ISTANBUL TECHNICAL UNIVERSITY GRADUATE SCHOOL

COLLECTR: A GAMIFIED EMOTIONAL DATA COLLECTION AND LABELLING PLATFORM FOR CHILDREN

M.Sc. THESIS

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Department of Game And Interaction Technologies

Game And Interaction Technologies Programme

JUNE, 2021

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ISTANBUL TEKNİK ÜNİVERSİTESİ LİSANSÜSTÜ EĞİTİM ENSTİTÜSÜ

COLLECTR: ÇOCUKLAR İÇİN OYUNLAŞTIRILMIŞ DUYGU VERİSİ TOPLAMA VE ETİKETLEME ARACI

YÜKSEK LİSANS TEZİ

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Oyun Ve Etkileşim Teknolojileri Ana Bilim Dalı

Oyun Ve Etkileşim Teknolojileri Programı

Tez Danışmanı: Prof. Dr. Hatice KÖSE

ŞUBAT, 2021

Turgut Can Aydınalev, a M.Sc. student of ITU Graduate School 529181019, successfully defended the thesis entitled **"COLLECTR: A GAMIFIED EMOTIONAL DATA COLLECTION AND LABELLING PLATFORM FOR CHILDREN",** which he prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

Thesis Advisor :	**Prof. Dr. Hatice Köse** Istanbul Technical University	....
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Date of Submission : 11.06.2021
Date of Defense : 05.07.2021

To my spouse and family,

FOREWORD

“collecTR: A Gamified Emotional Data Collection and Labelling Platform for Children” is created for the Game and Interaction Technologies graduate program at the Istanbul Technical University. I want to specially thank my advisor, Prof. Dr. Hatice Köse for her guidance and understanding of behaviors during the research process. I would like to thank all participants to the testers for their participation and my family for supporting me.

May 2021 Turgut Can Aydınalev

TABLE OF CONTENTS

ABBREVIATIONS

JS	**:** JavaScript
UI	**:** User Interface
SQL	**:** Structured Query Language
RNG	**:** Random Number Generator

LIST OF TABLES

LIST OF FIGURES

COLLECTR: GAMIFICATION OF AN EMOTIONAL DATA COLLECTION AND LABELLING PLATFORM FOR CHILDREN

SUMMARY

Emotion detection is a topic that has been studied by researchers from different majors As a result of these studies, some ground rules and relations about facial emotions have been set, such as the relation between lip motion and happiness. However, most of these ground rules are not applied to children due to their facial structures so the identification of children's emotions is different from adults. Children's faces have unique characteristics that make it harder to label with traditional methods. In order to understand their emotions, some machine learning methods can be used but these methods require a big amount of facial data, for the training. In this thesis, a tool with gamification is implemented to gather labeled emotional data of children.

The tool is developed with React Native which is a JavaScript Framework that can export applications cross-platform. Many libraries can be imported in React Native but a high-performance camera library is one of the main reasons for using React Native. Because React Native is an open-source project, it has a great community that develops many optimized libraries which are included in this project.

For storing game data, different storages are used according to requirements. For storing user data, PostgreSQL-based Hasura is selected because of usability reasons. It uses GraphQL for queries and creates schemas by itself. For storing images, MinIO object storage is used which provides data breach and loss protection.

There are four modes of usage in the tool which are Shipy, Dropy, Basic Tool and Photo Evaluation. Shipy is an endless runner genre game with serious game features. It gathers photos in every five scores. In Dropy, some emotions drop slowly from the air. Users must break them before it reaches the ground. To achieve this goal, the user should pose the emotion and standstill. The user gets a score for each emotion that is broken and a photo is taken. Basic Tool mode is designed mostly for teenagers and adults which only requires posing given emotion. In Photo Evaluation, the user evaluates the photos of the child which are generated by playing games.

The application is tested with 7 children. After the experiment, some questions about the game are asked verbally to children. It can be said that they are liked the game. While Shipy has a lack of diversity of emotions, it has 85 percent of valid images which means that these images are usable for future work. On the other hand, Dropy has 82 percent of valid image rate with diversity of the emotions. In general, the application collects images with %83 success rate. Thanks to Dropy, emotion diversity is acceptable even though children have some trouble with posing angry emotions.

COLLECTR: ÇOCUKLAR İÇİN DUYGU VERİSİ TOPLAMA VE ETİKETLEME ARACININ OYUNLAŞTIRILMASI

ÖZET

Duygu tanıma üzerine birçok araştırma yapılmış hem sosyal bilimcilerin hem bilgisayar bilimcilerin çalıştığı önemli bir konudur. Bu araştırmaların sonucunda bazı dünya genelinde kabul gören temel kurallar ve ilişkiler ortaya konmuştur. Ancak bu araştırmalar genelde yetişkinler üzerinde olduğu için ve çocukların yüz yapısı farklı olduğu için çocuklarda geçerliliğini yitirmektedir. Günümüzde bilgisayar bilimciler bu temel kuralları kullanarak veya yüz anahtar noktalarını tespit edip onlar ile makine öğrenmesi yaparak duygu tespiti yapmaktadır. Duygu tanıma için bilgisayar bilimcilerin en önemli ihtiyacı yüz verisidir. Yüz verisi, özellikle görüntü işlemede kullanılan önemli bir veri türüdür. Bu yüz verileri aynı zamanda makine öğrenmesi ile duygu tanıma yapılmasında da kullanılmaktadır.

Bu projede, yüz verilerinin toplanması için bir araç geliştirilmiştir. Bu araç ile çocuklar üzerinde daha kolay veri toplanabilmesi adına mini oyunların yanında oyunlaştırma teknikleri de kullanılmıştır. Oyunlaştırma, uygulamaya odaklanmayı ve bağlılığı arttırıcı bazı yöntemler bütünüdür. Bu araçta kullanılan yöntemler bazı temel başlıklar altında toplanabilir.

- Alındı geri bildirimleri kullanıcıya yapılan oyunlaştırılmış geri bildirimlerdir. Bunlara madalyalar, kupalar, unvanlar, destek mesajları örnek verilebilir.
- Skor sistemi neredeyse tüm oyunlarda ve oyunlaştırılmış araçlarda kullanılan, kullanıcıya neyin doğru neyin yanlış olduğunu anlatabilen en temel ve en elzem oyunlaştırma yöntemlerinden biridir.
- Zaman kısıtlaması aplikasyona heyecan katan ve kullanıcının odağını arttıran öğeler arasında sayılabilir.
- Kişiselleştirilmiş karakterler oyuna olan bağlılığı ve odağı arttırır.
- Dinamik geri bildirimler oyuncuyu görsel veya işitsel olarak uyaran, oyuncuyu doğru yöne sevk etmeyi amaçlayan efektlerdir. Bu araçta bu oyuncu karakterinin hareketleriyle sağlanmaya çalışılmıştır.

Her ne kadar Unity en çok kullanıldığı düşünülen oyun geliştirme platformu olsa da bu aracın geliştirilmesinde bazı sebeplerden ötürü tercih edilmemiştir. Öncelikle, bu araçta oyun özelliklerinden çok kamera ve sunucu iletişimi önemli olduğundan onlar göz önüne alınmıştır. Unity'nin de cihaz kamerası desteği sunan kütüphaneleri olsa da uzun zamandır güncellenmeyen bu kütüphaneler performans açısından da verimsiz oldukları için kullanılamamışlardır.

Unity veya diğer oyun motorları yerine bu araç React Native kullanılarak geliştirilmiştir. Her ne kadar React Native JavaScript kullanılarak kodlanan bir dil olsa da tüm temel kütüphaneleri ve aygıtla konuşan tüm iletişim kodları platforma özel yerli dillerde, yani iOS için Objective-C, Android için ise Java kullanılarak yazılmıştır. Bu da tüm temel bileşenlerin yerel kodla yazılmış performansında sağlanması anlamına gelmektedir. Her iki platforma da sorunsuz çıktı alabilen React Native, platform bazında kodlamaya da izin vermektedir. Ayrıca, açık kaynak bir kütüphane olan React Native, yerel dillerde yazılmış üçüncü parti kütüphanelere de izin vermektedir. Dolayısı ile geniş bir kullanıcı kitlesi olan bu kütüphane, aynı zamanda çok geniş bir kütüphane desteğine sahiptir. React Native'in diğer özellikleri şöyle sıralanabilir.

- İnteraktif kullanıcı ara yüzü ile hata ayıklanabilen ve anlık kod değişiklerini simülatöründe gösterebilen bir yapı sunar.
- Bileşen tabanlıdır. Bu obje temelli yaklaşım kompleks yapılar kurmayı ve sonrasında bakımını yapmayı kolaylaştırır.
- Yaratılan bileşenler çoğu zaman React Native'in temel bileşenlerine dayanır böylece farklı platformlar için farklı bileşenler oluşturmaya gerek kalmaz.
- Esnek bir yapı sunar. Yerel dillerle yazılmış projeler ile bağlantı imkânı sunar.

Bu projede kullanılan dışarıdan yüklenen React Native kütüphanelerinin en önemlisi, *react-native-camera'dır*. Hiçbir oyun motorunun sunamadığı bu yüksek performanslı kamera bileşeni, her iki platform için de geniş kamera yönetimi imkânı sunmaktadır. Ayrıca yüz tanıma ve yüz noktalarını tespit etmek için Google'ın geliştirdiği Firebase yüz tanıma aplikasyonu ile entegre çalışabilmektedir. *React-native-game-engine* kütüphanesi ise aplikasyonda gereken temel oyun döngüsü mantığı için kullanılmıştır. Her ne kadar çok gelişmiş bir kütüphane olmasa da temel oyun işlevlerini sağlamaktadır. Yer çekimi mekanikleri içermemesine rağmen diğer kütüphanelerle entegre çalışabilmektedir. Yer çekimi mekanikleri için *matter-js* kütüphanesi kullanılmıştır. Uygulamadaki temel tema akışının sağlanması için *react-native-paper* ara yüz kütüphanesi kullanılmıştır. Kullanıcı karakterleri için *react-native-bigheads* kütüphanesi kullanılmış olup, bazı özellikleri çocuklara uygun olması açısından kısıtlanmıştır.

