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Development and Implementation of 3D Anatomical Exercise Encyclopedia Application Optimized for Korean Users

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Abstract

In modern society, with the growing emphasis on health and fitness, the need for education on proper exercise methods is increasingly highlighted. The purpose of this study is to develop a 3D anatomical exercise encyclopedia application optimized for Korean users, enabling them to clearly understand the anatomical structure of exercises and easily learn proper exercise methods. In this study, a user-friendly interface was developed using Flutter and Unity, and a feature was added that allows users to intuitively check muscle activation through 3D models. Users can easily understand the anatomical structure of the exercise areas through 3D models that can be zoomed in, out, and rotated, and can easily access information such as exercise definitions, exercise sequences, agonist muscles, and synergist muscles. As a result of the study, most of the 21 users who used the application showed high satisfaction with the intuitiveness of the interface and the accuracy of the information, suggesting improvements such as the addition of exercise items and muscle highlighting effects, confirming the potential for developing an exercise encyclopedia application optimized for users.

Keywords: *3D Anatomy, Flutter framework, User interface, Unity, Weight training*

1. Introduction

In modern society, as the importance of health and fitness becomes increasingly emphasized, the need for education on proper exercise methods is emerging. Incorrect exercise not only reduces effectiveness but can also cause serious health problems [1-2]. In particular, beginners or those without professional guidance on exercise find it difficult to learn and master proper exercise methods. Due to a lack of understanding of exercise, they are more likely to continue exercising with incorrect posture or methods. Therefore, there is a need for a systematic and intuitive educational tool for them, and to solve this problem, applications that visualize 3D models to inform users of the stimulated areas during exercise exist overseas, but such applications developed in Korea are lacking [3]. An example of the necessity for using 3D models can be found in the study by Kim et al. (2014), which investigated the level of immersion between 2D and 3D-based content. The study concluded that 3D content demonstrated a significantly higher sense of presence [4]. In addition, Kim et al. (2008) analyzed exercise injury factors in bodybuilders, pointing out that a lack of understanding of exercise areas was a major cause, but no specific visual tool was developed to solve this [5]. Lastly, Lim (2019) discussed the necessity and effects of exercise and emphasized the importance of applications providing various exercise information, but due to the complexity of the interface and accessibility issues, practical

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usability was low [6].

Figure 1. 3D Atlas, iMuscle 2

Furthermore, in the study by Yu et al. (2015), the user interface of exercise-related mobile healthcare applications was evaluated, but a complex GUI that hindered intuitive use by users was identified as a problem [7]. Additionally, TEPLÁ et al. (2022) studied the positive effects of 3D models and animations on learning outcomes, but examples of this technology being optimized for Korean users were lacking [8]. POWER (2022) provided information on various exercises and their associated muscle activation, but problems such as the lack of multilingual support and inaccurate translations were found to degrade user experience [9]. These previous studies have contributed to the development of tools for exercise education, but most studies revealed limitations due to the lack of intuitive 3D visualization and user-friendly interfaces. In particular, applications optimized for Korean users have rarely been developed, and due to the lack of multilingual support and accurate translations, there are issues that degrade user experience [10]. This study developed a 3D anatomical exercise encyclopedia application using Flutter and Unity to address these issues. During development, 3D models were used to allow users to intuitively understand the anatomical structure of exercises, and a user-friendly interface and accurately translated exercise information in Korean were provided. Additionally, a system was designed using an SQLite database to store and effectively retrieve information such as exercise definitions, exercise sequences, agonist muscles, and synergist muscles. This application is expected to overcome the limitations of previous studies by providing an optimized educational tool for Korean users and to offer practical help in learning proper exercise methods.

2. Development of 3D Anatomical Exercise Encyclopedia Application

2.1 Development Environment and Tools

The hardware environment used in this study includes macOS Sonoma as the OS, Apple M1 as the CPU, Integrated 7-core GPU, 8GB of memory, and 256GB SSD for storage. The software environment utilized Flutter (3.19.6), which is a cross-platform user interface framework developed by Google that allows the same codebase to be used on both iOS and Android. Flutter offers fast development speed and high productivity, and flexible user interface design is possible through various widgets.

Table 1. Configuration of Development Environment.

Specification	Modules Used in Flutter
macOS Sonoma	flutter_unity_widget: 2022.2.1
Apple M1	path: 1.9.0
Intergrated 7-core GPU	sqflite: 2.3.3+1
8GB	path_provider: 2.1.3
256GB SSD	

Unity (2022.3.26f1) was used for 3D modeling, Android Studio for the integrated development environment, and SQLite for the database.

2.2 Operational Structure of the 3D Anatomical Exercise Encyclopedia Application

The application structure consists of four main parts: the main screen, search function, 3D model screen, and database function, as illustrated in Figure 2.

