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An Adaptive System Architecture for Creating Visual Stories for Children on the Autism Spectrum

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***Abstract*—Children with ASD need personalized therapy in order to overcome social and emotional difficulties that they experience in their daily routine. They have hugely varied, heterogeneous needs, and should therefore be well served by services truly tailored to an individual, with all of his/her personal needs and preferences. As they learn better visually, visual stories are often a valuable tool for their education and their everyday life. In this paper we propose a tool that enables parents make their own visual stories using artificial intelligence in order to be personalized to every child's needs.**

***Index Terms*—autism, visual stories, AI tool.**

I. Introduction

THE diagnoses of children with ASD are constantly increasing. Autism is a spectrum, which means it affects each child differently in terms of cognitive abilities, behavior, sensory processing, and social interaction [1]. Despite these variations the vast majority of children with ASD struggles with social cues, sensory sensitivities, or emotional regulation [2]. Except the social challenges that children with ASD have to face, they have also difficulties coping with changes [3]. If they have to interrupt their routine they may respond with repetitive behaviors, tantrums, or even aggression. A right preparation for the unpredictable situations such as a delay or a queue is crucial.

It has been found that children diagnosed with autism tend to learn better visually [4]. According to Temple Grandin, people with ASD translate spoken and written language into colorful movies. When someone addresses them, his words are automatically translated into images [5]. The method of visual stories largely reflects this particular way of thinking and consequently the way of learning. These stories present information visually in a clear and reassuring manner and this makes their environment more predictable and as a result more affordable. Visual stories are brief stories with images and short texts that describe social situations and how to respond and behave to the specific situations. This is really helpful when live sessions are not enough or not possible for various reasons, e.g. due to the pandemic or because the child is in isolated areas where there is no speech therapist.

Most technological applications focus on improving learning disabilities and have not concerned improving social skills [6], [7], [8]. In this paper a software application is presented with a strong focus on visual stories, helping children with ASD address social dysfunction. This application will help parents and therapists build custom visual stories. The application will integrate a set of functionalities assisted by appropriate recommendation mechanisms in order to address in the best way each child's special needs and will be accessible from everyone and everywhere.

The scope of the paper is to present and evaluate the architecture of a software application that will support parents and therapists to use and create visual stories that will improve their children's social skills and their everyday life. The impact of this solution is multifaceted as it will allow people to have access to multiple visual stories remotely without restrictions. Moreover, therapists will be supported by a powerful tool that will facilitate the creation of visual stories. This support will increase the capacity of therapists and medical experts, since the need for physical presence will be decreased significantly. On the technological point of view, the proposed platform incorporates technologies in a state-of-the-art, scalable architecture that manages to efficiently handle heterogeneous data in terms of data type (images, structured data) and data volume.

The rest of the paper is structured as follows: In Section 2 the proposed architecture is presented. In section 3 the basic components are shown and section 4 concludes this work.