Sunucu tarafındaki gereksinimler için birden fazla uygulama kullanılmıştır. İlk olarak, kullanıcı bilgilerinin ve fotoğraf detaylarının tutulacağı bir veri tabanı kurulması gerekmektedir. Bunun için PostgreSQL tabanlı GraphQL ile sorgu yazılabilen bir ara yüz sunan Hasura kullanılmıştır. Arka planda en klasik ve stabil veri tabanı yapılarından olan PostgreSQL'i kullanan Hasura, bu sunucu ile iletişimde kolaylıkla kompleks sorgular yazılabilen GraphQL'i kullanmıştır. Hasura kullanılması ile, sunucu ile iletişim kurması gereken ara bir aplikasyon ihtiyacı ortadan kalkmıştır.

İkinci olarak, fotoğrafların bir buluta kaydedilmesi ve gerektiğinde erişilebilmesi gerekmektedir. Bu fotoğraflar geleneksel veri tabanlarına kaydedilebilse de hem işgal ettiği yer olarak çok verimsiz olmasından hem de fotoğrafları gösterme ihtiyacı olmasından dolayı farklı bir veri tabanı ihtiyacı doğmuştur. Bunun için obje veri tabanları araştırılmıştır. Birçok obje veri tabanı olsa da birçoğu ücretlidir. *MinIO* ise geliştiricinin sunucusuna kurulursa ücretsizdir. Veri kaybı ve veri ihlaline karşı güvenlik önlemleri de sunan bu obje veri tabanı, kullanışlı bir ara yüz de sunmaktadır.

Bu sunucu ile iletişim için bir ara aplikasyon yazılması gereksinimi doğmuştur. İstenilen fotoğrafın getirilmesi, istenilen klasörün altındaki fotoğrafların getirilmesi, istenilen fotoğrafların silinmesi gibi servisler gereklidir. Bunun için GoLang kullanılarak bir aplikasyon yazılmıştır. Bu aplikasyon, bir sunucuda koşturulmaktadır. Obje veri tabanıyla konuşup fotoğraf servislerine erişim sağlanmaktadır.

Uygulama ilk olarak giriş yapma ekranından başlamaktadır. Oyun her açıldığında ilk defa oynayanlar için bir bilgi ekranı gösterilmektedir. Burada uygulamanın kullanım şekli özetlenmiştir.

Uygulama için basit bir üyelik sistemi geliştirilmiştir. Bu üyelik sisteminde, kullanıcı eğer ilk defa giriş yapıyorsa, üyelik numarası kısmı hariç diğer bilgileri girmelidir. Üyelik numarası kısmı boş işe kullanıcıya yeni bir üyelik yaratılıp bir kullanıcı numarası atanmaktadır. Kullanıcı üyelik numarasını ana ekranda giriş yaptıktan sonra ekranın üstünde görebilir. Tekrar giriş yapmak için bu numara unutulmamalıdır. Hali hazırda üye olan bir kullanıcı, ismi ve numarası ile giriş yapabilir.

Kullanıcılara uygulama boyunca bir karakter eşlik etmektedir. Bu karakter özelleştirilebilirdir. Ana ekranda karaktere tıklayarak özelleştirme sayfasına kullanıcı yönlenebilir. Burada kullanıcı cinsiyete göre rastgele özelliklere sahip bir karakter edinebildiği gibi, aşağıda bulunan seçeneklerden bu karaktere özellikler seçebilir.

Kullanıcı mod seçme ekranına geçmek için ana ekranda giriş yaptıktan sonra oyna tuşuna basmalıdır. Bu ekranda, dört tane tuş bulunmaktadır. İki tanesi oyun olup diğerleri ise yetişkinler veya gençler için geliştirilmiştir yüz verisi toplama modu ve toplanan fotoğrafların değerlendirilmesi modlarıdır.

Dropy oyununda, yukarıdan duygu kutucukları düşmektedir. Kullanıcının yapması gereken bu duyguları yere düşmeden kırmaktır. Kırması için ise belirtilen duygu durumu ile sabit durması gerekmektedir. Kullanıcı eğer hareket ederse, yukarıdaki sayaç başa sarılmaktadır. Eğer ki kutucuk havada iken sayaç sıfıra gelirse kullanıcı sayı almaktadır. Karakteriyle bu sayıyı aldığı kullanıcıya geri bildirim olarak söylenmektedir. Kullanıcı skor aldığında fotoğraf çekilip etiketi ile kaydedilmektedir. Duygu durumları rastgele seçilip düşmektedir. Her bir duygu durumundan en az bir adet fotoğraf toplandıktan sonra oyun bitmektedir.
Shipy oyununda ise uçan bir karakter kullanıcıya eşlik etmektedir. Kullanıcı ekrana tıklayarak karakteri yönlendirebilmektedir. Amaç engellere takılmadan alabilecek en yüksek puanı almaktır. Kullanıcı her engeli aştığında bir puan almaktadır. Oyun her beş skorda daha da hızlanmaktadır ve böylece kullanıcıyı zorlamaktadır. Aynı zamanda, her beş skorda bir kullanıcının o anki duygu durumunun fotoğrafı çekilip o anki skorla beraber kaydedilmektedir.

Yüz verisi toplama modunda ise kullanıcıya poz vermesi gereken duygu durumları gösterilmektedir. Kullanıcı, bu duygu durumunu sayaç bitene kadar korumalıdır. Sayaç bitince ise kullanıcıdan fotoğraf alınmaktadır. Alınan bu fotoğraf, kullanıcı onayına sunulmaktadır. Kullanıcı onay verirse, sonraki duygu durumuna geçilmektedir. Tüm duygu durumlarından birer adet onaylandıktan sonra uygulama sonlanmaktadır.

Fotoğraf değerlendirme modu ise ancak ebeveyn modunda kullanılabilmektedir. Bu mod, ana ekrandaki sol alttaki küçük tuşa basılarak açılabilir. Çocukların dikkatini çekmemesi için silik olarak tasarlanan bu tuş ile ebeveyn moduna geçilir. Sonrasında ise, onaylanmayan fotoğraflar bu moddan etiketlenebilir. Kullanıcı sadece o kullanıcının yarattığı fotoğrafları görebilir.

Araç ilk aşamada yedi çocukla test edilmiştir. Test esnasında çocuğa herhangi bir baskı yapılmamış olup ne kadar oynamak istiyorsa o kadar oynaması istenmiştir. Oyun kısaca açıklanmıştır fakat detaylı bir şekilde anlatılmamıştır. Sadece ebeveynine üyelik işlemleri gibi kayıt aşamaları anlatılmıştır. Çocuklar genel olarak oyunu beğenmişlerdir. Dropy oyununu tüm çocuklar beğenirken, Shipy oyununun kontrollerinde zorlanan bazı çocuklar bu oyunu sevmemişlerdir. Bu durum oyun kültürü olmayan çocuklar için Shipy oyununun bir miktar zorlayıcı olduğunu göstermektedir. Uygulamada genel olarak yüzde 83 başarı yüzdesiyle geçerli fotoğraf alınmıştır. Geçerli fotoğrafın anlamı, sonraki çalışmalarda kullanılabilecek düzgün fotoğraflardır. Fotoğrafların geçerli olup olmadığına çocuğun ebeveynleri karar vermektedir.

Shipy oyununda her ne kadar duygu durumumu çeşitliliği kısıtlı olsa da oyundan yüzde 85 oranında geçerli fotoğraf elde edilmiştir. Dropy oyununda ise yüzde 82 oranında geçerli fotoğraf elde edilmesinin yanında, bu fotoğrafların yüzde 67'si doğru olarak poz verilmiştir. Yüzde 14'ü ise geçerli fotoğraflar olmasına karşın çocuğun poz vermesi gereken duygu durumuna ait değillerdir. Bunlara karşın Dropy oyununda neredeyse her duygu durumu başarılı bir şekilde alınmıştır. Çocuklar sadece kızgın duygu durumunu poz vermekte zorlanmışlardır. Bu duygu durumunda başarı yüzdesi her ne kadar yüzde 35 olsa da ortalama olarak her çocuktan bir adet başarılı kızgın duygu durumu alınabilmiştir. Bu da tam olarak istenen kadar olmasa da yeterlidir.

Uygulama genel olarak özellikle çocuklardan, çocukları sıkmadan çocuklardan çeşitli duygu durumlarını poz vermelerini isteyip yüz verisi almayı amaçlamaktadır. Bu amaca da genel olarak yüzde 83 oranda başarı yüzdesi yakalayarak ulaştığı söylenebilir. Gelecek çalışmalarda çocukların zorlandığı kızgın duygu durumuna yoğunlaşacak oyun modları ve yeni oyunlaştırma elementleri eklenmesi hedeflenmektedir.

1. INTRODUCTION

Emotion is a noticeable state of consciousness that mostly causes physical reactions. According to Ekman, there are seven main emotions which are enjoyment, sadness, fear, anger, disgust, contempt and surprise [1]. If a person describes her/his feeling as good, calm, pleased or happy, this feeling is categorized as enjoyment. In enjoyment emotion, the person might express the feeling by facial reactions like smiling or laughing. On the other hand, in sad emotions, negative facial reactions like crying might appear. Sadness is mostly caused by a specific event, a mental issue or nothing. Sometimes people cannot describe why they are feeling sad. Moreover, fear emotion appears when some type of threat is sensed. When this emotion happens, mimics may not be responded but eyes will do. Like fear, eyes and eyebrows react when anger happens. Anger happens when something unjust happens according to the person. In addition to the anger, the mouth of the person may react to disgust as well as eyes and eyebrows. Like other emotions, disgust is a natural response to something unpleasant. Ekman added two more main emotions to these in his later researches. Contempt is mostly described as the feeling when the person feels superiority over another person. Lastly, the surprise is an instant reaction to an unexpected movement or sound. Although adults mostly express their emotions with their words alongside natural physical responses, without words detecting emotions might be tricky.

Expressing emotions is one of the biggest struggles for children. Especially for disabled children which mostly have lack social communication skills. Moreover, the recognition of the emotional states in children's education and therapy processes will provide them to be successful in their educational and social life.

Emotion recognition is a topic that has been researched by behavioral scientists for centuries. Firstly, John Bulwer has defined different mimics and head movements in his book, *Pathomyotomia* in 1649. After that, Darwin in 1872, has described the facial expressions of humans and animals. According to Darwin, these expressions are not universal and they can be varying with age [2]. Moreover, Ekman, who is a pioneer in facial expressions, creates seven basic emotions by evaluating the movement of the mouth corner [1]. In computer science, based on Ekman’s work, facial landmark models have been created in order to detect expressions.

