository is a place to store files and directories, and by organizing the directories under the repository, you can manage your data easily and clearly.

8)What is UMA TRACKER ?

Summary: UMA TRACKER is a framework developed by Mr. Takeuchi and others at Tokyo Institute of Technology to track individual animals. The UMA tracker-filter Generator, Uma tracker-tracker, Uma tracker-tracking, Uma tracker-area51, and Uma tracker-filter Generator can be used to extract data such as the trajectory of the animal's movements, where it has been and for how long. The following is a brief description of the analysis process.　The screen diagrams are taken from the Uma Tracker Quick Start Guide, so the numbers (1), (2), etc. on the diagrams represent the chronological order of the process.

<The process of image processing in UMA TRACKER>

Phase 1: Processing with Uma tracker-filter Generator.

This is a software program that blackens the background and whitens only the object to be analyzed, to make it more visible. This is done manually.

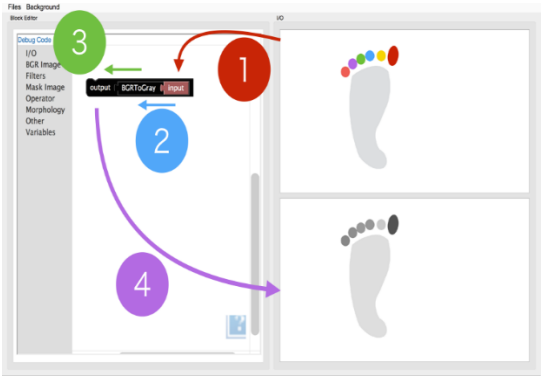


Fig.1:　The first process of UMA tracker

As shown in the figure 1, in order to isolate the image of the toes, we use input and output tags as a base and also use BGR to GRAY tag and the Circular selection tag to extract the image of the toes and change the color to black. The tags are selected by hand. Below is a demonstration of this using a video of an ant to replace the footprint image.

Fig.2: The other first process of UMA Tracker

Finally, the analysis preparation is complete when the following processing is complete.

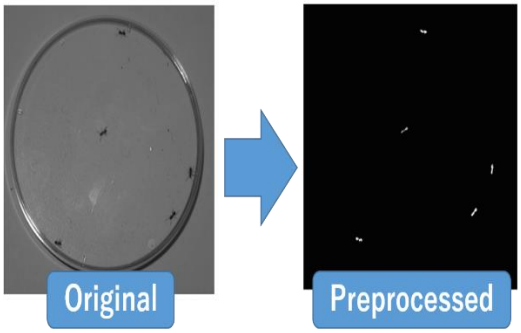


Fig.3: The last step of the first process of UMA tracker

Phase 2: Processing in UMATracker-Tracker:

Drag and drop the items created in the first step into this software, and you can number the items to be tracked

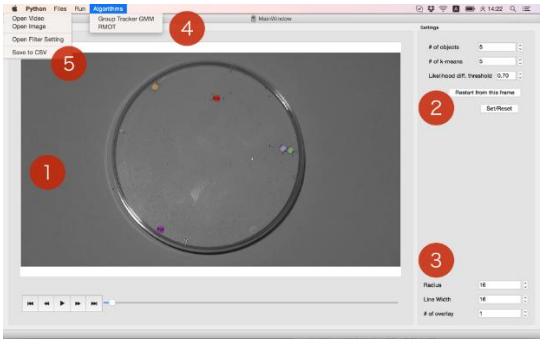


Fig.4: The second process of UMA tracker

Phase 3: Processing with UMA Tracker-Tracking Corrector

The tracking errors from the first and second phases will be corrected here. The correction is done manually. This is the most labor-intensive part of the process, and not having the necessary tools for this has been an issue in the past.

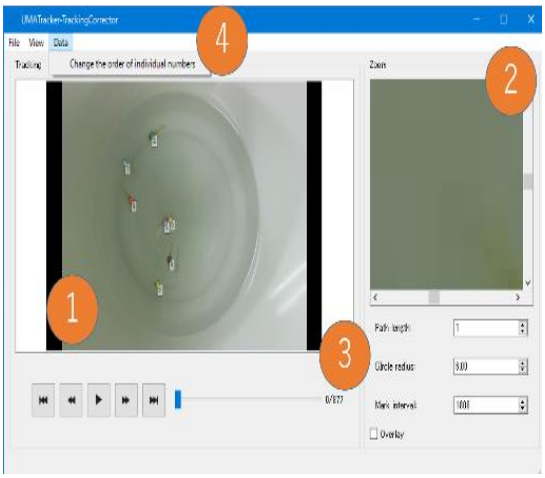


Fig.5: The third phase of UMA tracker

Phase 4: Processing in UMA TRACKER AREA 51

Drag and drop the analysis result image that has been corrected in the third step into this software, and click the RUN button on the upper left to display the analysis result in a graph.

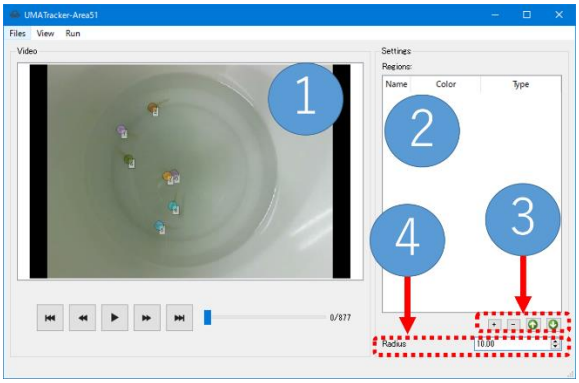


Fig.6 The fourth process of UMA tracker

V. Real-time analysis program development procedure

Most of the data analysis that I think the water polo club members would need can be processed through Excel. Mr. Teramoto gave me some advice on how to use Excel to compile data, and I listed as many inconvenient parts of Excel as I could find, and was told that the most inconvenient parts were the ones that needed to be developed for programming. After having done that, I tried data entry and graphing of actual games. My parents taught me the basic Excel data entry and graphing.

In addition, it would be better if the necessary steps for analysis could be separated into those that remain as manual work and those that can be automated. At the same time, we solidified the output image of the ideal program.

1. Analysis using Excel

At the end of July 2017, we were able to win the second place in the Chiba Junior Championship, the first match between Toho and Chiba Water Polo Club.

1) Excel data entry trial

I created a sheet for each player's number, with columns for the type of shot and their result (hit or miss). The data was entered while watching videos of actual matches.

Table1: Toho side play of Toho vs Chiba water polo

2		結果	
	場所	成功	失敗
	ミドル	0	1
	フローティング	0	2
	レフト	0	1
	ライト	0	0
	退水	0	0
	5ぺ	0	0
	カウンター	0	0
	カットイン	0	0
	アシスト	0	0

2) Graphing trial

I finished entering the data in Excel 1 for each player numbers (by sheet), and converted it to a graph.