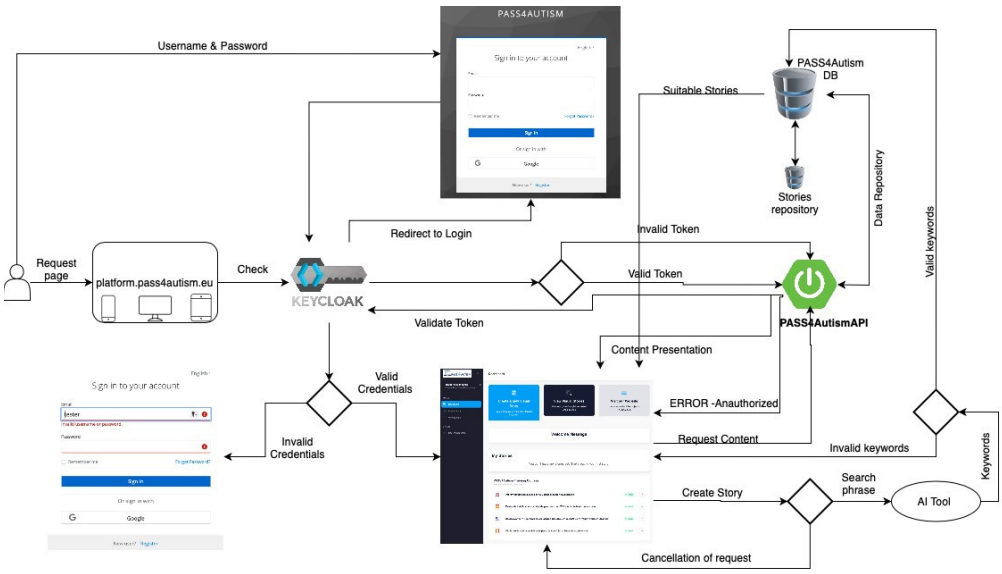

Figure 1. System Architecture

II. Architecture

The two main entities of the proposed application are: the cloud computing infrastructure and the graphical interfaces (Figure 1). The cloud computing infrastructure comprises of the stories component, the AI ranking and the stories repository and the graphical interfaces are the ones that are required to offer the user all the functionality and intelligence of the system.

The AI Tool is based on keyword matching algorithm to provide the most suitable story/environment according to the user's input. The user selects the story that is most relevant with the searching keywords according to the rankings provided by the AI Ranking module. Then, the story can be personalized based on the gender or the name of the child. The stories created are stored in the Stories repository as files as well as the images of the visual stories separately. The repository also includes all files of the educational module.

III. Basic Components

A. Cloud Infrastructure

An architectural style that can effectively address the above requirements of modern applications is micro-services [9]. Micro-services are small autonomous services that are developed independently, with a single and well-defined purpose. Their independent development capability has the advantage of continuous implementation and delivery of new versions of each application. They can be scaled up or down independently of other microservices and developed with tools that best suit their needs. In addition, because of their size, they are easier to maintain and more fault-tolerant, as the failure of one service does not affect the whole system, which could happen in a monolithic.

The infrastructure shown in Figure 2 is based on Docker technology [10] and follows the microservices architecture.

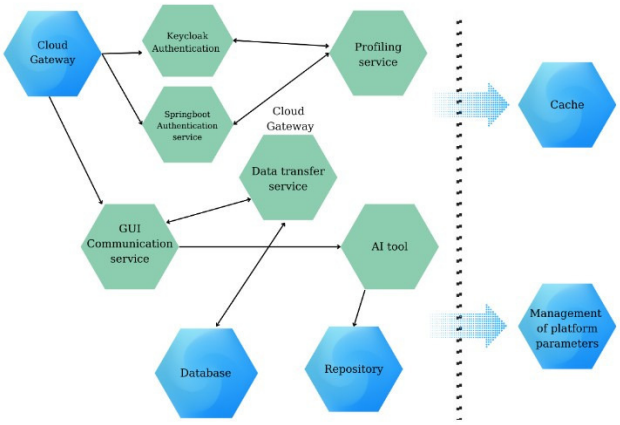

Figure 2. Microservices that are implemented

B. Database schema

The data of the stories and the users are stored in a relational database that was implemented in the open-source PostgreSQL solution [11]. There are 2 groups of users (parents, therapists) and for each entity a table is created as shown in Figure 3.

Each story is saved in the stories table, with a unique code, the images used and the corresponding texts. It also has the id of the user who created it, the keywords that characterize it and whether it is public or not. All the information needed for each user's feedback is stored in the table with the homonymous title.

A user can have multiple stories. Also, each user (parent or therapist) is provided by the application with a unique "token" through which they can enter and implement all the actions he/she wants. At the same time with the information stored in the "token" table and the time until the key is expired and needs to be refreshed, we can also have a record of how active the users are.

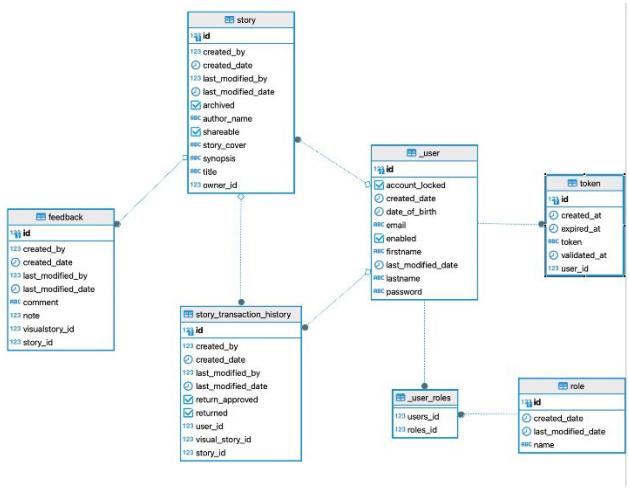

Figure 3. Database schema

The multimedia needed or resulting from the stories will be stored in the file repository that will be implemented and there will be tables that will associate the stories with the paths of the corresponding files.