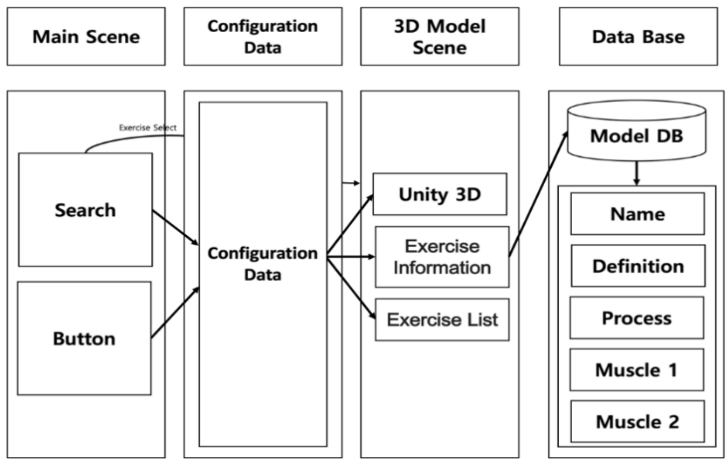

Figure 2. Operational Structure of the 3D Anatomical Exercise Encyclopedia Application

When the application is launched, the user can select the desired body part from the main screen. Once the desired part is selected, the Configuration Data is configured, and the user is taken to the 3D model screen. Additionally, if the user searches for and selects an exercise from the main screen, the Exercise Select information is sent along with the Configuration Data to configure the 3D model screen. The 3D model screen displays the 3D model, exercise list, and detailed exercise information. The 3D model uses Unity 3D objects. The exercise list consists of images and names of the exercises and allows horizontal scrolling to select many exercises. When the user selects a desired exercise from the configured exercise list, the application communicates with the database to retrieve and display the detailed information on the screen. The detailed exercise information includes the exercise definition, exercise sequence, agonist muscles, and synergist muscles. The Name field is configured to retrieve data by comparing the name of the selected exercise with the exercise name stored in the database. Additionally, when an exercise is selected, the information on the agonist and synergist muscles of the selected exercise is sent to Unity to activate the outline on the corresponding area, allowing the user to see which area will be worked on during the exercise.

2.3. Application Implementation

Table 2 contains pre-defined information structured in SQLite format and included in the application. The "Name" field refers to the name of the weight training exercise, and the "Definition" field describes the definition of the exercise. The "Process" field contains the sequence of the exercise, while "Muscle1" and "Muscle2" describe the agonist and synergist muscles, respectively.

Table 2. Table Structure.

Field Name	Content
Name	Weight training name
Definition	Weight training definition
Process	The order of exercise in weight training
Muscle1	Agonist

Muscle2	Synergist

Figure 3 illustrates the part of the application where communication with the database occurs, specifically in the exercise detail section. The database connection is specified in the initState() function, so when the 3D model screen is accessed, the connection to the database is completed immediately, making it possible to query the data right away. When a desired exercise is selected from the exercise list configured on the 3D model screen, the DBHelper class function is executed, concluding with final user feedback.

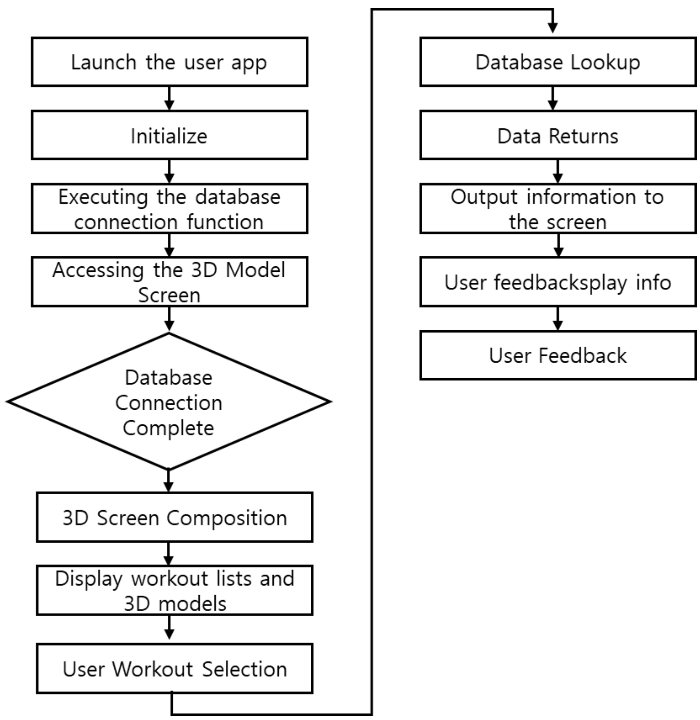

Figure 3. Communication Process between the Application and Database

This function queries the database based on the table name, field name, and value to return matching data. The retrieved data is stored in an instance object of the Model class, which is responsible for holding the exercise information, and is displayed on the screen to show the exercise definition, sequence, agonist, and synergist muscles for the user to review.