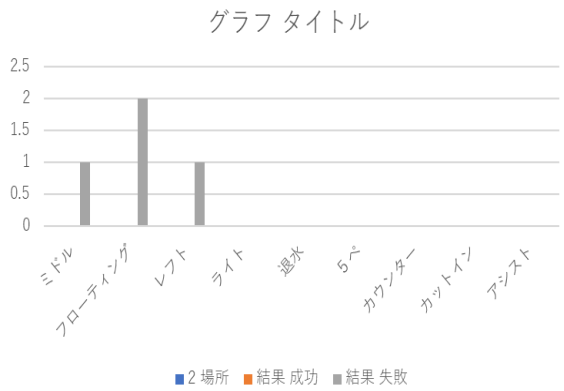


Fig.8: Toho side attacking style of Toho vs Chiba water polo

3)List of limitations using Excel input

(1) The game analyzed this time was a shortened version of the Chiba Junior Championship, a

four-minute, one-period game. The Toho water polo team lost the first game, a game in which they could only score one goal. We had to follow every movement of each player with our eyes, which took an enormous amount of time to enter the data.

(2) Graphing requires to many enter data, specifying the data range, selecting a graph from the tabs, and creating it.

(3) When watching a video and inputting on a PC, it was difficult to input data in real time while the video was playing on the spot, so I had to stop the video and input each time, which took about 30 minutes in total.

(4) The fact that the numbers have to be entered for each sheet is troublesome. When there is no movement linked to an input item (e.g., shooting, retreating, etc.), I have to enter 0 in every table.

(5) In the case of inputting data in Excel, it would take twice as long to input data for the other team. Also, if you consider that a typical game lasts two periods of seven minutes, not only will it take you more than two hours to enter your team's data, but it will also take you half a day to enter and graph the other team's data.

(6) Four hours of data processing for a four-minute match is unrealistic.

(7) By the time the data is complete, it is too far in the past to be meaningful.

(8) Unrealistic because it requires a dedicated person to process the data, and it is quite difficult to create a graph that includes all the data you want.

(9) You have to choose every time which graph is better depending on your data.

(10) The title of the data will not be entered.

(11) You have to enter all the basic information, such as the schedule of each match and the opponent, from scratch every time.

(12) There is a huge amount of data to be graphed, and it is not automatically saved, so the overall data of an individual cannot be automatically calculated.

(13) The comprehensive data for individuals cannot be calculated automatically.

(14) You have to save it manually every time.

(15) The total distance swum must be measured manually with a stopwatch while the video is played back, and then entered manually.

(16) Need a dedicated person for analysis

(17) Bringing a PC to the poolside is not practical.

4)In Order to Make the Program Practical;

I thought that we should eliminate as much manual input and manual work as possible in all the processes required for analysis, and that the program should be easy to operate by anyone, including players, coaches, and officials, using iPads, which are easy to carry around, instead of inputting data on a PC.

For the analysis of the swimming distance of each athlete, the existing real-time analysis program for water polo seemed to automatically process the data from high-quality video cameras shot from two locations. However, since it was not practical to set up a large-scale facility, we needed to find a software program that could analyze the movement.

This is where Mr. Teramoto's advice came in and, we decided to research the possibility of using the UMATRACKER, a software program developed to analyze the movement of ants.

2. About output images

1) Processes Required for Automation

First, as shown in Table 2, we identified the necessary tasks and procedures for game analysis, and examined whether each task was manual or could be automated.

Table 2: Differentiate between tasks and work.

task	work
Data entry required for the analysis	can be automated
record the game	manual
Watching the video to record the data	can be automated
Input the wanted data while watching the video	can be automated
Save the data	can be automated
Calculation and data treatment	can be automated
make a graph	can be automated
displaying outputs	can be automated
result distribution	manual or automatic

2) Creating a Screen Image

From the results of the preliminary research survey, I found out that shot analysis is indeed important, but the data we had at the time was not enough to understand the overall structure of the game, so I took the time and decided what to research from there on. In addition, I created an image of the input and output screens in PowerPoint, referring to the content of iPad real-time analysis using from "Making Data Your Weapon", a book by a data analyst for Japan's national volleyball team, (Watanabe 2013).

3) Required data entry

When thinking about the output image, it became clear to me that in addition to the structure of the game, such as shots and assists, I also need basic information about the opposing team, as shown below.

As for the rules of water polo, I wrote about them in detail in last summer's research paper, "An Attempt to Analyze the Game of Water polo " , so I won't go into the details here.

a. Opponent Team Name
b. Schedule of matches
c. Data on how your team plays the game.
-Shoot Positioning*: From which position on the field did the player shoot?
-Was it successful or unsuccessful?
- How many assists?
-The number of interceptions or deflected passes
-How many counterattacks have been made?
-Number of fouls
-Number of outside water shots
-Number of saves made by goalkeeper
-Number of times a center ball was taken

d. How the other team plays the game (identical to the data entered for your own team on step c).

e.Data on the distance swum by each swimmer in a period

f.. Combining data from (c) and (e) in order to understand the game structure

g. Combining data from (d) and (e)to understand the game structure of the opposing team.

*What is shot positioning?

This is the Latko-Rudici classification method used by Takahashi et al. (1989) to analyze shoot positions in game analysis.

	5	4	3	2	1
A					
B					
C					
D					
E					
F					

Fig. 9: shot positioning

This is a vertical classification as shown below, with lines drawn parallel to the goal line at 2meters, 4meters, 7meters, 11meters, and 15meters, and divided into six sections from the top, A, B, C, D, E, and F, where F refers to all fields after the half line. In the horizontal direction, two lines are drawn from the goal posts to the sideline and the midpoint of the sideline, and the classification is divided into five sections from the right: 1, 2, 3, 4, and 5. "In the horizontal direction, two lines are drawn from the goal post to the sideline and the midpoint of the sideline. (Sonoda 2016)

4) Output image of input and output screens

First, we created a screen of the output image, and then we created a possible input screen. (The data used to create the screen image was used as an example and irrelevant to the research.)

