Tutorial

Healthc Inform Res. 2018 October;24(4):394-401. https://doi.org/10.4258/hir.2018.24.4.394 pISSN 2093-3681 • eISSN 2093-369X



Augmented Reality to Localize Individual Organ in Surgical Procedure

Dongheon Lee, MS¹*, Jin Wook Yi, MD²*, Jeeyoung Hong, PhD^{1,3}, Young Jun Chai, MD, PhD⁴, Hee Chan Kim, PhD^{3,5}, Hyoun-Joong Kong, PhD⁶

¹Biomedical Research Institute, Seoul National University Hospital, Seoul, Korea; ²Department of Surgery, Inha University Hospital, Incheon, Korea; ³Institute of Medical & Biological Engineering, Medical Research Center, Seoul National University College of Medicine, Seoul, Korea; ⁴Department of Surgery, SMG-SNU Boramae Medical Center, Seoul, Korea; ⁵Department of Biomedical Engineering, Seoul National University Hospital, Seoul National University College of Medicine, Seoul, Korea; ⁶Department of Biomedical Engineering, Chungnam National University Hospital, Chungnam National University College of Medicine, Daejeon, Korea

Objectives: Augmented reality (AR) technology has become rapidly available and is suitable for various medical applications since it can provide effective visualization of intricate anatomical structures inside the human body. This paper describes the procedure to develop an AR app with Unity3D and Vuforia software development kit and publish it to a smartphone for the localization of critical tissues or organs that cannot be seen easily by the naked eye during surgery. **Methods:** In this study, Vuforia version 6.5 integrated with the Unity Editor was installed on a desktop computer and configured to develop the Android AR app for the visualization of internal organs. Three-dimensional segmented human organs were extracted from a computerized tomography file using Seg3D software, and overlaid on a target body surface through the developed app with an artificial marker. **Results:** To aid beginners in using the AR technology for medical applications, a 3D model of the thyroid and surrounding structures was created from a thyroid cancer patient's DICOM file, and was visualized on the neck of a medical training mannequin through the developed AR app. The individual organs, including the thyroid, trachea, carotid artery, jugular vein, and esophagus were localized by the surgeon's Android smartphone. **Conclusions:** Vuforia software can help even researchers, students, or surgeons who do not possess computer vision expertise to easily develop an AR app in a user-friendly manner and use it to visualize and localize critical internal organs without incision. It could allow AR technology to be extensively utilized for various medical applications.

Keywords: Virtual Reality, Medical Education, Three-Dimensional Imaging, Thyroidectomy, Augmented Reality

Submitted: September 21, 2018 Revised: October 22, 2018 Accepted: October 22, 2018

Corresponding Author

Hyoun-Joong Kong, PhD

Department of Biomedical Engineering, Chungnam National University Hospital, Chungnam National University College of Medicine, 266 Munhwa-ro, Jung-gu, Daejeon 35015, Korea. Tel: +82-42-280-7252, E-mail: gongcop@cnu.ac.kr (https://orcid.org/0000-0001-5456-4862)

*These two authors contributed equally to this work.

© 2018 The Korean Society of Medical Informatics

I. Introduction

Since it has the advantage of visualizing complex human structures in three dimensions, augmented reality (AR) technology has been developed over the last 20 years and its utilization has recently become more common in various medical applications [1,2]. In particular, research on AR have been actively conducted regarding its application in the surgical field, which deals directly with human tissue [3]. A search for the keyword, 'Augmented Reality Surgery' in PubMed shows that approximately 50 to 70 papers have been annually published on this topic since 2015.

The advantages of applying AR in the surgical field are as

This is an Open Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (http://creativecommons.org/licenses/bync/4.0/) which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.



Figure 1. Installation procedures of Unity and Vuforia.