To interpreting emotions, there are certain ways. Although fuzzy logic algorithms created with Ekman’s ideas give great results in happiness, they mostly fail at distinguishing close emotions like disgust and fear. On the other hand, machine learning algorithms that use facial landmark points as input data mostly generate successful results. However, machine learning algorithms need meaningful datasets for correct evaluation.

Machine learning is a branch of artificial intelligence that aims to interpret data. To simplify, the analysis of data in order to make the computer learn automatically is called machine learning. There are several approaches to machine learning.

- Reinforcement machine learning can be simplified as trial and error. There are no labels in this method, there are only rewards. The algorithm starts randomly and tries to evolve into a solution that gets more rewards. Genetic algorithms mostly use reinforcement learning to achieve better generations.
- In supervised machine learning algorithms, there is training labeled data. The algorithm takes the features of the data and tries to classify them according to their labels. For instance, if a supervised emotion detection algorithm takes enough happy and sad labeled images with their meaningful features such as some facial organ angles, it can guess data with the same features whether it is happy or not. It is the most successful method with the right amount high quality labeled data.
- On the other hand, unsupervised machine learning algorithms just take raw data without any labels. It simply aims to create clusters according to the data. For instance, with the right features, an unsupervised machine learning algorithm can guess whether there is a human in the picture or not.
- Between unsupervised and supervised machine learning, there is another approach that is called semi-supervised machine learning. It usually uses a small amount of labeled data for clustering. This method is used for the classification of special clusters.

Although acquiring high-quality labeled data is tricky, with this serious game, it is targeted that gather high-toned facial data remotely.

Serious games or applied games that have other priorities than entertainment. These games are used in numerous sectors for different goals. In education, lessons or specific subjects are gamified in order to accelerate learning speed and increasing immersion. Especially for children, this method is very useful because of their lack of focus. These games which are also called educational games are one of the well-known usages of serious games. In the health sector, some games are developed for rehabilitation or medical simulations. Besides, military training games or social awareness games are considered serious games. Many advantages put forwards serious games over traditional methods.

- They provide engagement and immersion because of the nature of games. As in normal games, although the player will not achieve anything related to real life, just for the success feeling, the player will engage in the game.
- They are more fun. Simply, they are more enjoyable than traditional methods for the target audience.
- They provide a safer and more experimental virtual world. For instance, for better understanding, things that cannot be created in the real world can be created.

In addition to serious games, gamification can be used in order to transform a basic application into something enjoyable. Gamification is using game elements in non-game applications in order to improve user motivation and user engagement. According to [3], motivation is a basic requirement for successful learning. This rule can be applied to anything. Especially for children, motivation is the key to concentration. For instance, although teenagers experience a lack of concentration while studying or doing homework, they can play computer games or talking their friends for hours without experiencing inattentiveness. Toda et al. have analyzed classified gamification elements and the gamification taxonomy [4]. According to them, there are five dimensions of gamification which are performance, ecological, social, personal and fictional gamification elements. Firstly, some elements are related to environment reactions which can be grouped as performance elements. These elements can be summarized as

- Acknowledgments are gamified feedbacks like badges, trophies, medals.

- Leveling system for skills or main character in order to extend playtime for becoming more powerful.
- Progression feedback for creating improvement feeling.
- Scores feedback in order to guide the player in the right way.

Ecological elements are related to the created game world. These elements make the world more dynamic and enjoyable. They can be divided into groups as

- Change factor which is also called RNG factor for making the game more unpredictable.
- Choices in order to create an interactive environment.
- Rarity factor-like limited-time items to make players feeling special.
- Time limits in order to create excitement.

There are also social elements that include interactions between players. These elements can be classified as follows.

- Competition elements can be provided with leader boards or challenges between players.
- In-game reputation elements such as titles, statuses can be used to create a challenging environment.

The personal dimension contains elements that are related to the player. These elements can be summarized as follows.

- Novelty elements are unusual elements for the surprise factor.
- Creating objectives like missions provide goals for the player. These elements create an ending for the player and give the player a reason to play.
- Puzzle like challenges stimulates player in order to create a focus factor.
- Sensation elements are feedbacks that poke the player visually or vocally. These elements are mostly created with dynamic feedbacks.

Lastly, a fictional dimension is a dimension that contains elements that creates a connection between player and environment.

- Storytelling is about creating a background story for the game in order to increase immersion.

1.1. Purpose of Thesis

This thesis is a part of the 118E214 coded Roborehab project which is supported by The Scientific and Technological Research Council of Turkey. The purpose of the project is to identify emotions, especially the emotions of hearing-impaired children. In this thesis, a tool with a gamification approach is developed in order to gather data that will be used for the aforementioned reason.

For machine learning methods, finding a specific dataset is one of the biggest struggles. In facial recognition, firstly the landmarks should be detected via a face model. The locations of the landmarks are important because of the machine learning evaluation; therefore, images should be cropped according to the head size. There are some datasets with these specifications that can be accessed with permission. For example, *Radboud Faces Database* has 67 face adult models from different races. Besides 67 models are not enough for creating a facial recognition model, facial models are all adults. For children's face data, there is a *CAFE* dataset that contains various posed emotion images which are collected from 100 children which are from different races. However, this dataset has its problems. Firstly, some images are not realistic because a child is smiling in the sad labeled image. Secondly, the dataset contains various races can be complicated for a machine learning algorithm that will use only one race of images for the product.

In this thesis, a serious game for mobile platforms is designed and implemented for collecting meaningful facial data from, especially disabled children for future use.

1.2. Literature Review

With this special topic, there are no exactly matched works. However, there are works about disabled children focused on serious games and children emotion-focused serious games separately.

Firstly, works that about disabled children are analyzed. In [5], a game is developed for children between 2 to 6 years old with speech disorders and hearing problems to test their learning ability after playing the "learning level". The game contains a virtual teacher which means that the child can play it by himself/herself. It uses a sense of sight and hearing. The main character is moving with a child’s voice commands or a keyboard. In this work, the main purpose is to find objects with voice commands which give the game opportunity to measure the pronunciation. Moreover, another paper [6] is about a video game for hearing-impaired children which doesn't require speaking skill. The game is very basic for present-day technology. It aims to test the child's hearing ability with similar-spelled words.

Alongside serious games about disable children, there are works about children's emotions. For example, in [7], the game is made for recognizing people's emotions which has eating disorder. Alongside cameras, biosensors are also used. The game has 3 mini-games with different topics. The difficulty of the games is decided via biosensor data. This study aims to measure emotional expressions and reactivity while the patients playing the game. Another work [8] is about a game called *LIFEisGAME* is made for children with ASD. The game has 5 sub-games that are related to emotions such as emotion recognition, a memory game with emotion pictures.

Apart from this, there are papers about affective computing which can be summarized as programming with human behaviors and data from humans. In [9], details of affective computing are explained. It is pointed out that physical data which are the face, mimics, speech, heart pulse are the most important technic for emotion recognition. To support this, [10] says that for making effective computing, physical data should be used instead of in-game user data. According to [11], endless games can be used for emotional transitions. For example, if the game is too easy, the player can get bored and lose attention easily. On the other hand, if the game is too hard, the player gets easily angry and can quit playing.

About the impacts of gender on the game, there are some researches. In [12], it is pointed out that different genders may respond with different emotions to the same emotion trigger. To solve this within a serious game, players should get into the game flow. According to [13], customizable characters will help the player to get into game flow. Moreover, the game difficulty can be dynamically adjusted according to the performance of the player. This adjustment will provide flexibility for different aged children because the ages target audience of the game differ. Another work [14] is about how designs of serious games should be. According to Plass et al., if the game uses too many warm colors, it may be distractive but it may help trigger positive emotions with roundly environmental details.

Besides these topics, general serious games about children are covered in order to design the game well. In [15], it is researched that how serious games should be designed for children which stay in hospital. Survey-typed this paper classified researched papers according to ages of children, device type (head-mounted device, tablet, computer with a keyboard, computer with a mouse, etc.) and they concluded as the head-mounted device is not suitable for the children because of their illnesses. In [16], there is an application that predicts the emotion from touch interaction speed. They installed the application into their tester's smartphones and asked them to type some text occasionally for three weeks. After that, they analyzed the interaction speed data with the "Smote" technique and they predicted emotions with a success of %73. Moreover, [17] has researched *Exergames* which are exercise games that need physical effort in order to play the game. As we know this doesn't mean it is effective computing, this paper slightly irrelevant for the current topic.

On the other hand, there are emotional triggers that don't need any technology. For example, in [18], some negative emotional triggers were tried in a case study. The first trigger is simply stabbing some objects for disturbing the tester. Another trigger is saying bad swear words to the tester. These methods were unethical and unacceptable for a kid but their last method, which is making the tester draw something nice and after that deleting it in front of them, may be used for a video game that aims to trigger negative emotions.

Apart from all, the game should entertain children alongside the purpose of the game. In [19], how the children's games should be designed according to children's age is explained. According to him, the age groups should be divided into small groups because children's ages make a lot of differences about video games like 4-6, 7-9 and 10-12 age ranges. According to the text, 4-6 age range which is the target audience of the game likes tapping screen randomly and see what changes in the screen. So, if negative emotional triggers are used, the screen should be more static instead of dynamic.

There is an article that aims to collect data from children with ASD. In [20], a game called *Guess What?* is a revised version of the popular game, *Heads Up.* In the game, the parent or the caretaker holds the mobile device on her/his forehead and asks the child to make that impression. If it is correct the parent shakes up the device to gain a score. Meanwhile, the face of the child is recorded. In this game, gamification is not enough to keep the child in the game. Moreover, the video should be processed for future use.

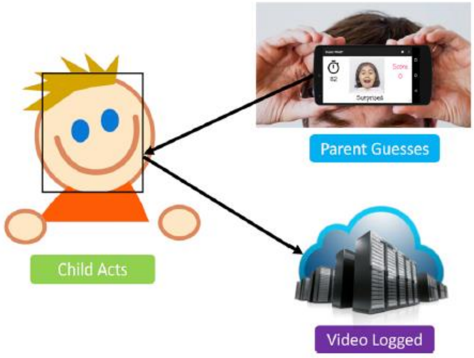

Figure 1.1 : Game flow of Guess What?

Moreover, key factors of the game design for keeping children in the game flow have been investigated. In general, gamification has been using for increasing attention for nearly two decades. According to [21], there are 6 basic game design elements which are,

- points,
- badges,
- leaderboard,
- performance graphs,
- meaningful stories,
- avatars
- and teammates.