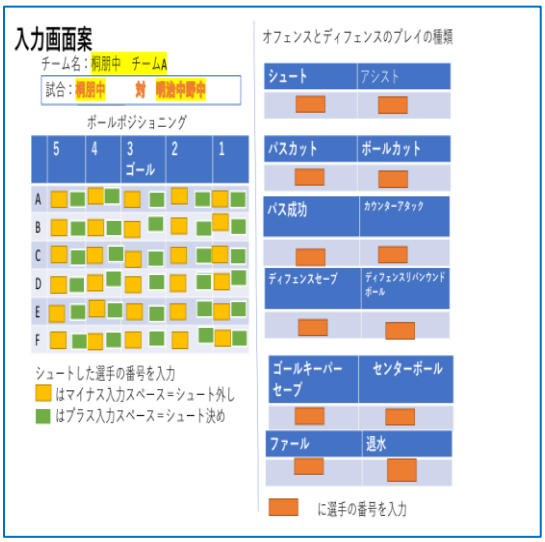


Fig. 9:　Input screen image

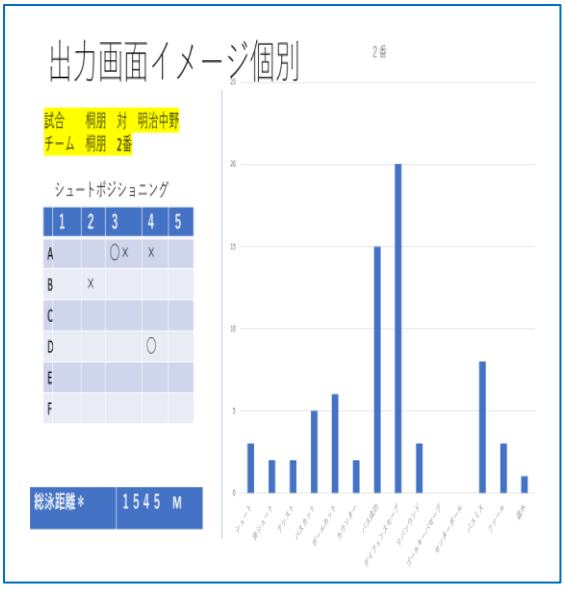


Fig.10:　Output screen image by player

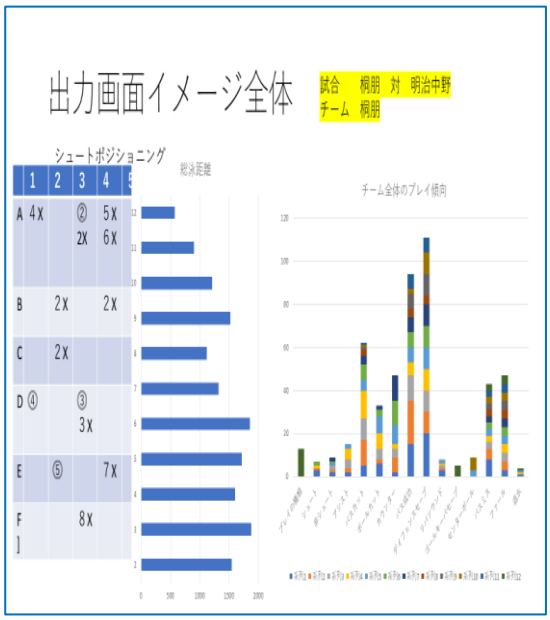


Fig. 11:　All output screen images

Once I had a solid idea of the overall image and what kind of work would be required, Mr. Teramoto advised us on the steps to take to create the actual website, and we began to create the source code in HTML.

3.Real-time game analysis Web site development

1) Create a Real-Time Game Analysis Login Screen in HTML

In creating the screen, I was careful to make sure that only members of the water polo team, coaches, advisors, and other related people could view the screen, and that they could not enter the site without entering a password that was set in advance. Also, if the URL was leaked, the site would

forcibly redirect the user to a password entry screen, so that the information would be protected.

In addition, since I did not know how to copy and paste the completed site screen, I decided to take a picture of the screen with my iPhone, send the picture to my PC via e-mail, and paste it as shown below. I've also included some of the source code for each screen for reference.

Fig12: Cover Screen 1

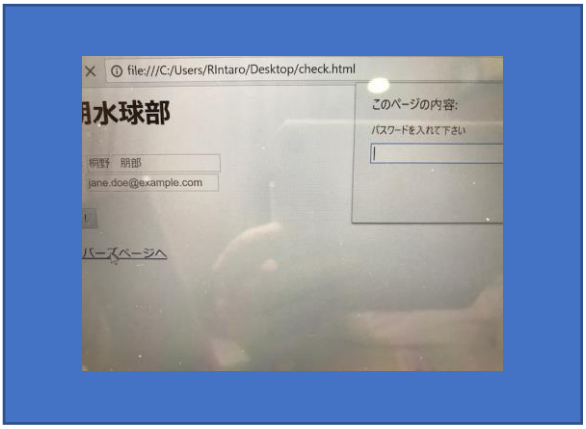


Fig 13: Cover Screen 2

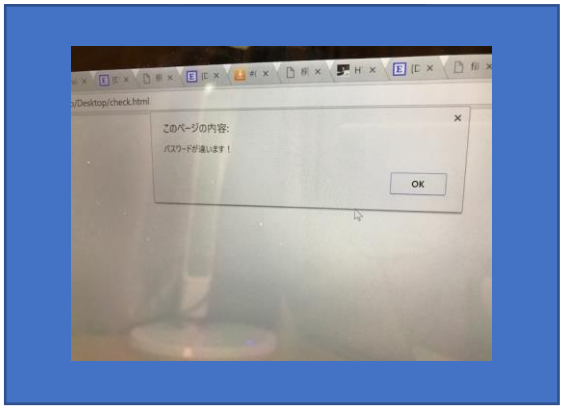


Fig14: Cover Screen 3

Part of the source code for the login cover screen

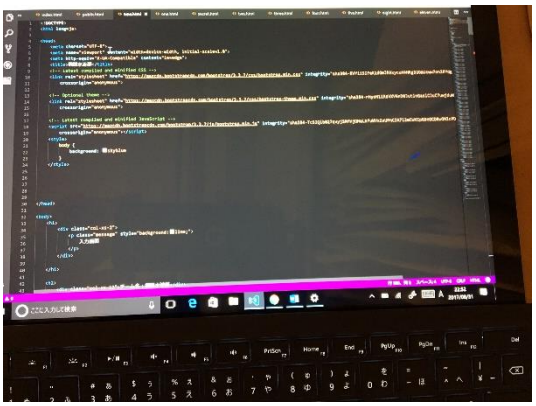


Fig.15: Source code of first cover screen 1

2) Create a Real-Time Game Analysis Input Screen in HTML.

After carefully examining the input image screen that we initially created, we narrowed down the entry for both offense and defense to the following necessary data.

The screen is designed to allow the user to enter the player's head number (similar to the number on the player's back) in the corresponding field.

(1) Shoot positioning: where the shot was taken and whether it was successful

(2) Assist pass: a pass that leads to a shot

(3) Cutting off an opponent's pass.

(4) Counter: to gain a numerical advantage by attacking faster than the opponent.

(5) Hand-up-blocking: To enter the opponent's shooting trajectory and block the opponent's shot.

(6) Successful pass

(7) Missed pass: A failed pass.

(8) Fouls: Minor foul (any number of foul)

(9) Ejection: serious foul (up to 3 times per game)

(10)Floating: Taking the "middle" of the field* and being in a place where it is easy to shoot.

(11　)Cut-in: Getting yourself "inside" the field.

*The "inside" of the field refers to the area surrounded by zeros in the figure shown next.