C. *Authentication Service*

A primary concern for any web-based program is application security. Reliability and confidence are maintained only when user data is protected. Our application security procedures need to be strengthened as cyberattacks become more complex and common. One important step in this direction is the integration of Double Authentication (2FA) with Oauth [12].

Open Authorization (OAuth) is an open protocol that protects application authorization without requiring user credentials to be disclosed. This implies that without disclosing their passwords, users can grant access to particular data or features of an application. Tokens with a limited lifespan and particular access rights are used in place of passwords.

A security measure called double authentication (2FA) requires the user to provide two distinct forms of identity. This usually involves both something the person has (like a mobile phone or a unique token) and something they know (like a password). Even if the password is compromised, it will be far more difficult to access accounts with this additional degree of security.

OAuth and 2FA must be included to keep the application safe from online threats. The risk of eavesdropping is greatly reduced when user passwords are transmitted over OAuth instead of being stored. In addition, even if someone gets to get the password, 2FA adds an extra layer of security that makes it very difficult to access accounts illegally. Using these technologies also makes it easier to abide by laws requiring stringent data protection procedures. For instance, laws like the General Data Protection Regulation (GDPR) [13] mandate the adoption of sophisticated security mechanisms to safeguard consumers' personal information. By using the OAuth and 2FA protocols, our business can comply with these requirements and lower the risk of penalties and other legal repercussions.

Furthermore, improving the application's security boosts user confidence. Customers are more inclined to select and stick with a service that demonstrates its concern for data protection. In addition to safeguarding data, additional security improves our organization's reputation as a reliable, responsible corporation that makes investments to protect its clients.

We will utilize OAuth 2.0, the most recent version of the protocol that provides enhanced security and flexibility, to incorporate OAuth into our application. To authorize users, we will collaborate with reliable identity suppliers like Facebook, Google, and other reliable sources. By doing this, we will be able to take use of these providers' current security architecture and give our users a seamless, safe experience.

We will give several verification options to integrate 2FA in order to maximize flexibility and user-friendliness. Users will have the option of confirming through e-mail or verification apps like Google Authenticator. We'll make sure the verification procedure is simple to use and accessible while maintaining the highest level of security.

D. *Profiling Service*

User authentication and authorization services are supported by Keycloak [14]. Keycloak is an open source software product that enables simple connection to identity and access management aimed at modern applications and services. As of March 2018, this WildFly community project is managed by Red Hat and used as the upstream project for the RH-SSO product.

The proposed platform, through Keycloak, supports 3 three distinct user roles, each with specific permissions, reflecting the desired level of interaction with the platform’s content. The simple user can browse stories, create their own private stories, visible only through their personal profile, plus can delete them at will. The second user type is the “Therapist”, a verified professional accredited by the project’s partners. Therapists are granted extended rights: they can access all user-submitted stories, evaluate them using a 0–5 star rating system, and decide which stories are appropriate for public display. Lastly, the “Administrator” possesses all the aforementioned capabilities, along with the authority to remove stories or suspend user accounts that violate the platform’s usage policies.

E. *Repository*

The repository for all the images and training material will be implemented using the platform Minio [15]. MinIO is an efficient open-source distributed object storage server that offers the ability to store and manage large volumes of data and it is suitable for storing unstructured data such as photos, videos, logs, backups and containers. It is characterized by high performance, scalability and security, while supporting advanced functions such as load balancing and data replication. Integrating MinIO into an application can significantly improve the efficiency and reliability of data storage, while ensuring ease of infrastructure deployment and management. The architectural choice of microservices

through the distributed operation of multiple docker containers within a Kubernetes cluster gives many conveniences as has become clear so far. But at the same time, it also introduces many challenges such as that of managing the files that the platform must share. These files concern images that make up the visual stories. This challenge was addressed by adopting MinIO [3] as the technology to store and share the files necessary for the execution of the intervention plans.

The basic interface to the MinIO service is given in Figure 4, where the 3 endpoints are shown. The image illustrates the available RESTful API endpoints of the "File Handler" subsystem, which manages file storage and retrieval using the MinIO service. The POST /minio/fileHandler endpoint enables users to upload files to the storage system. The GET /minio/file-url endpoint returns a URL for secure and temporary access to a specific file, allowing users to download it without further authentication procedures. Finally, the GET /minio/all-files endpoint provides access to the full list of stored files, facilitating comprehensive oversight and management of the stored content.