Also, Sailer et al. said that feedbacks in gameplay should be used for gamification.

Elements that are suitable for children and the game were used in the project. For that matter, gamification and serious games for children's topics have been researched deeply. In [22], psychological mechanisms of game influence for children have been researched. According to the article, there are some base rules for creating serious games for children.

- The game should be challenging. The difficulty should be dynamic according to the game performance of the child.

- The game should create a *flow experience,* the player should be interested in the game and future objectives.
- The game must provide feedbacks for achievements and progress.
- Customizing characters or avatars helps the flow experience.
- The fun factor is important in serious games as well as in other games. However, it can be challenging that create a game that generates fun factors for all age groups.

2. THE TOOL

2.1. System Design

2.1.1. Development platform selection

While developing a game, there are many development platforms that can provide different advantages.

Unity is the game engine that first comes to mind. With cross-platform export support, Unity is the most used game engine in the world. Rich in-app asset store, easy usability, base 2D, 3D and VR libraries some of the reasons that Unity is preferred by game developers. However, in this game, it is mandatory that using the front camera on mobile devices. While Unity has 3rd party support for mobile cameras, it has terrible performance with the game loop. The project initially started with Unity but because of this performance issue, the development platform was changed.

Because most of the game engines fail in-game camera performance, other development options were considered. The requirement of a mobile camera with performance leads the project to native applications.

For the efficiency, cross-platform mobile application framework **React Native** which is developed by Facebook was studied. Although it was only an internal hackathon project on Facebook, it turned out to be so magnificent that many big companies now using React Native in their main applications like Airbnb, Uber and Discord [23].

Although React Native is a JavaScript-based framework, all of the base libraries of it were written in native languages (Objective-C for iOS, Java for Android) which provides a native-like performance alongside cross-platform support. Besides, because React Native is an open-source framework, there are a lot of 3rd party libraries for a lot of purposes. Therefore, React Native has been selected for the development platform. React simply renders its components as native from the platform, which means that its basic components have native performance. Furthermore, React provides seamless cross-Platform support. For instance, different screens can be coded for different platforms. Also, React Native is

- Declarative. React provides interactive UIs and debuggable code with ease
- Component-based. This object-oriented approach makes it easier to create complex UIs.
- Easily debuggable. Thanks to JavaScript, every change can be instantly observed via the programmer.
- Portable. Most of the created components can be used on multiple platforms.
- Flexible. React Native allows that native codes can be bridged into the React Native projects.
- Open-sourced. Anyone can develop a component or library using basic React Native codes or native codes and then publish it to everyone.

Table 2.1 : Comparison of Unity and React Native

	Unity	**React Native**
Native Performance	No	Yes
Light-weight application	No	Yes
Native Camera Component	No	Yes
Libraries	Limited, most of them are not open sourced and priced	Everything is open-source

2.1.2. Libraries

react-native-game-engine

For developing a game, a game loop is a basic requirement to manage game objects, to keep score, to detect collisions. Of course, React Native has not this feature because of the performance. React Native only updates the screen when a *state* changes which is a variable for updating the screen upon change because in a mobile application every render has a cost on account of performance or battery. React-native-game-engine provides this basic game loop with some basic game features like touching, collision mechanisms while sacrificing these performance improvements which cannot be used in a game application.

matter.js

Although react-native-game-engine does not provide a physics engine, matter.js can be used for a 2D rigid body physics engine. It provides some physical properties and restitution properties. It also supports static bodies. While it is developed for a web environment, it has mediocre performance in React Native. In this application, this performance is enough.

react-native-camera

the react-native-camera library provides native performance with cameras in both android and iOS. It is the main reason for the selection of React Native. It provides photographs, videos and face detection for both android and iOS with excellent performance. It also allows modifying image properties.

react-i18next

This library provides language support for the application. However English and Turkish languages are currently supported, more languages will be supported in the future.

react-native-paper

Paper provides basic UI elements for the application. The theme is controlled by one main code so the color scheme can be updated easily. Components like button, card, text input, the text use the same theme; therefore, it provides visually coherent UI.

react-native-bigheads

Art of the avatars in the application is provided by react-native-bigheads. It provides several accessories and styles for customization. Randomizing or selecting these features and avatar animations are not provided with this library.

apollo client

Apollo is a GraphQL client for JavaScript with cache features. It is highly compatible with Hasura and fetches queries rapidly.

2.1.3. Back-end

At the back-end of the project, firstly requirements have been created. These are,

- Saving user information at the start of the game like name, age, start date, game selection and generate an id for the player,
- Saving responses for future analysis,
- Saving images with emotion and user id label,
- Getting images for that player for labeling afterward by a parent,
- Saving new labels,
- Exporting images from the cloud to local.

For these requirements, a database for user information and object storage for store images in the cloud were needed.

For database, instead of long raw SQL queries, **GraphQL** is preferred because of easy usability which is a query language for databases. GraphQL is like a mask for traditional databases for simpler queries without complicated join or alters queries. It is a Schema Definition Language (SDL), which means that a schema is defined in order to determine what queries are allowed to be made [24]. After defining a schema, a back-end application should interpret that query into a query for an actual database like PostgreSQL or MySQL.

GraphQL has three primary operations:

- *Query* for reading already existing data
- *Mutation* for inserting or updating data
- *Subscription* for receiving real-time data with web socket

Moreover, GraphQL has many advantages over traditional databases. For this thesis, the main advantages are

- Fetching data with a single API call. With created relations, it is very simple to call different tables that connected each other with foreign keys.
- Auto-generated API documentation. Because of the strict rules of GraphQL, after creating the schema, all queries can be created that are known so the query editor of GraphQL can detect wrong queries and make suggestions.
- Detailed error messages. GraphQL even shows the errors that are given by the back-end database so it is really fast to solve GraphQL errors.
- Permissions for different roles. For instance, a role can be defined that can only see user information of himself/herself but an admin role can see and fetch all user information.

With a proper GraphQL engine, there is no need for a handwritten back-end GraphQL interpreter because these engines interpret any query which follows GraphQL rules. As a GraphQL engine, **Hasura** is a fast alternative with webhook triggers and remote schema connections [25]. Hasura simply takes the traditional database like PostgreSQL and interprets queries into PostgreSQL queries. Hasura also comes with a great UI that provides table overviews, query editors and more. For instance, a table can be created in the Hasura UI with a few clicks. It also supports remote schemas and SQL queries for more complicated operations which made Hasura flawless. Hence, Hasura is selected for the back-end controller.

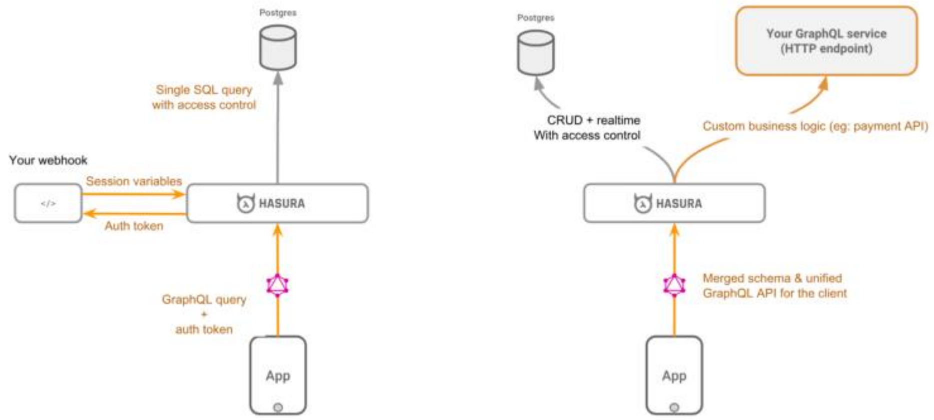

Figure 2.1 : Basic Hasura Flow. Source: Adapted from [25].

In addition to these, it is mandatory that saving the collected data to the cloud for future usage. Because saving images to traditional databases is not usual and not suggested, proper storage method has been researched. Because images are relatively large files, simultaneous demands may exhaust the file storage database. For accessibility and performance for storing images, object storage servers are the most suitable ones. Object storage databases split data into “objects” and stores them in separate locations which are called storage pools as objects. Data information is held in metadata in each individual data. With this metadata, the object can be created easily and these object fragments can be duplicated in different locations for increasing accessibility and speed.

For object storage, there are few alternatives like Amazon Simple Storage Service, Google Cloud Storage, Azure Blob Storage. However, these are using their servers and get priced accordingly. On the other hand, **MinIO** provides an open-source community edition with data loss and data breach prevention [26]. Therefore, MinIO was selected as the object storage server.

2.1. System Flow

The tool starts with a home screen. On the home screen, an information modal appears to inform about the game. Users can listen to this information with the speaker button.

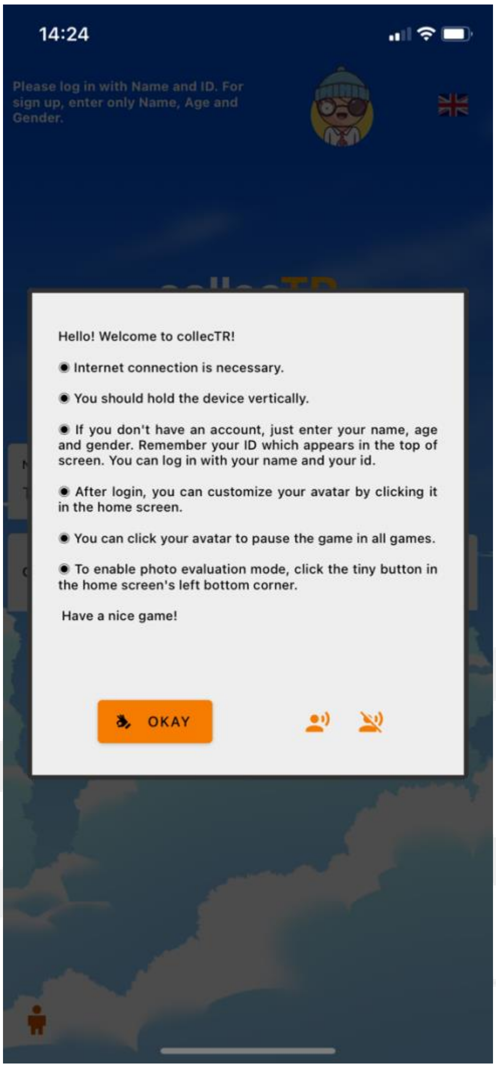

Figure 2.2 : Welcome modal of the game

After authorization, the user can go to the game mode selection or customize the avatar. In customize avatar screen, the user can personalize the avatar with multiple customization features. Also, the user can get a random avatar that selects random options from each feature. After saving, the avatar appears in-game modes; therefore, the tool gives feedback with the personalized avatar animations to the user to improve game flow. The customized avatar screen is redirected to the home screen after the selection.