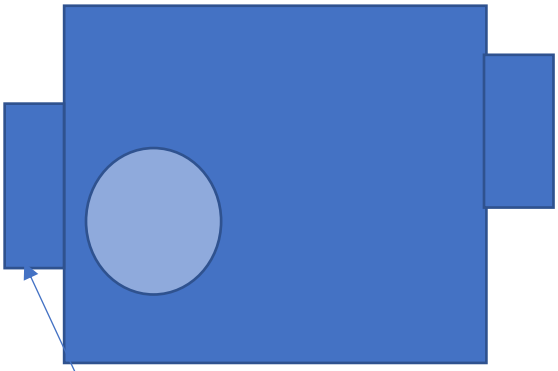


Fig 16: Field of a water polo game

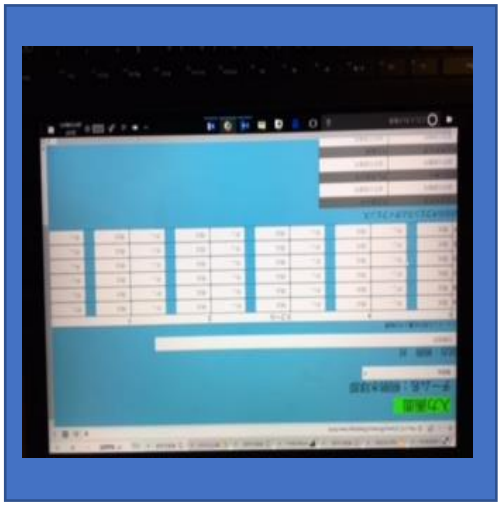


Fig17: Photo shot of Data entry screen

*For details, see page 26 and following

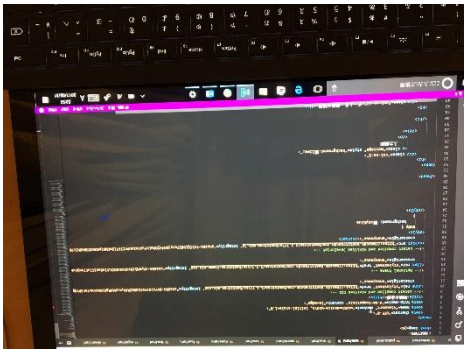


Fig18: Screen shot of Part of the source code for the data entry screen

After the data has been entered, click on the "Go to output screen" button at the bottom left of the screen to jump to the first selection screen. If you want to see the data of player number 1, click on number 1 to see the data of player number 1 only. If you want to see a summary of the playing styles of all the players, click on the ALL button to jump to a screen where the data of all the players is calculated and output.

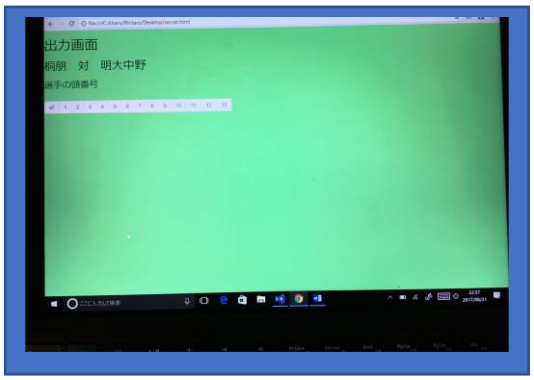


Fig20: First screen of output (selection screen)

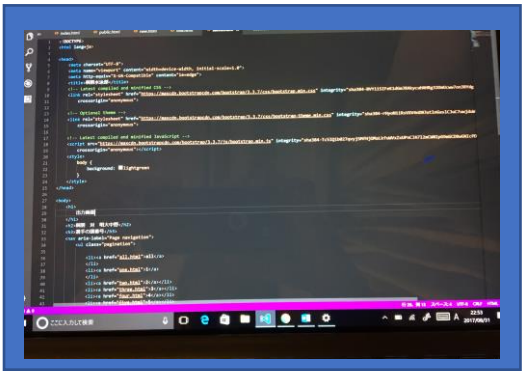


Fig21: A piece of source code for the first screen of output

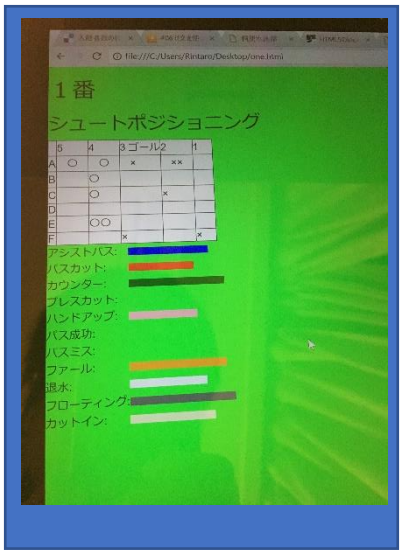


Fig 22: By player (by head number) screen

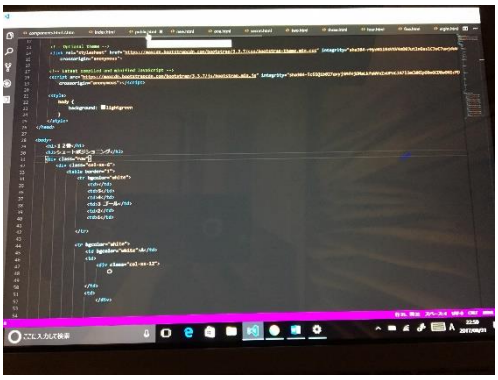


Fig23: Part of the source code for the screen by player

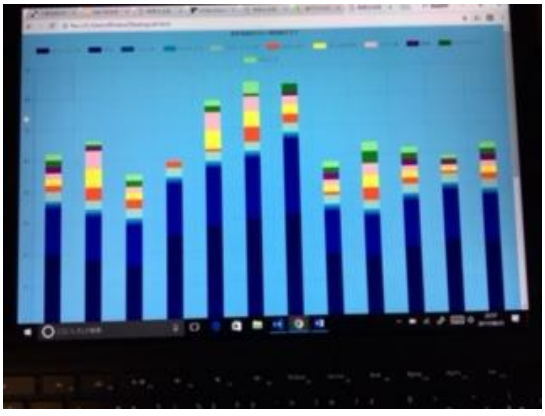


Fig24: Above screenshot of all player's output

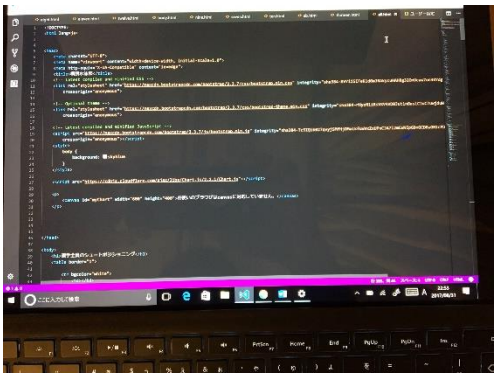


Fig 25: Part of the source code for the ALL screen

The above is a screenshot of the summary output of all the players' performance trends. At this stage, the trend analysis of playing style and the results of shot positioning are not output simultaneously but are displayed separately at the top and bottom. In the future, we plan to revise it so that all the data will be displayed on one screen. The table above and below the screen are as follows. Attached On the next page please find couple of graphs and data.

3)Results of analysis of Toho team's performance trends

The performance trends and playing styles of all the players of Toho team is shown in a graph using JavaScript. Not only the trend of each player, but also the trend of the entire team can be seen at a glance.

Fig26　: Table of shooting positioning for all players.(shown next page)

If the number is surrounded by a circle, it means the shot was successful, and if it is marked with a ●, it means the shot missed. Therefore, if you see ①, it means that the player with the number one uniform shot from that spot and succeeded, and if you see ❶, it means that the player with the number one uniform shot but missed. Note however, that number one is a goal keeper so he would in fact rarely shoot the ball. Please regard this as a theoretical example.

The entire team tended to shoot from any part of the field, and we devised a way to see at a glance where they were succeeding or failing.

Each screen could be printed by clicking the "Print" button on the screen, and will be introduced in the following pages. However, only the individual player page did not print the graphs shown in different colors, probably due to the background setting. Since there are situations where data is printed and shared, we would like to make improvements in the future, such as making it possible to print a single screen as it is.