Figure 4. Interface to the MinIO service

F. AI Tool

The AI Tool is responsible for providing a list of the most suitable stories according to the user's inputs. In specific, the tool allows users to perform a keyword search and ranking, listing their required environment (e.g., super market) and context (e.g., large crowd) in a search bar. Ranking is a fundamental concept in information retrieval, where the goal is to sort items in a way that the most relevant results appear first in response to a user's query. By effectively ranking documents, we ensure that users receive the most pertinent information first, enhancing the overall user experience.

The AI tool performs a keyword search on existing stories and ranks them as per their relevance to the user keywords. To this end, AI-driven document search and ranking will be implemented. Modern AI-based document ranking algorithms based on the Transformer architecture have superseded previous approaches (e.g., TF-IDF, bag of words, word2vec, etc.). AI ranking models are able to consider language semantics and not just keyword matching to rank items based on relevance to a given query (i.e., they can establish when items and queries are semantically related). To this end, the AI Tool will leverage the Transformer architecture, to capture context from and the semantic meaning of queries and social stories in ranking tasks. For a given query, the AI Tool will compute a relevance score for all existing social stories (pointwise ranking approach). In specific, the AI tool pointwise ranking approach is descripted in Figure 5 and will be implemented as follows:

- A pre-trained Transformer model and tokenizer is loaded.
- A user query and the list of social stories (i.e., items) with their description is provided as input.
- The query-item pairs are tokenized.
- The tokenized pairs are given as an input to the model to get their ranking scores.
- The items are ranked based on their scores.

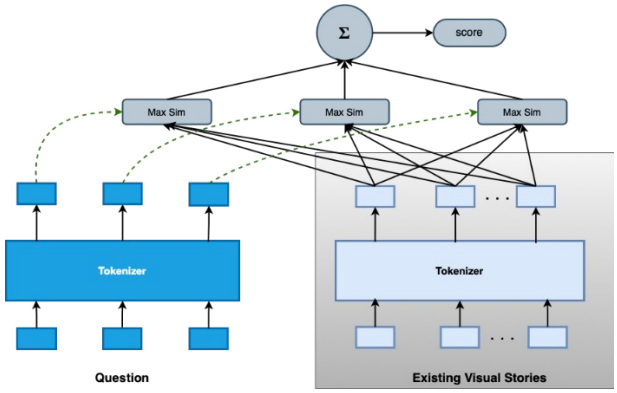

Figure 5. Ranking Process

G. Interfaces

The graphical interfaces are designed to provide end-users with the project's full range of services in a user-friendly, clear, and comprehensible manner. These interfaces aim to both therapists and parents. Through these, therapists and parents can create new visual stories aimed at addressing the specific challenges of parents of children with autism, while parents are encouraged to benefit from the use of technology and find the visual stories that interest them.

To achieve the goal of developing efficient reactive web interfaces, an important tool is the React library. React (also known as React.js or ReactJS) is a free and open-source JavaScript front-end library for building user interfaces and user interface components. It is maintained by Facebook and a community of individual developers and companies. React can be used as the foundation for developing web applications that are responsive to different screen sizes. The React code consists of building blocks called components. These components can be rendered to a specific element in the DOM using the React DOM library.

The View Stories page is one of the most critical pages of the platform and it is designed to provide users with a seamless and engaging experience for exploring all the visual stories created within the platform. This page serves as a comprehensive library, where users can view, filter, and navigate through a wide array of visual stories that have been crafted by others or themselves. The platform's intuitive design and

filtering capabilities ensure that users can easily find stories that meet their needs or interests.

Upon accessing the View Stories page, users are presented with a complete catalog of available visual stories. These stories may include those created by the user, as well as stories shared by the broader community, depending on their access level and privacy settings.

Story Display: Each visual story is displayed in a clean, organized layout, showing the story's title, a thumbnail image representing the story, and brief metadata such as language and target audience (age group or difficulty level). Users can click on any story to view it in full detail.