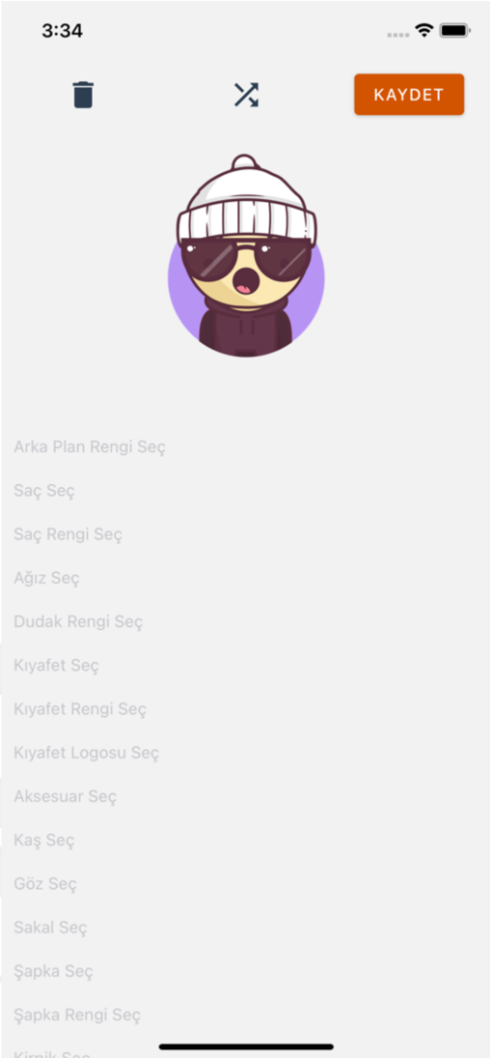

Figure 2.3 : Customize avatar page

The game mode selection screen is an interval screen that redirects the user to the modes. In each mode, there is a pause menu the user can pause the game. In that menu there is a mode explanation, resume button and return to the home button.

Figure 2.4 : Pause Menu

After the mode is finished, the user can return to the home screen. On the home screen user can log out and log in as another user. The user can see their information on the top of the screen. Also, the user can click the name of the game for displaying the greeting information modal again.

2.2.1. User Management

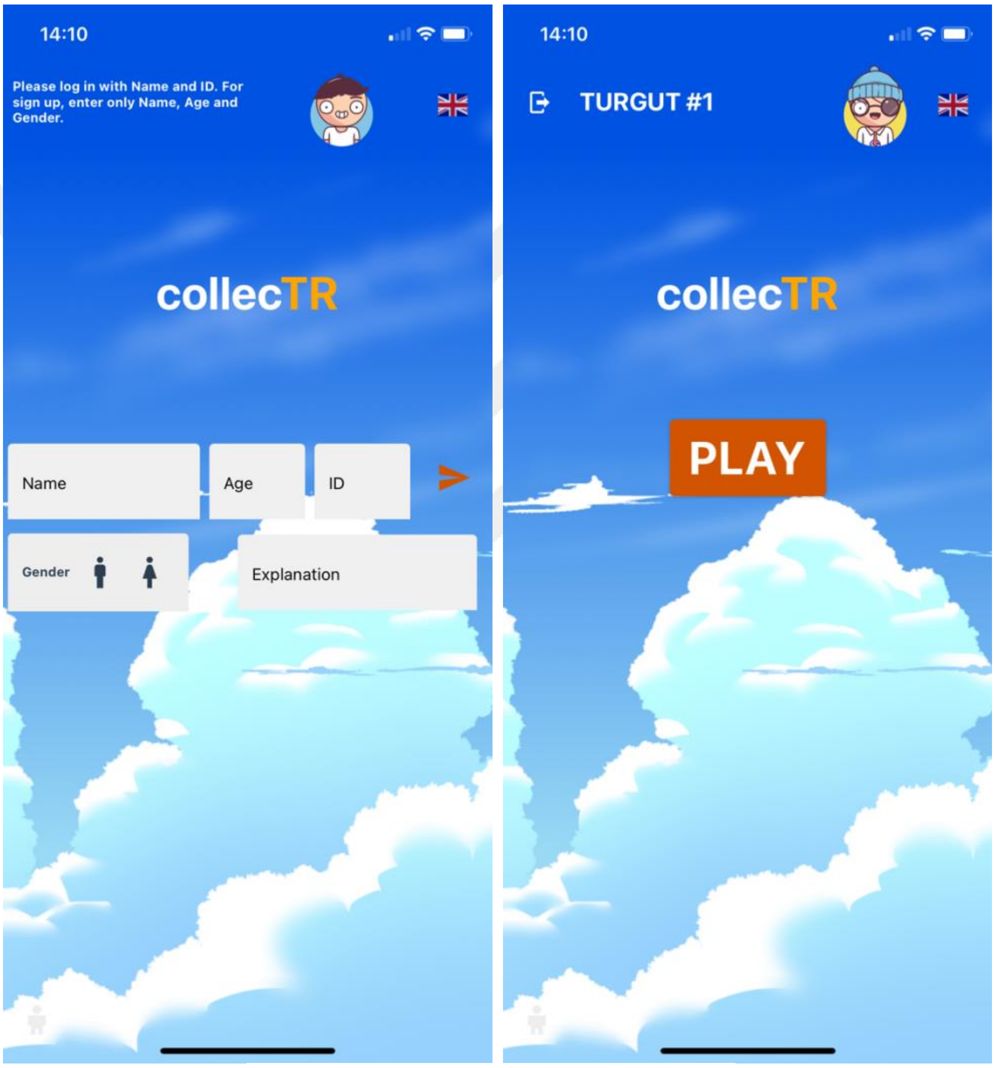

Figure 2.5 : Home page

At first, a home page welcomes the user which asks for user information. A user management system is implemented for controlling user traffic and classify users properly. To simplify logging in to the system, user name and user id are used as login credentials. To sign up, the user enters his/her name and age; therefore, an id automatically will be generated for that user. After that user can log in with that id to the system. Also, user can save the personalized avatar to the database for future logins.

The information is stored in a PostgreSQL database which is controlled by Hasura. Hasura provides query functions as well as auto-generated update and insert functions for each table. After login, avatar details will be loaded from the database. User information will be appeared at the top of the screen alongside with logout button.

2.2.2. Photo Management

In the application, some photos are taken from the front camera of the device. Although storing these photos in the device is the easiest solution, storing them in a remote server is a better solution for managing the facial database. When saving a photo, the photo information is saved into the PostgreSQL database through Hasura. This information contains the image name, user id, predicted label and actual label if it is decided. The route of the image in the MinIO server is created as *user id/image name* so with the saved row, the image is accessible.

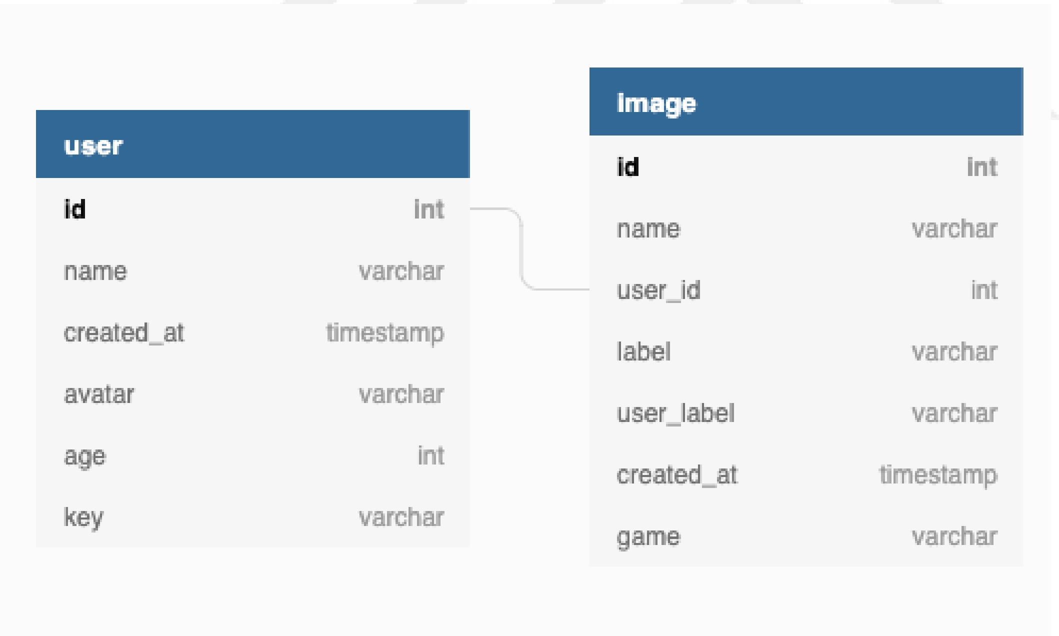

Figure 2.6 : Database diagram

Designated labels, especially the labels of the images that are gathered from children, are not very trustworthy in reality. For preventing that, after the game, the adult evaluates the gathered images and these evaluated labels are stored as ground truth in the database.

The image application is written with *Golang* and it contains endpoints that are used by the tool such as save an image, delete an image and get an image. It works together with the MinIO server. Both of these applications are password protected. In fact, the image control application also has authorization token control which prevents unauthorized access.

For saving media, three keys must be provided.

- Bucket is provided for special MinIO schema name
- File is provided as bulk file
- File-path is provided for classifying images correctly

For getting media, only two keys must be provided.

- Bucket
- File-path is also stored in the database so this endpoint is callable after creation.