The URL for this real-time game analysis test website is as follows.

試合：桐朋　対

ゴールした時の位置とその結果

	4		3ゴール		2		1	
A	得点	外し	得点	外し	得点	外し	得点	外し
B	得点	外し	得点	外し	得点	外し	得点	外し
C	得点	外し	得点	外し	得点	外し	得点	外し
D	得点	外し	得点	外し	得点	外し	得点	外し
E	得点	外し	得点	外し	得点	外し	得点	外し
F	得点	外し	得点	外し	得点	外し	得点	外し

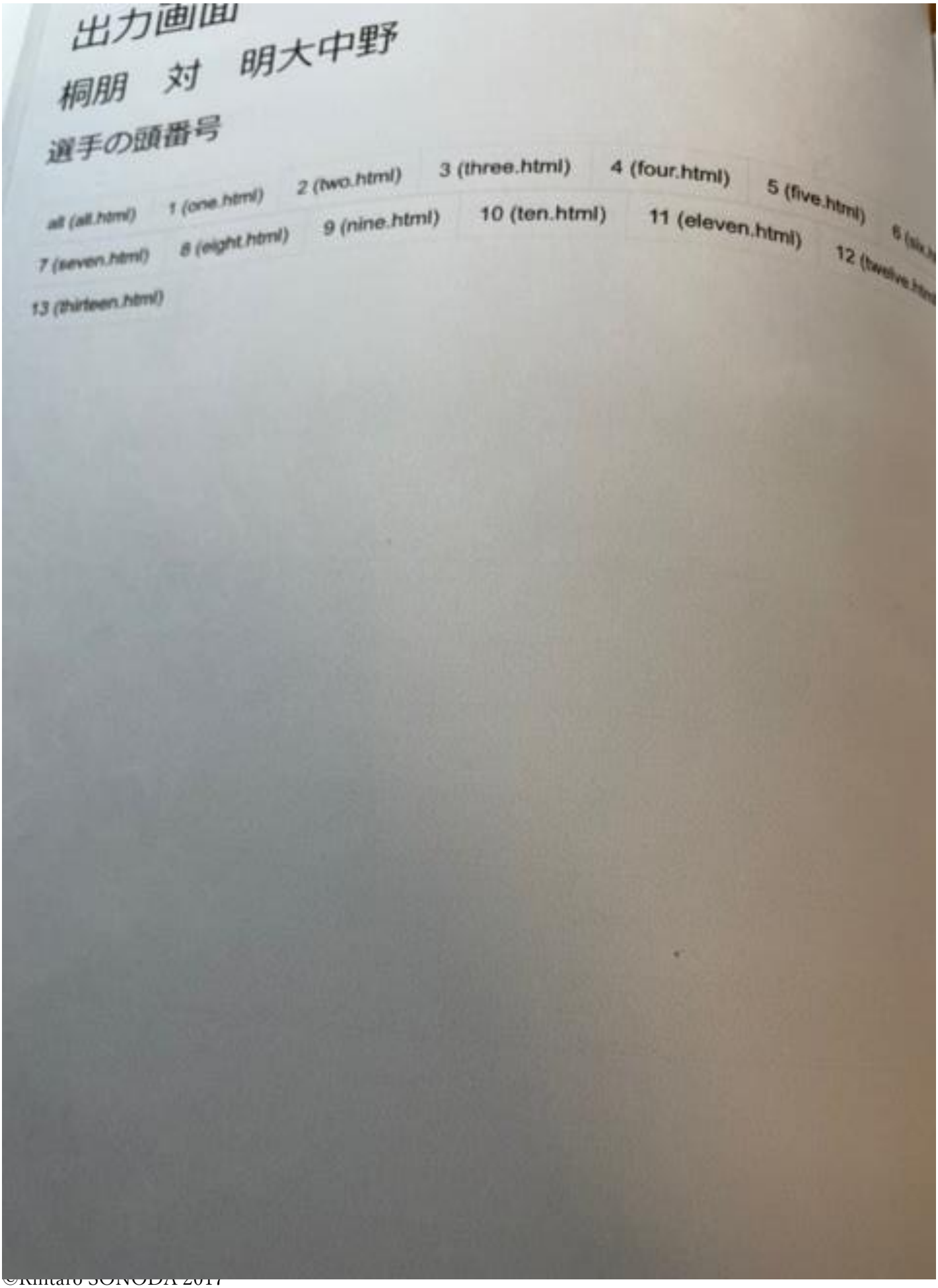
試合のオフェンスとディフェンス

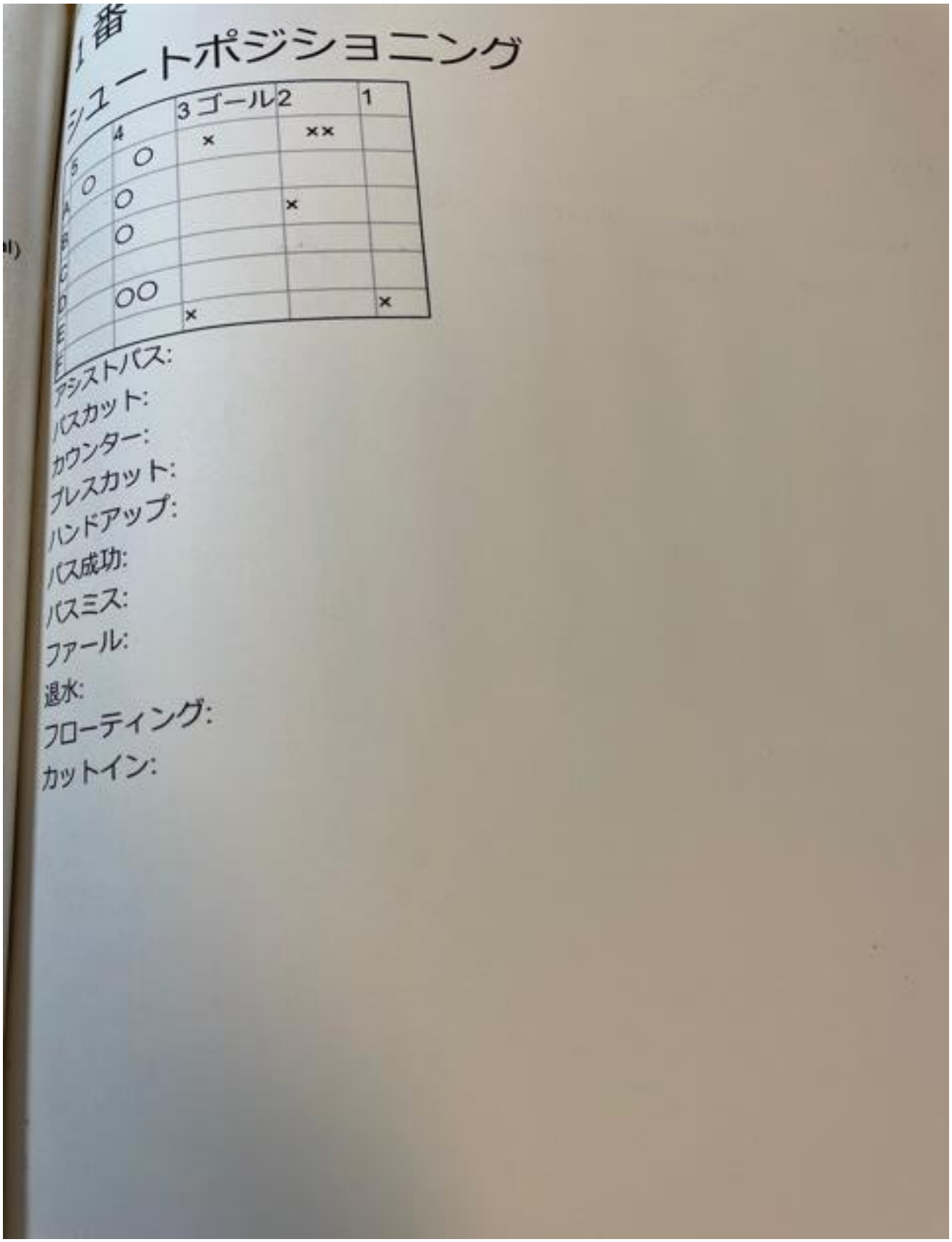
アシストパス	パスカット
選手の頭番号	選手の頭番号
カウンター	プレスカット
選手の頭番号	選手の頭番号
ンドアップ	パス成功
選手の頭番号	選手の頭番号
スミス	ファール
手の頭番号	選手の頭番号
	フローティング
手の頭番号	選手の頭番号
トイン	
の頭番号	