2.4. Main Screen Configuration

When the application is accessed, the main screen is displayed. Users can select a button corresponding to the body part where the desired exercise is located to proceed to the 3D model screen. The button consists of the model's image, the name of the body part, and the main muscles in that area. Users can also directly access the description of a specific exercise by searching for it. Figure 4 shows the main screen and the exercise list displayed when a search is performed.

Figure 4. Main Screen and Search Screen

When a search is performed, the function shown in Figure 5 is executed every time there is input in the TextField.

```
void _updateSearchResults(String query) {
    List<String> results = [];
    Scenedata armsData = Scenedata.setData('팔');
    Scenedata legsData = Scenedata.setData('하체');
    Scenedata bodysData = Scenedata.setData('상체');

    if (query.isNotEmpty) {
      results.addAll(armsData.workNames.where((name) => name.contains(query)));
      results.addAll(legsData.workNames.where((name) => name.contains(query)));
      results.addAll(bodysData.workNames.where((name) => name.contains(query)));
    }

    setState(() {
      _searchResults = results;
      _searchQuery = query;
    });
  }
```

Figure 5. Pseudocode for Exercise Search Function

Query refers to the text entered by the user in the search bar. Results is declared to store the search results, and the information from the Scenedata class's arms, legs, and body is retrieved. The query is compared with the information in the Scenedata class to determine which part of the body the searched exercise belongs to, and the results are stored. Then, the results and query are saved in _searchResults and _searchQuery to display the exercise list in the main screen, creating the searched exercise list. In this way, two access methods are configured: selecting a body part to approach or searching by the name of the exercise to access the description. Once the desired part is selected, the Configuration Data is constructed, and data is sent to the 3D model screen to configure the display. Additionally, when the Unity project is loaded for the first time in Flutter-Unity-Widget, there is an issue with the initial loading time being long. To solve this problem, UnityController is pre-connected to Flutter-Unity-Widget from the main screen, making the connected controller invisible to the user. The connected controller is then transferred to the 3D model screen to be used continuously. This approach is advantageous for memory management and reduces initial loading time because it uses only one instance of UnityController. Thus, by initializing UnityController from the main screen in advance, the problem is solved, allowing users to quickly view the model when moving to the 3D model screen. This is an important aspect of improving application performance.

2.5. 3D Model Screen

Figure 6 shows the 3D model screen, which is configured to provide the 3D model, exercise list, and detailed exercise information.

Figure 6. Pseudocode for Exercise Search Function

The 3D model in the center of the screen highlights the muscle areas activated by the selected exercise. The exercise list corresponding to the selected body part is provided in a horizontal scroll format at the bottom of the screen. Users can select various exercises from this list, which includes the exercise name and its representative image, providing intuitive options for the user. When an exercise is selected, the exercise definition, sequence, agonist, and synergist muscles are provided in text format. The information on the agonist and synergist muscles of the selected exercise is then sent to Unity. Communication between Flutter and Unity is handled through functions such as SendMessageToFlutter(), onUnityMessage(), UnityWidgetController.possMessage(), and unityMessageManager.SendMessageToFlutter() within Flutter-Unity-Widget. The names of the objects in the 3D model are then compared with the names of the agonist and synergist muscles sent from Flutter, and an outline effect is added to the matching objects. This allows users to easily identify the agonist and synergist muscles, helping them understand which muscles are being used during the exercise. This information aids users in performing exercises correctly and understanding which muscles they are working. The 3D model screen also provides features that allow users to manipulate the 3D model directly. Users can check the position of the agonist and synergist muscles, their relationships with other muscles, and their attachment points on bones in detail. Figure 7 shows the screen when using the main manipulation functions of the 3D model.

Figure 7. Model Movement and Rotation, Model Zoom In and Out

The movement function allows users to drag the 3D model within the screen using two fingers. This allows users to observe the model from different angles and examine specific areas more closely. The rotation function allows the 3D model to be rotated by using one finger to perform a rotating motion on the touchscreen. Users can rotate the model 360 degrees to view muscles from various angles, which greatly aids in understanding the three-dimensional structure of the exercise. The zoom in and out function is implemented with a pinch gesture using two fingers. Users can zoom in on specific areas to see muscles in detail and zoom out to view the overall structure. This is particularly useful when checking small muscles or detailed anatomical structures. With these functions, users can freely manipulate the 3D model and easily understand the anatomical structure of the exercises.