		S vuforia" Developer Portal	
		Home Pricing Downloads Library Develop Support	
Home Pricing Downloads Library Develop Support		License Manager Target Manager	
License Manager Target Manager		License Manager > Thyroid	
License Manager Create a license key for your application. Get Development Key Buy Deployment Key		Thyroid Edit Name Dalete License Key License Key Usage	
Name Type Status v	Date Modified	Please copy the license key below into your app	
Thyrold Develop Active	Jul 26, 2017 01:06	Alterna 67 // // / AdAM chargement 61 k count (og) abon 4 state 5 state) (of c4 lb. I - thomatonyong 4 transformation (of calce transformation) (or count of the state) (of c4 lb. I - state) (or count of calce) (or count of calce) (or count of calce transformation) (or count of calce) - state) (or count of calce) (or count	
		Type: Develop Status: Active Created: Jul 26, 2017 01:06	
Last updated: Today 9:33 PM Rafresh		History: License Created - Jul 26, 2017 01:06	

Figure 2. Usage of License Manager to get development key, which is used in Unity environment for Vuforia configuration.



Figure 3. Usage of Target Manager to add target database. There are four target categories that can be selected: Single Image, Cuboid, Cylinder, and 3D Object.

Dongheon Lee et al

Healthcare Informatics Research HIR

follows. The exact anatomical location of the organ to be operated on can be determined before the skin incision [4]. It can provide safe and efficient surgery by visualization and localization of critical anatomical structures inside the human body, such as blood vessels, nerves, and bile ducts, which cannot be seen easily by the naked eye [5]. In addition, it is important to have a proper surgical margin in the case of cancer surgery. In the case of a tumor located in an organ, it is possible to obtain a sufficient and safe surgical margin by visualizing the location of the tumor with AR [6]. Finally, AR data for each patient can be used to help establish a preoperative plan, and it can be used in surgical educa-







Figure 5. Basic settings.

HIR Healthcare Informatics Research

tion for students or surgeons [2,7].

This paper describes methods for using Unity and Vuforia to realize AR and presents some scenarios in which AR can be used for medical applications.

II. Methods

1. Installation of Unity and Vuforia

AR can be achieved using Vuforia software development kit (SDK) in the Unity development environment. Unity is an editor for creating products such as 3D video games or animations, and Vuforia is an AR software platform created by Qualcomm. In the Vuforia version 6.5, Unity and Vuforia do not need to be installed separately because Vuforia is integrated with the Unity Editor and will work if the files are installed. The personal version of Unity is available free of charge and the download assistant file can be downloaded at the following web address (https://store.unity.com/). The system requirements are Windows 7 SP1+, 8, or 10, or Mac OS X 10.9+.

The installation process is conducted as follows. Double-

click the 'UnityDownloadAssistant' file and choose 'Components' on the pop-up screen, then check the 'Vuforia Augmented Reality Support' option additionally. Next, sign in with your Unity ID and access Unity with your account. Complete the license agreement and survey to finish the installation (Figure 1).

2. Uploading Target Database

To use the AR features provided by Vuforia, one should first request a license key. To request a license key, log in to your account on the Vuforia homepage, and click the 'Develop' button to open the 'License Manager' window. Then click on the 'Get Development Key' button to request a license key (Figure 2).

To implement AR, one of two image models should be selected to determine either 'where it appears' or 'what appears'. Here, the 'where' in 'where it appears' is called a marker or target.

① On the Vuforia homepage, click the 'Develop' button to open the 'Target Manager', and then click the 'Add Database' button. Next, click the 'Add Target' button to select