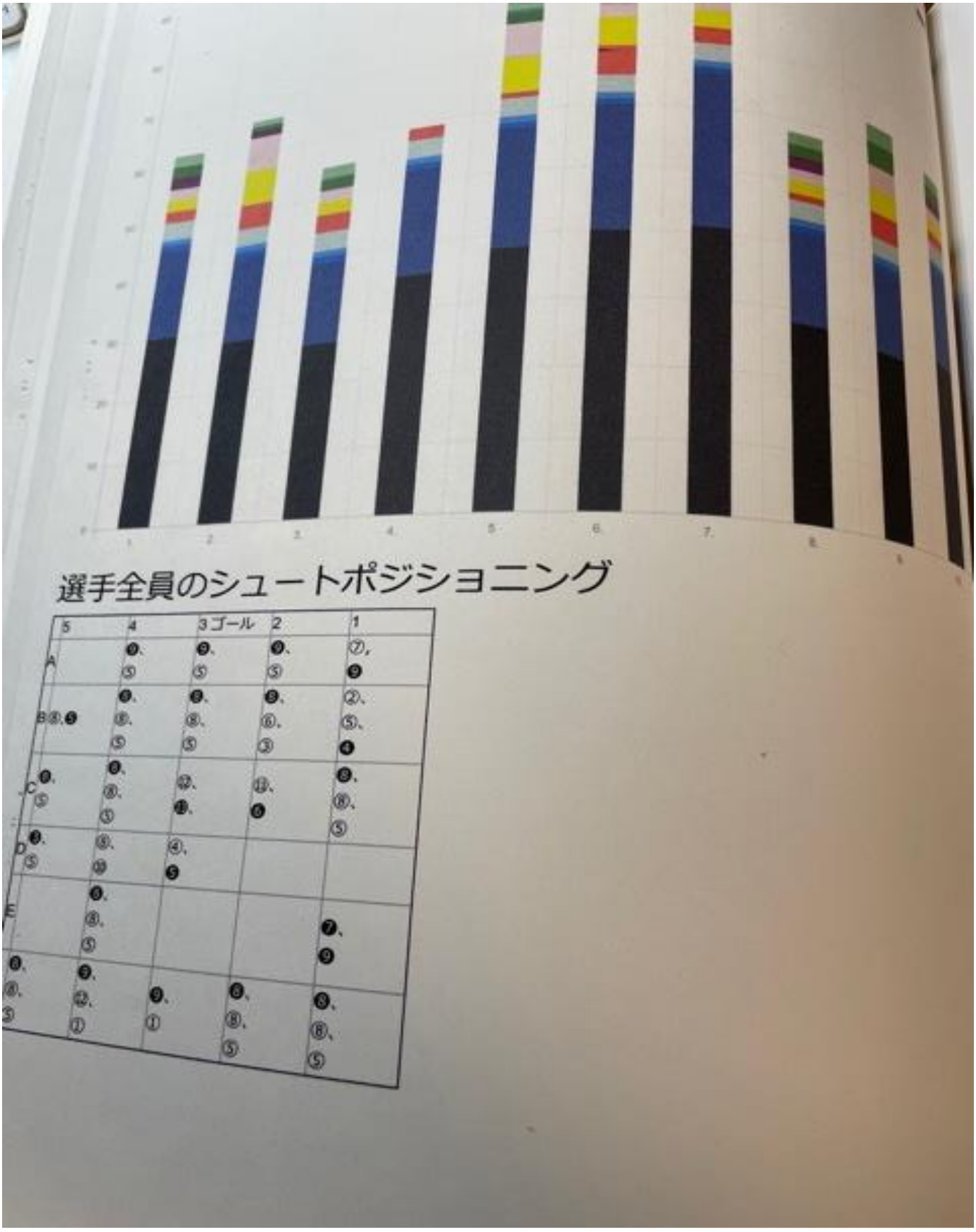
力画面へ (secret.html)

28

ers/Rintaro/Desktop/new.html







VI Results of live video analysis attempt

I have attempted to study whether UMATRACKER can be used to measure the total swimming distance. Before analyzing an actual water polo match, I first needed to familiarize myself with this software.

I managed to do the basic work by following the manual, but for the second step of the transition, I thought that I needed a video suitable for the UMATRACKER to learn the basics of analyzing movements, so I searched the Internet for videos of small animals moving within a certain range, but I could not find any suitable videos.

Therefore, Mr. Teramoto provided me with a video of the killifish from the developer of the software, and I attempted to analyze it using the four software tools of UMATRACKER. The video files of the analysis results cannot be included in this paper, so I have saved them in a separate USB file with the title described in this paper.

After that, I tried to analyze videos of actual water polo matches.

1) Trajectory analysis of killifish

Phase 1.

Processing with Umatracker-filterGenerator

Fig30;　Video for killifish trajectory analysis

I got and downloaded the video of the killifish.

Phase 2

Processing with UMATRACKERTRACKER. Each killifish was given a number on its back.

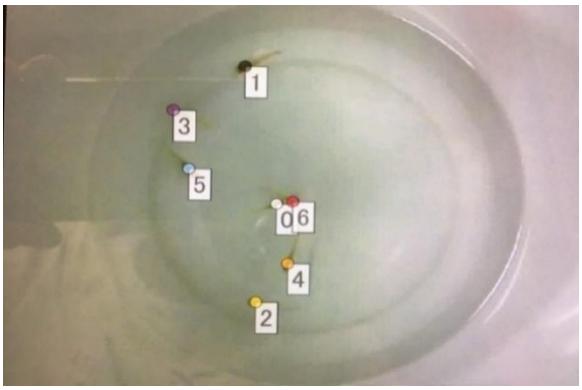


Fig 32: Killifish Orbit 1 Video

(For the actual video, see the USB file.