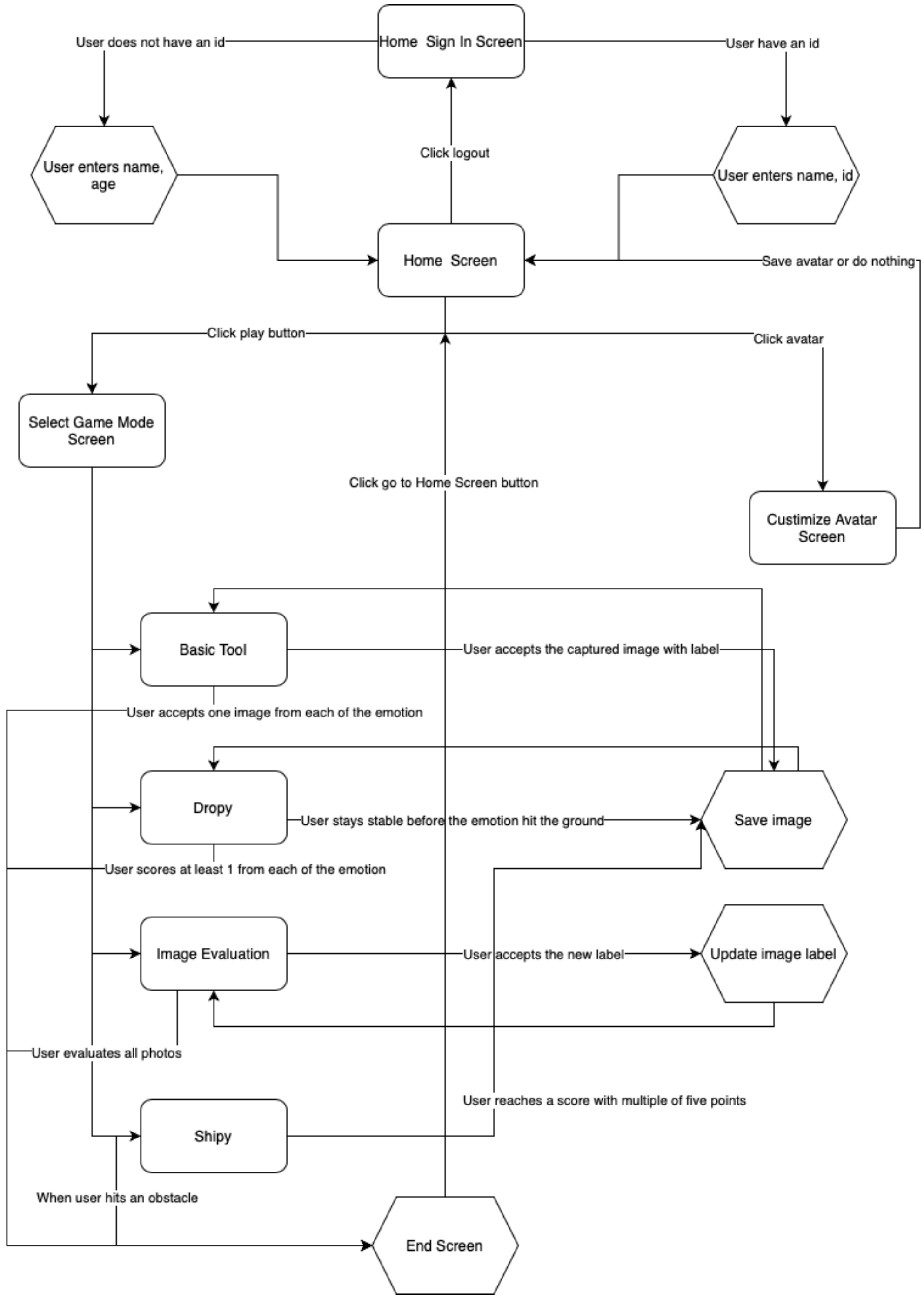

Figure 2.7 : Game flow

General system flow is given above. After logging in, the user can navigate to the select game mode screen. On that screen, the user can navigate back to the home screen or select a mode. There are four modes on that screen. Three of them for photo gathering and one of them is for evaluation of the saved photos.

2.2. Tool Modes

Figure 2.8 : Select mode page

An interval screen welcomes to navigate the user to tool modes.

2.3.1. Basic Tool

Basic Tool mode is primarily designed for adults or teenagers who want to pose emotions. In the top left corner, there is a timer that the user should follow because when it hits zero the photo is captured. In the top center, there is an avatar which is customized by the user. This avatar is working as a pause button as well as a feedback tool. It moves after some user actions for coloring the game screen. In the bottom left corner, there is an emotion to pose. After the counter times out, the captured photo appears in the right bottom corner with approval buttons. Users can deny the photo and recapture the emotion again. If the user approves, the tool continues to the next emotion. These captured images are stored in the application until all emotions are saved. After that, images are saved to the object database and their information is saved

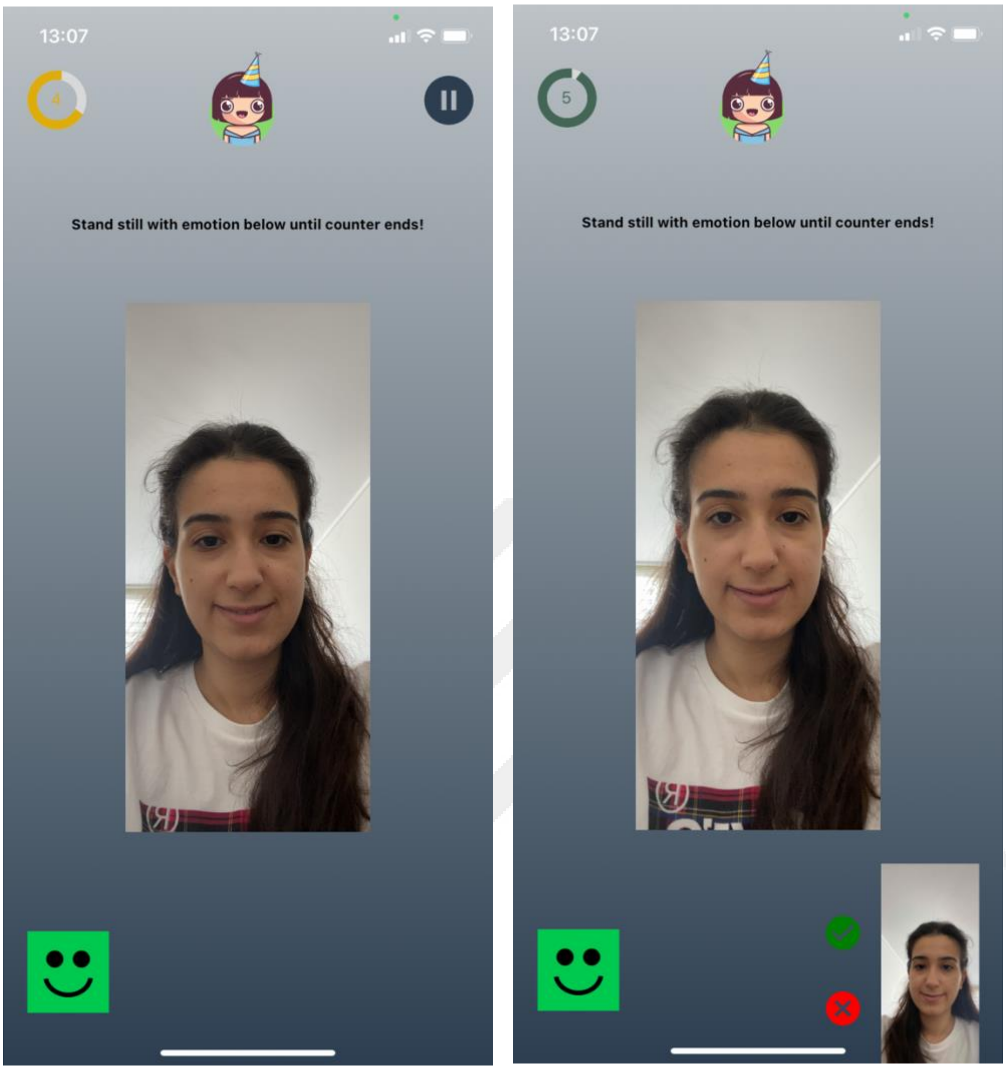

Figure 2.9 : A screenshot from BasicTool

into Hasura with labels. In termination, there is an end screen that navigates the user to the home screen.

2.3.2. Dropy

Dropy is a game that player tries to break falling emotions with posing them. The player should stay still with that emotion in their faces while emotion falls. If the player moves, the counter resets. When the counter hits zero, emotion will break and the player gets a point. Whenever the user gets a point, the game saves the image with that label. After at least one image from each emotion gathered, the game ends.

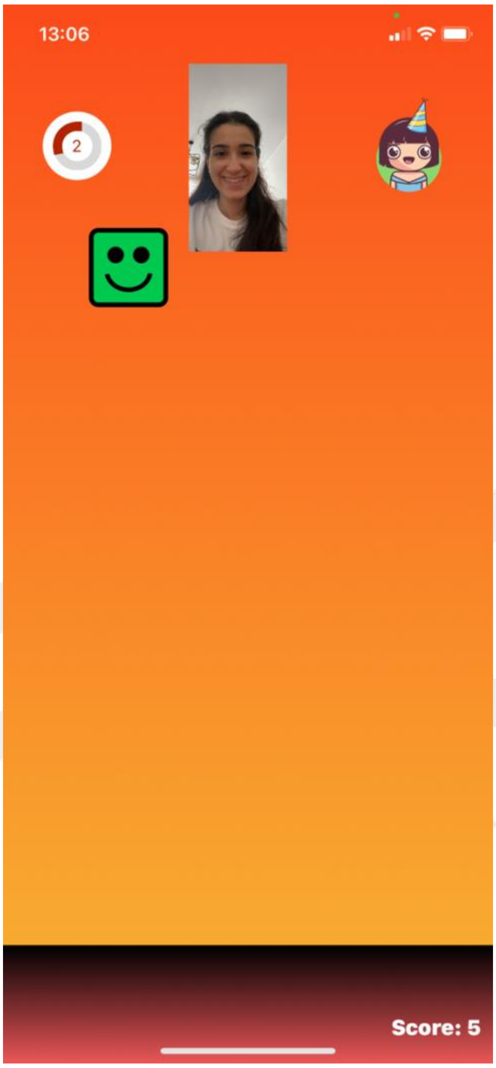

Figure 2.10 : A screenshot from Dropy

In the top left corner, there is a counter that shows the time left for breaking the emotion. If the player does not stand still this timer will be reset and the player may not get the point if there is not enough time. In the top middle, there is a camera view for the player to see themselves. In the top right corner, there is an avatar that works as a pause button. It also creates reactions like wiggles, rotations. Also at the bottom, according to player actions, snack bars may appear in order to give positive and negative feedback.