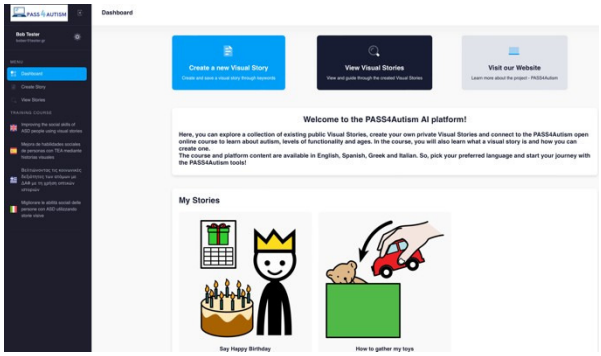

Figure 6. Main Dashboard

To ensure that users can quickly find the most relevant stories, the View Stories page includes robust filtering options. Users can refine their search results by using several key filters:

Language: This filter allows users to view stories in their preferred language. It's particularly helpful for those working in multilingual environments or for users who want to read stories in a specific language, such as English, Spanish, Greek, or Italian.

Levels: Users can also filter stories based on functionality levels. The three ASD levels of severity according to the DSM-5 were used in the filter to ensure users can find stories appropriate for different developmental or language stages. Specifically, the levels are: level 1 - "requiring support", level 2 - "requiring substantial support" and level 3-"requiring very substantial support".

Age: This filter helps users sort visual stories based on the age group they are targeting. Whether the user is searching for stories designed for young children, teenagers, this option ensures that the content they view is age-appropriate and developmentally suitable.

These filters provide a streamlined browsing experience, enabling users to quickly narrow down the available stories to those that align with their specific needs.

Once a user finds a visual story that interests them, they can click on it to view the story in full. The detailed view showcases the sequence of images and titles that make up the story. Users can navigate through the story page-by-page, gaining insight into how each visual and caption builds the narrative.

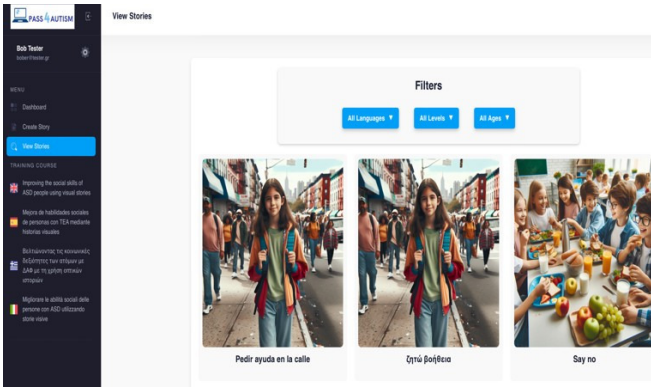

Figure 7. Search stories page

Additionally, users can benefit from the following options while viewing a story:

Story Overview: The detailed view provides an overview of the story, including the language, level, and target age group. This helps users immediately understand the context of the story and how it can be used effectively.

Story Preview: As users scroll through the pages of the visual story, they can gain a full preview of the content, making it easier to decide whether the story is suitable for their needs.

For users who want to explore similar stories, the platform offers story recommendations based on the current selection. If a user views a particular story related to social skills, for example, the platform may suggest other stories that also focus on social development for individuals with autism. This enhances the user's discovery experience and promotes engagement with additional content.

The View Stories page is not only a tool for browsing, but also a showcase of the collective work of the community. Users who have chosen to make their stories public contribute to a growing repository of resources that others can ben-

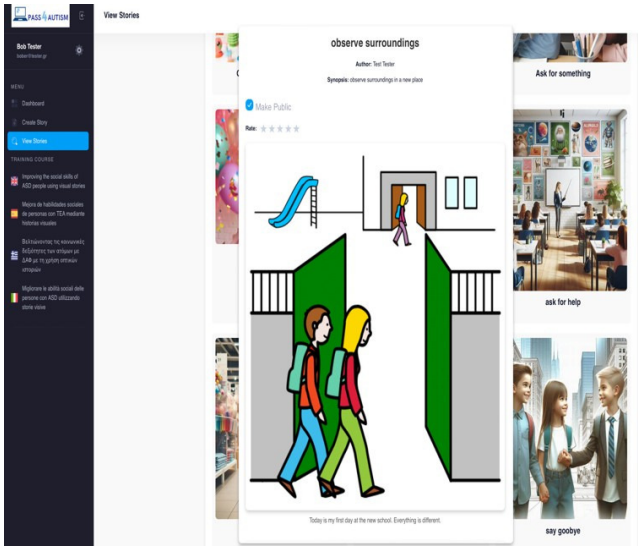

Figure 8. View story interface

efit from. These shared stories can be used for teaching, therapeutic interventions, or even personal use, helping to support the social and communication skills development of individuals with autism.

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