Phase 3.

Processing with UMA Tracker-Tracking Corrector

Trajectory analysis was performed using UMATRCKER. We also measured which killifish entered the colored area and when. The area can be set by clicking on the area button, and adjusting the area range. Imagining a water polo field, I set the colored area to be analyzed toward the right center and measured the results.

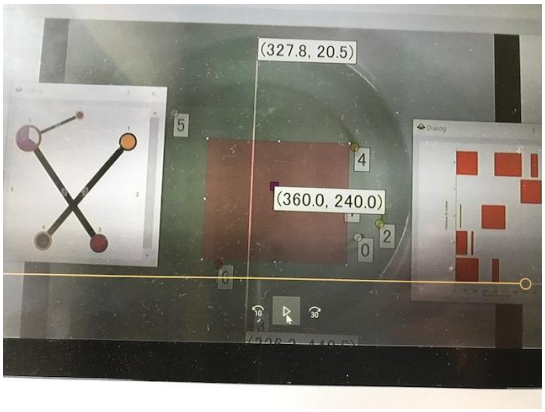


Fig33:　Killifish Orbit 2 Movie
(For the actual video, see the USB file.)

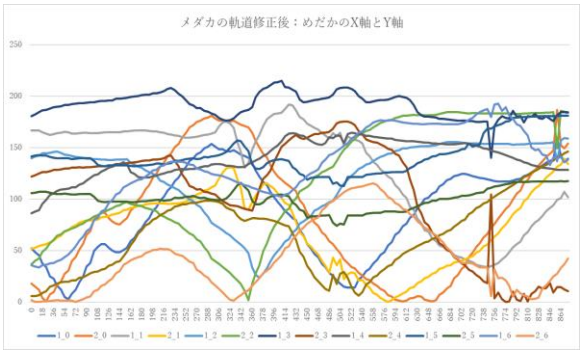
Phase 4.

Data conversion and graphing of the analyzed trajectory of the killifish. This is the data and graphing after the data was modified (see appendix for details)

Table 3: Generate corrected Excel data (1 part)
(Trajectary Coordinate of killfish)

position	1_0	2_0	1_1	2_1	1_2	2_2	1_3	2_3	1_4	2_4	1_5	2_5	1_6	2_6
0	52.43198	18.44199	166.769	52.2044	140.1303	36.99683	180.6863	121.9899	86.69108	5.916981	141.863	106.1399	35.96473	2.213407
6	48.8474	15.10401	166.8817	53.21852	141.5625	40.40962	182.5721	123.6471	88.32955	6.244363	142.4625	106.6872	34.677	0.525253
12	45.77078	12.10656	166.791	54.57489	142.5304	42.72451	184.6413	125.119	89.64914	6.864121	143.1403	107.4743	34.0577	0.537206
18	38.01118	4.535063	165.0639	55.73727	144.9325	49.30635	186.555	126.5906	95.63843	9.029455	142.4973	107.1978	36.06926	0.804877
24	34.25552	0.934908	163.9663	56.41299	144.9247	52.08984	186.7916	126.4456	99.37506	10.86582	142.4973	107.1978	36.41176	1.370582
30	25.40469	7.754051	162.5819	58.37872	145.3978	57.48249	188.2423	127.5916	104.5229	15.35742	141.5056	106.4406	37.80216	1.467326
36	23.06117	10.09166	163.3507	60.03607	146.0573	60.77132	189.7633	128.8229	105.9767	16.61093	140.4096	105.5448	38.19891	1.741837
42	16.23889	16.79391	164.2774	63.17748	146.4341	64.96544	190.1517	128.8985	108.2055	18.29444	139.7719	105.0418	39.86049	2.291553
48	12.80561	20.19973	164.8942	64.91085	145.156	66.06679	190.5522	129.1871	109.5791	19.54895	140.0345	105.289	41.39234	1.680348
54	5.330273	27.86875	165.4773	68.52824	143.5657	69.17082	191.5636	129.8679	110.0761	19.904	140.1804	105.4378	44.05331	1.524188
60	3.074836	30.97654	165.1302	70.07256	143.0641	70.34843	191.6567	129.9609	110.4877	20.13436	139.8039	105.1691	46.66516	1.6985
66	8.203175	39.81348	163.9505	72.95137	141.9571	71.75204	192.7384	130.6616	111.7651	21.46447	139.2518	104.7046	50.1959	1.719744
72	12.05209	43.70412	163.9663	74.74358	141.3643	72.8252	192.9056	130.8373	111.8079	21.4643	139.5002	104.9472	54.25126	0.397569
78	19.74373	51.07505	164.3504	77.39863	140.6556	75.12864	193.6838	131.3393	114.4884	23.74828	139.7838	105.2119	60.0211	1.866138

Table 4 Graphical representation of (1) data.
(Result of Analysis of Trajectary of killfish)



In these graphs (2) and (4), the X-axis and Y-axis represent a single killifish.
(See appendix for details.)

2) An Attempt to Analyze Video of Water Polo Matches

When I went to support the Toho High School students in their Kanto tournament in June, I thought it might be possible to analyze the game since it was held in a venue with tiered spectator seating, so I recorded it. However, since this was a regular tournament and the games lasted 7 minutes per period, it was too difficult to analyze as a first attempt. Therefore, I first downloaded a 30-second video file of a qualifying game for the 2016 Junior Olympics, where part of the game was recorded, as shown below, and analyzed it in the same way as the killifish.

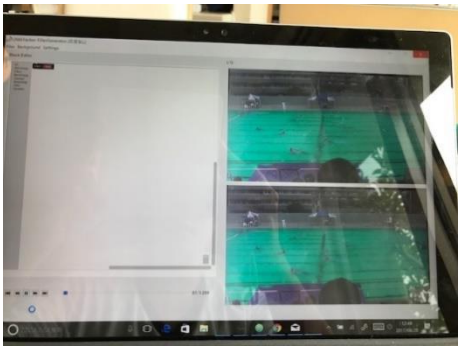


Fig34 : Image of Junior Olympics Qualifier matches in 2016 dragged and dropped into the UMA Tracker analysis software.

However, the image was too unclear to proceed with the analysis. Through Mr. Teramoto, we asked the developer to confirm if the image was ready for analysis. He replied that it was difficult to analyze the image because it was too unclear. Next, we tried a game of high school students, but the level of clarity was the same, so we decided that analysis would be difficult.

In late August, I recorded a practice game at Toho Junior High School in order to try again to record a clear video. However, since the pool at Toho is not designed to record from a fixed point, it was not possible to record the entire side of the pool, and as a result, the video was taken from a vertical angle, so UMATracker could not analyze it.

4. Issues

The challenges in analyzing a water polo match with UMATRACKER are as follows

(1) Fixed-point photography is not possible at some venues.

(2) The issue of video clarity when recording the entire water polo field needs to be resolved.

(3) Since a certain amount of manual work is required before the analysis process each time, it is difficult if this procedure cannot be automated.

If I could analyze the total distance swum by players in a water polo match using UMATracker, we could not only measure the total distance swum, but we could also analyze the tendency of players to attack in front of the goal, which is called the "middle" field in a water polo match, by setting a colored area in the final analysis of killifish.