2.2.3. Shipy

Shipy is an endless runner game designed for children. There is a main character called Shipy who tries to avoid obstacles to survive. If the user hits a number that can be divided by five, a photo is captured. It is labeled as unknown and it is expected that the user will evaluate these photos in the photo evaluation mode.

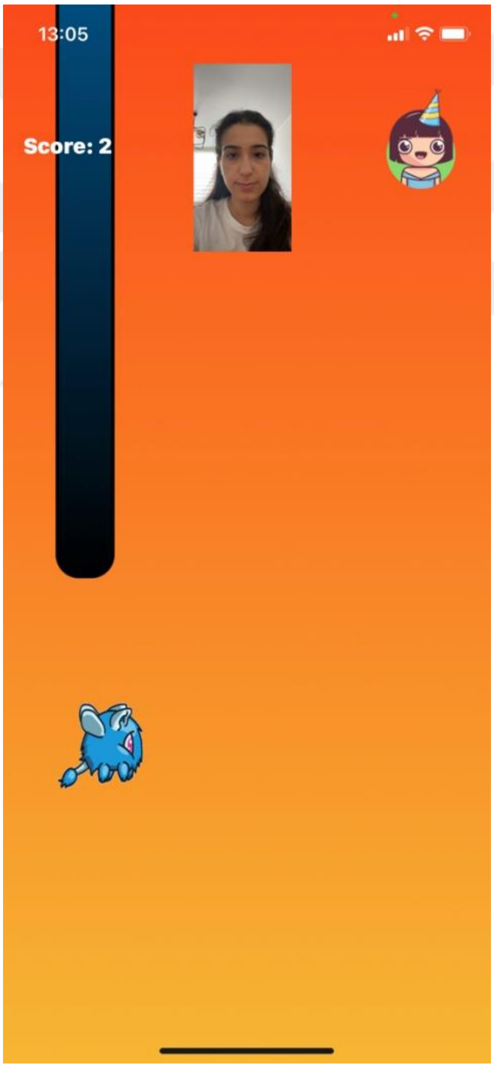

Figure 2.11 : A screenshot from Shipy

In the top left corner, there is a score area for following the progress. In the top middle area, there is a camera view for informing the player about capturing the image as well as to make them see themselves. In the top right corner, there is an avatar that feedbacks the player on each score. Also, it is working as a pause button.

2.2.4. Photo Evaluation

In tool modes, after some conditions happened, images are captured and saved to the database. Except for the images created by the Basic Tool mode, labels of these photos are not approved. They are needed to be approved because these images are created by games with predicted labels but they are not certain. In this mode, these photos will be evaluated by the player or anyone else to ensure that labels are correct. If they are the wrong user can update labels to correct ones.

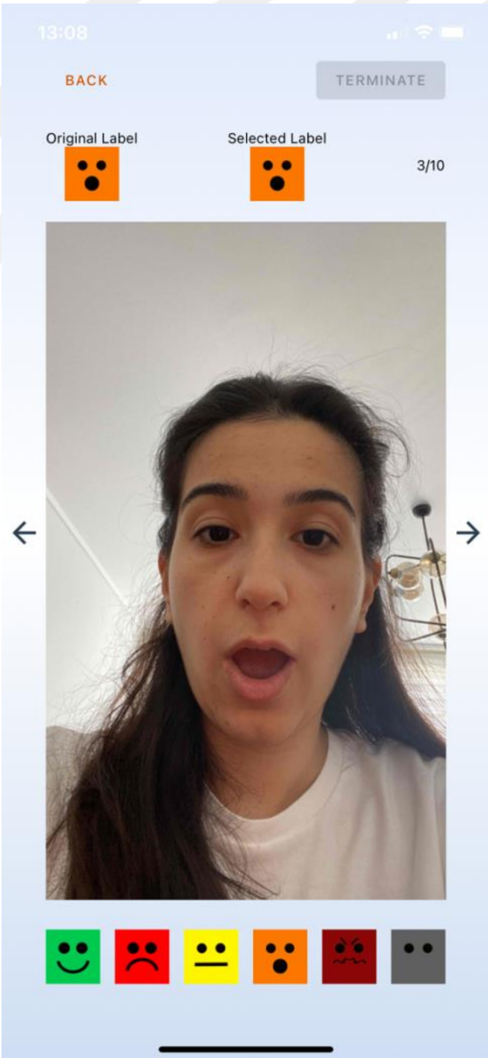

Figure 2.12 : A screenshot from Photo Evaluation

For each not ensured image, in the top left corner, there is an emotion icon for prediction by the game. In the top middle of the screen selected emotion is shown. In the top right corner, there is a terminate button that will stay disabled until all image labels are decided. On the left and right sides of the screen, there are navigation buttons to switch between photos. At the bottom of the screen, the user can select the emotion which fits the image. After termination, all image labels are updated in the database.

3. RESULTS & EVALUATION

Although the game is mainly developed for children, all game modes are tested with both children and adults. For iOS devices, the game can only be transferred via cable connection. So, without registering the application to the App Store, the game is not sharable via the internet. On the other hand, the application can be exported as an Android application without registration. Because of that, the application is shared as an Android application with the testers. While sharing the application, minimal information is given about the application but it is not detailly explained because of determining whether the game is self-explanatory or not.

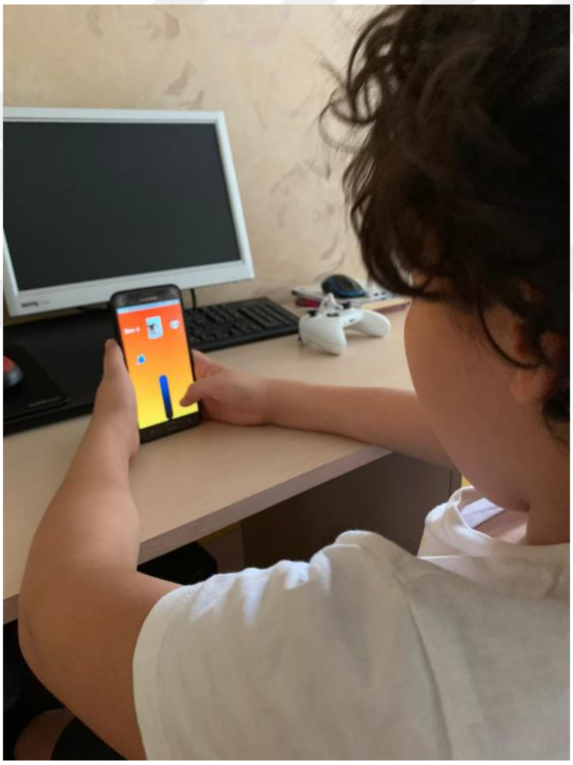

Figure 3.1 : A child testing the game

To child testers, it is told that you can play Dropy and Shipy until s/he is bored. The game is explained briefly but they are not forced to play. After the game, a mini verbal survey is conducted about whether they like the game or not. There is a total of 7 children testers that are 4 girls and 3 boys between seven and fourteen ages (average: 8.14 years).

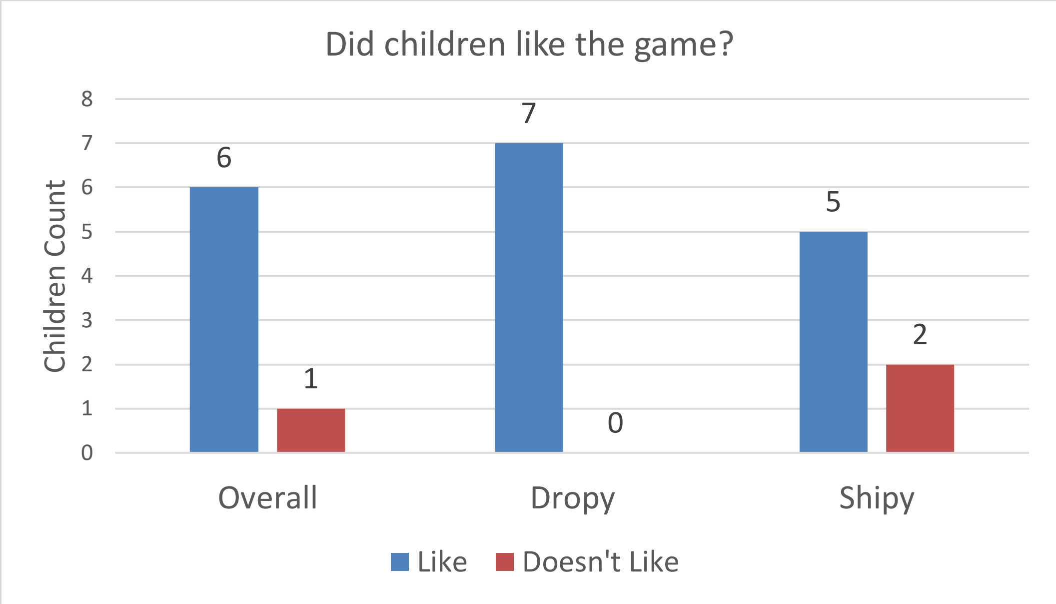

Figure 3.2 : Did children like the game? Chart

As shown in the Figure 3.2, children generally liked the games. It is observed that some children played the game the following days without asking from her/him. While 100 percent of the children like Dropy, 71 percent of the children like Shipy. When it is verbally asked why they don’t like Shipy, they mostly complain about the controls. It is observed that controls may be tricky for kids who do not play video games so often.