4. Results of the 3D Anatomical Exercise Encyclopedia Application Development

A 3D anatomical exercise encyclopedia application optimized for Korean users was designed and implemented. The main screen was developed to allow users to select a body part or search for a specific exercise, making it easy to find and access exercises. The 3D model screen visually emphasized the agonist and synergist muscles of the selected exercise. Users could intuitively understand the anatomical structure of the exercise areas by zooming, rotating, and enlarging the 3D model. Additionally, a database was designed using SQLite to store and retrieve information on exercise definitions, sequences, agonist, and synergist muscles. Finally, an evaluation of the application's usability was conducted with 21 users, and most users reported high satisfaction with the intuitive interface and accurate information provided. Improvement suggestions included adding more exercise items and enhancing the muscle highlighting effect.

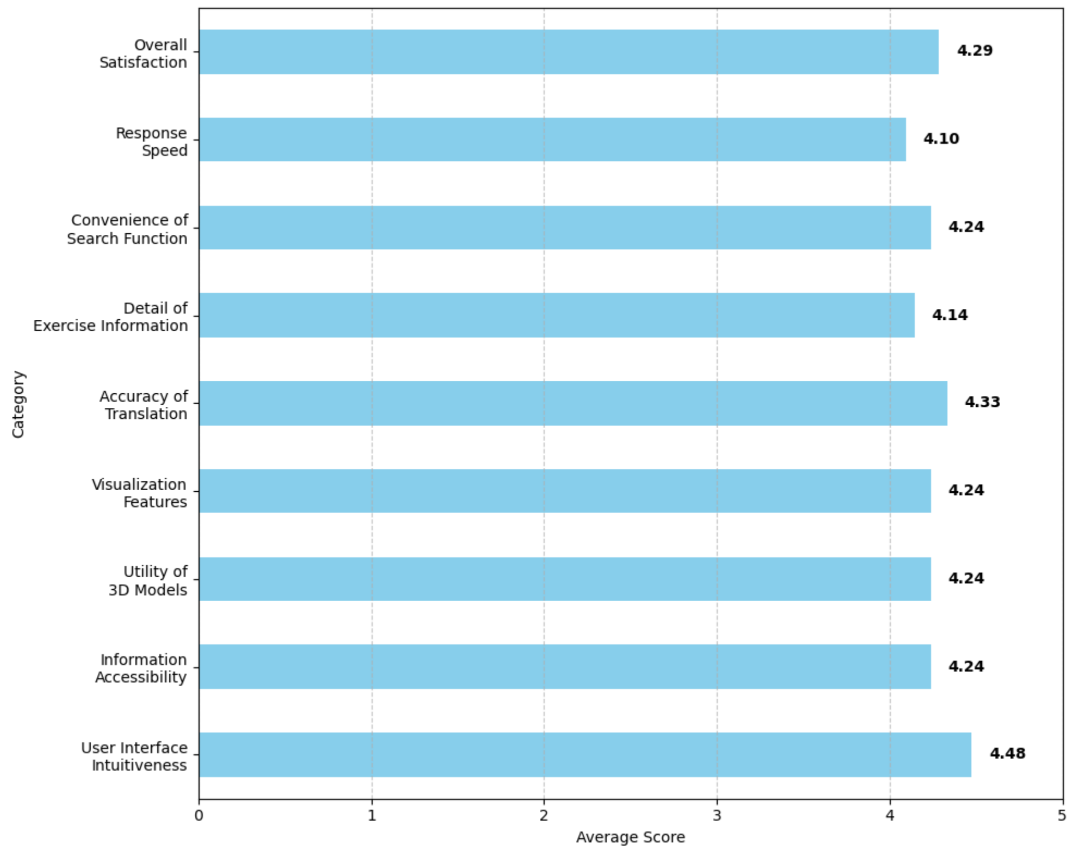

Figure 8. Application Satisfaction Survey 5-Point Scale Average

4. Conclusion

This study aimed to develop an application that informs users about exercise definitions, sequences, agonist, and synergist muscles by confirming the interoperability of Flutter and Unity through the development of a 3D anatomical exercise encyclopedia application. First, by utilizing 3D models to support the visualization of exercise areas, users could intuitively check muscle activation during exercises. Second, the 3D model screen was designed to provide both an exercise list and detailed exercise information, allowing users to understand precisely which muscles are being used. By adhering to accurate notation, confusion was minimized, maximizing the learning effect for users. Third, users could immediately check specific exercises through the search function. The diverse widgets and powerful UI framework of Flutter were advantageous in implementing a user-friendly interface. By developing an application optimized for Korean users, the study addressed the limitations of similar applications overseas, leading to a more efficient application.

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