However, after trying to analyze several videos of actual water polo matches, we found that unless the above issues are resolved, the current UMATracker is likely to be impractical for analyzing water polo matches. We decided to spend one more year to study other methods.

VII. Challenges for the Future

With this research, we were able to complete the basics of the real-time analysis program for water polo, but originally we had planned to complete the program to the point where the numbers, such as the player's style of play or shot positioning could be moved to the output screen with the click of a button. Since it took longer than expected to learn JavaScript, I was left with the time-consuming task of entering a number each time in order to save the values entered in the input screen. In the future, we would like to develop a system that would allow us to enter the schedule of games and accumulate data. In this way, we will be able to study not only our own games, but also the overall trends of each team, each period within the game, and each player, etc. In order to do this, I plan to continue to improve my programming skills and make it even better.

In addition, since we found that it was difficult to apply the existing software to analyze the movements of the athletes, we would like to research a way to create a program that can measure the total swimming distance and swimming trajectory of each athlete for each match without the need for large-scale equipment.

By the end of the summer of my third year of junior high school, I will have continued to work on this research, while improving the program I have made so far. I plan to work toward the practical use of a real-time analysis program for water polo games that can be used on iPad. We plan to continue this research and development for another year, exceeding the framework of my original free research project prompt.

VIII. Conclusion

After learning how to code, I thought that I could create almost any function that I wanted to make something better or more convenient. It was quite a challenge to create a website from scratch. Programming beginners often stumble at the beginning and give up after a while. However, thanks to Mr. Teramoto's advice, I was able to experience the fun of programming. I would like to thank him again.

Last year, my first year junior high school free research paper, "An Attempt to Analyze the Game of Water Polo", was displayed at the free research exhibition in the fall and at the Toho Festival in June. The display of my research paper gave me an opportunity to be seen by many people. In addition, a Toho Junior High School parent who knew the captain of Japan's national water polo team wrote in a questionnaire that the captain of Japan's national team might want to read my paper, and through him, I had the opportunity to have the captain of Japan's national team actually see my research paper. The experience of having my world somehow expanded through my research was almost as gratifying as having my research evaluated.

This year's research was also based on the theme of water polo, but it was necessary for me to learn a new field of programming, which is full of unknowns for me, and I experienced another expansion of my world. Not only did learning programming expand my world, but it also gave me the opportunity to meet Mr. Teramoto and make horizontal connections with other junior high school students who are interested in programming.

One such opportunity was the exchange with junior high school students from other schools participating in the "Mito Project", a program to foster young engineers sponsored by the Ministry of Economy, Trade and Industry (this year's camp was held at Keio University Fujisawa Campus).

Through my research, I have learned once again that pursuing one's interests to the fullest is the same as expanding one's world in various ways. In learning programming, I also learned that it is important to use programming for the benefit of others.

I hope I can make time to continue my research and development for the practical use of this real-time analysis program for water polo matches, and eventually be able to use it to help other people.

References

Enomoto I.: *Suikyu Kyougi ni okeru Game Bunseki 1995 Nen Fukuoka Universiade ni okeru Nihon Shien System nituite*[About a Japanese support-system in the Universiade of Fukuoka of 1995 years of a game analysis in the water polo competition.] Taiiku Kenkyu, 1995

Iwata I. : Ichiban *Yasashii Java Script no kyouhou* [The most easy way to learn Java Script.] impress, 2017

Hashimoto S. et. Al.: *Suikyu Game no Bunnseki* [Water Polo Game analysis]. Ibaraki University, liberal art division bulletin No. 19

Hashizume K. : *Hajimete no Proguraming* [The first time programming] Gakken Co., Ltd., 2017

Hattori Y.: *1 HTML to CSS to Web design ga 1 satude kichinnto minitsuku hon*[You can learn all HTML, CSS and Web design from this one book] Gijyutsu-Hyoronsha, 2017.

Miyao M.et.al: *Sports and Game analysis Conference* [The Sports and Game Analysis]Scientific Vol.51. No. 10, 2001

Nishiyama T.et. al: *Rugby kyougi no kirokuhou sono jyouhou kaisekini kannsuru kisokenkyuu* [About the recording method and its information analysis of the rugby games] Tokai University bulletin college of physical education, 1977

Okuda T. et.al: *Basket Ball ni okeru Game Bunseki kenkyuu no Genjou to Kdai* [game analysis research in the basketball Present Situation and Issues]. 54th volume of IV subdivision of a bulletin of Osaka Kyoiku University, 2005

Sakata I. et. Al.: *Suikyuu Game Bunseki Kougekiken Kara mita Game Kousei to Shouhai* [The victory or defeat with the game competions in the water polo game analysis from perspective of attack rights] Oosaka Taiiku University Research, 1987

Sonoda R.: *Suikyu Kyougi -Water polo-no Game Bunseki not Kokoromi* [Analysis of Japanese me's National Water Polo Team at the Rio de Janeiro Olyhmpics] Kiri no Tomo No. 54, Toho junior high school, 2017

Susa T. et.al: *Personal Computer wo katuyou shita Soccer Game Analysis System.*[Soccer game analysis utilized a personal computer] Industry Economic Research Institute yearbook of No.37, 1977

Takagi H. et. al: *Suikyu Kyougi no Real Time shori ni yoru Game Bunseki no kentou.*[A Game Aanalysis by the Real-time Processing of the Water Polo competition' issues]. Tsukuba University gym science system bulletin, 1989.

Takagi H. et.al.: *Suikyu kyougi no Rial Time shori ni yoru Game Bunseki 1985nen Universiade Kobe Taikai niokeru shoot ni kansuru Bunseki* .[An Analysis About a Real-time analysis regarding Shooting in the Water Polo Competition of Kobe of the Universiade of 85 years] Japanese Physical Education University Vol37, 1986

Takami R. et. al: *DLT hou wo mochiita Dousakeisoku/Kaiseki Syse¥tem no Ouyou to hyouka.* [The application and evaluation of the operation measurement/analysis system that used the method of DLT] . No. 6th volume of Okayama Prefectural University health welfare science department bulletin, 1999

Takahashi T. et. al: *Tsukuri nagara Manabu HTML¥CSS design no kyoukasho* [Textbook for HTML/CSS design to learn in spite of the making]. SB Creative, 2017

Takahashi Y. : *Oshiete Programming* [Please let me know about Programming]. Rick Telecom, 2017

Takeuchi M. et. al.; *Shuudann Unndou・Doubutsu Koudou no Kaiseki Soft ware no Kaihatsu*・Kotai tsuiseki Flame work[Development-individual chase framework UMA Tracker- of the analysis software of a collective-motion/animal behavior]. 2016

Takeuchi R: UMA Tracker quick start guide
URL https://umatracker.guide.github.io-manual-md/quick-ref.html 2016

Watanabe K. : *Data wo Buki ni suru* [Uses the data as the arms].Diamond company, 2013.

Techacademy.jp
URL https://techademy.jp/magazine/4843

Raw Data

Data1 : Result Result of analysis of trajectory of killifish

Data2 : Result trajectory coordinate of killifish in excel form

Data:3 :Result of Toho Water Polo Team Data at Junior Olympic Qualifier Matches

Data 4: Result of Oppenent Water Polo Team at Junior Olympic Qualifier Matches