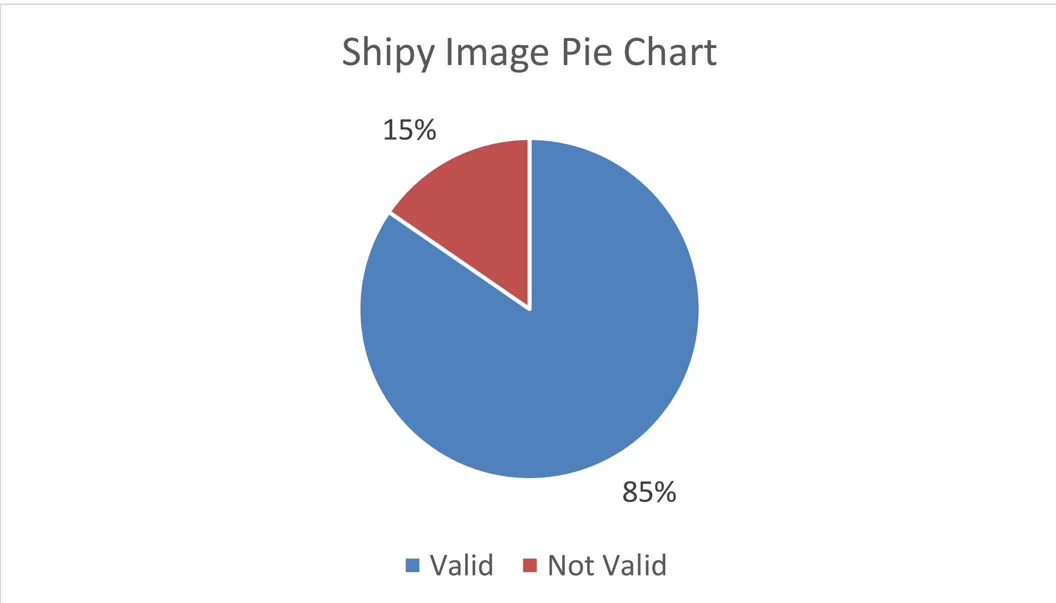

Figure 3.3 : Shipy game mode image validation rate pie chart

In Shipy, images are not labeled by the system so images are labeled after the game by their parents. As shown in the Figure 3.3, most of the images are valid. Validation of the image is decided as to whether is image can be used as data for algorithms or not. Validation of the image is decided by the parents of the children after the game.

In Dropy, images are labeled but they need approval. After image evaluation by children's parents, images are correctly labeled. Like Shipy, Dropy has a high valid image rate as well. 67 percent of the images are correctly posed and 15 percent of the images are wrongly posed but still usable. Only 18 percent of the images are not usable. Which makes that 82 percent of the images are usable.

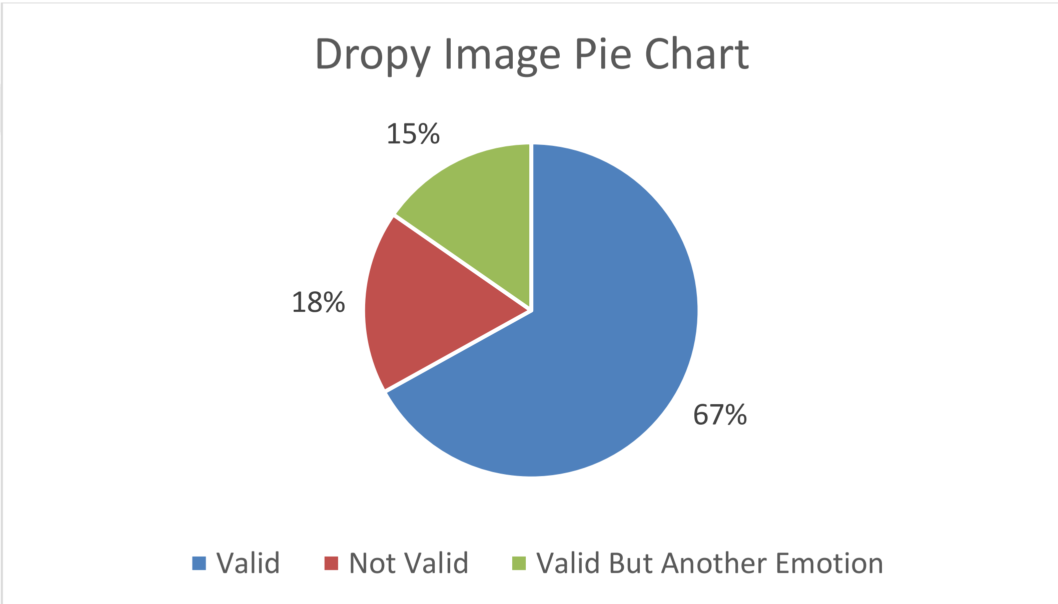

Figure 3.4 : Dropy game mode image validation rate pie chart

In addition to that, Dropy has distributed emotion types that are targeted. In Dropy, while children pose the dropping emotion and the images are saving with labels, these labels are not certain. After the game, the parents of the children validate the gathered images. As shown in the Figure 3.5, while children pose most of the emotions with ease, they have trouble posing angry emotions. Even in the angry emotion, there is 35 percent of the images are correctly posed which is adequate. On the other hand, all other emotions have good correct pose rates.

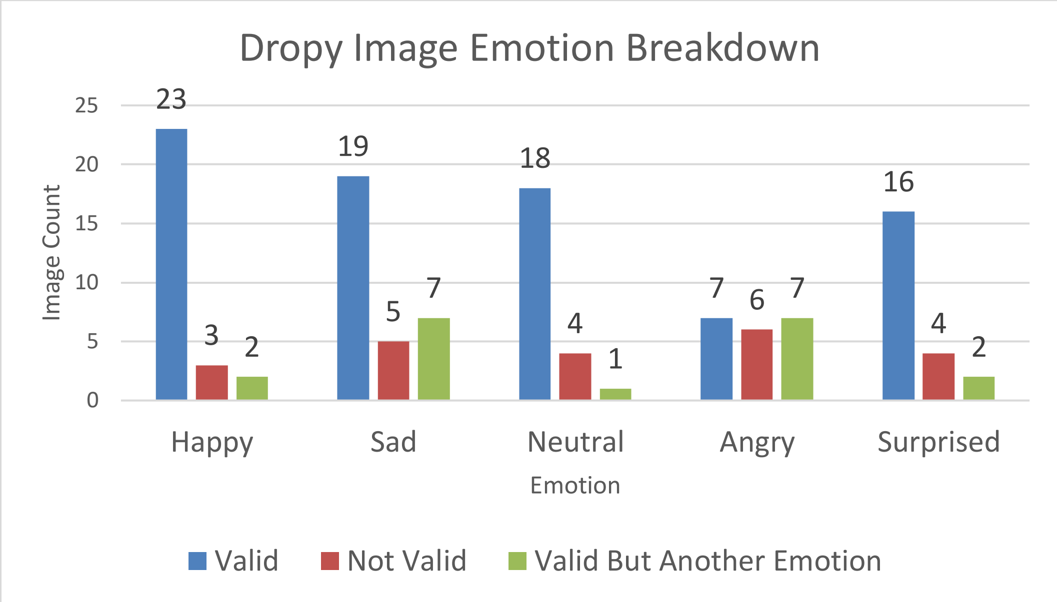

Figure 3.5 : Dropy game mode emotion distribution

Overall, from the all tools 123 valid images are gathered from 7 children. Other than angry emotion is distributes similarly.

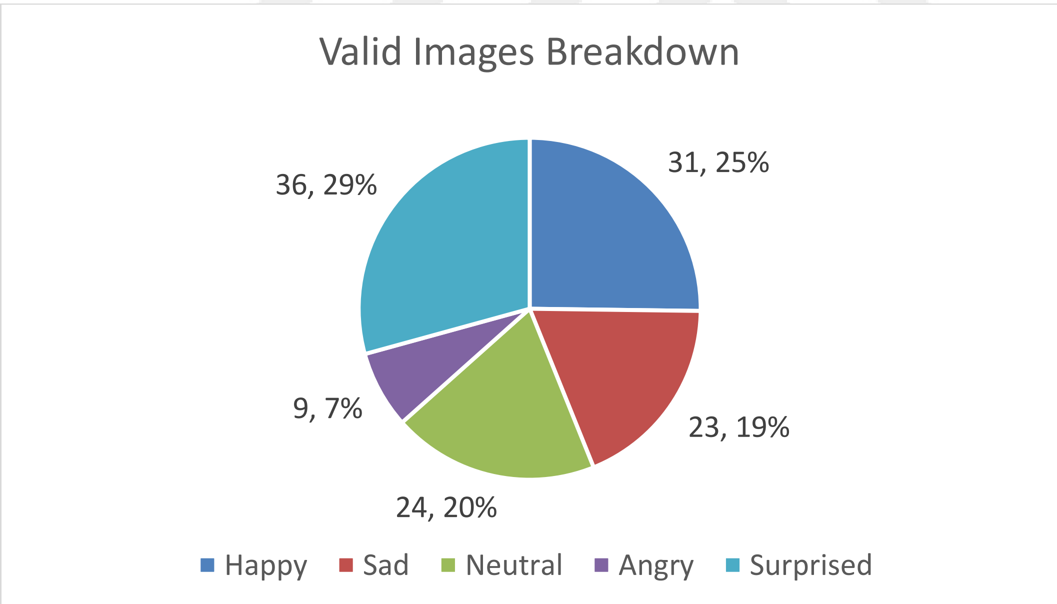

Figure 3.6 : Valid images breakdown

Averagely children played the game for 4 minutes and 18 seconds. It is observed that some children played again to raise their scores. While average playtime in girls is 3 minutes and 40 seconds, average playtime increases to 5 minutes and 8 seconds in boys. It is interpreted that this situation depends on the competitiveness of the children because boys try more than girls in order to beat their scores in the game.

To sum up, it can be said that the game is served its purpose. The goal was to gather images from children that contain different emotions with labels in order to feed face recognition algorithms. With these outputs, it can be said that this project may be used for generating facial datasets.

4. CONCLUSION & FUTURE WORK

Detecting emotions without any previous information about that person is a challenging problem because every face has unique features. Problems like that are solving by machine learning techniques but it needs serious pre-work.

In this thesis, a tool for gathering data for the pre-work is developed in order to collect facial data, especially from children for facial emotion recognition. The tool has three modes that include gamification elements. A customizable avatar is added to create a more intense game flow. Dynamic feedbacks and score mechanics are some other gamification elements that added the tool to increase immersion.

In order to create a long-term usable application, cloud-driven application features are added. Firstly, user information and actions are held in the database for further analysis work. For the images, an object storage server is built in order to store images. Images are gathered by several data collection tool modes and labeled according to the action.

The application is tested with children. In 147 collected images, 83 percent of the images are usable. Children generally liked the game and they perform well in general. However, most of the children are troubled to pose angry emotions. In angry emotion, although only 35 percent of the images are correctly posed, still averagely one angry labeled image is collected per children which is acceptable.

With this tool, labeled high-quality face photos are gathered from children. This work is developed for an academic work team and this tool will be used by other team members. In future work, new modes and gamification elements will be added in order to collect negative emotions, especially angry emotions. Besides, these collected images will be used to construct facial emotion recognition models for children based on machine learning and deep learning techniques.

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