Inspector Services				Open
Impector Services 0 Impector ACCamera 0 Impector Static 0 Impector Impector 0 I			▼ Vuforia	
ARCamera I ayer Database Yearsform I ayer Database Position X 0 Y 0 Z 0 Scale X 1 Y 1 Z 1 Add License Scale X 1 Y 1 Z 1 Add License Add License Scale X 1 Y 1 Z 1 Add License Image: Static of the	O Inspector Service	s 🔒 📲	Vuforia Version 6.5.22	
Tage Untragged 1 Layer Default 1 Transform Position 2 0 Rotation X 0 Y 0 2 0 Scale X 1 Y 1 2 0 Scale X 1 Y 1 2 0 Clear Flags Stid Clov 0 0 0 Background Culling Mask Everything 1 0 Field of View 0 0 0 0 Clipping Planes Far 2000 0 0 0 Viewport Rect W 1 H 1 0 0 0 Clipping Planes Far 2000 0 0 0 0 Clipping Planes Far 2000 0 0 0 0 0 Allow MDA Ital Graphics Settings 1 0 0 0 0 0 Allow MDA Ital Graphics Settings 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	ARCamera	Static 🔻	App License Key	GbEconY6Ik6xyniOay5b++8
Viewport Ret Viewport Ret Viewport Ret X0 Viewport Ret None (Render Texture) Occlusion Culling View Careet Viewport Ret None (Render Texture) Occlusion Culling Viewport Ret View Datage Seture Viewport Ret Viewport Ret None (Render Texture) Open Vufraia configuration Viewport Ret	Tag Untagged	Layer Default	DE+1×20jQfx1blFn	InKrwyq+IUE5wUqj6wkbrnaa
Patien Position Rotation X 0 View Scale X 1 Y 1 2 1 Scale X 1 Y 1 Y 1 </td <td>Transform</td> <td>a</td> <td>tvalDrko04G1N5GV</td> <td>tER 03053cz+9m0Moze9wJie</td>	Transform	a	tvalDrko04G1N5GV	tER 03053cz+9m0Moze9wJie
Petation X Scale X Y Y Scale X Y Y Z Clear Flags Solid Celer Culling Mask Everything I Projection Projection Projection Projection France Clipping Planes Far 2000 Viewport Rect X X Viewport Rect X X Y 0 Qubits Extract 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2 2 2 2 2 2 2 3 2 2 2 2 2 3 <	Position	X 0 Y 0 Z 0	Add Licens	e
Scale x 1 y 1 2 1 Camera Camera Camera Camera Calcar Flags Said Caler Camera Camera Dackground Camera Camera Camera Camera Culling Mask Everything I Max Simultaneous Tracked Ob I Cilling Mask Everything I Max Simultaneous Tracked Ob I Cillipping Planes Near 0.05 Far Comera Default I Camera Doit Y 0 I <td>Rotation</td> <td>X 0 Y 0 Z 0</td> <td>Delayed Initialization</td> <td></td>	Rotation	X 0 Y 0 Z 0	Delayed Initialization	
Clamera Clear Flags Bald Clar Clig Flags Back ground Culling Mask Everything Projection Perspective Clipping Planes Near 0.05 Far 2000 Viewport Rect X0 Y0 Load Object Targets on Detect Clipping Planes Near 0.05 Far 2000 Viewport Rect X0 Y0 Load Object Targets on Detect Camera Direction Chamera Direct	Scale	X 1 Y 1 Z 1	Camera Device Mode MODE_DEFAULT	•
Clear Hage Sald Caler Back ground Culling Mask Projection Praspective Field of View Cipping Planes Near 0.05 Far 2000 Viewport Rect X 0 Y 1 H 1 Depth I Rendering Path Use Graphics Settings I Allow MSAA Allow MSAA Viewport Kect Y Unforia Behaviour Youforia Behaviour (Script) Video Background Open Vuforia Behaviour Yuforia Behaviour (Script) Yufde Background Cull Default InitializationError Haudier Add Component Yudec Background Yufde Background Open Vuforia Behaviour Yuforia Behaviour (Script) Yufde Background Component Add Component Yuforia Behaviour (Script) Yuforia Background Mase [Hidden/VR/VideoBackground On Allow Mase] Yuforia Background Mase]	🔻 📾 🗹 Camera		Max Simultaneous Tracked Im 1	
Background Culling Mask Everything Projection Perspective Field of View Clipping Planes Read 0.05 Far 2000 Viewport Rect X 0 Y 0 H 1 Depth 1 Rendering Path Target Farture None (Render Testure) Occlusion Culling Allow MDR Allow MDR Allow MDR Allow MDR Allow MDR Gript Viergets Tasker Open Vuforia Behaviour Video Background Video Background Video Background Video Background Video Background Mirror Video Background Video Background <t< td=""><td>Clear Flags</td><td>Solid Color 1</td><td>Max Simultaneous Tracked Ob 1</td><td></td></t<>	Clear Flags	Solid Color 1	Max Simultaneous Tracked Ob 1	
Culling Mask Everything Camera Direction	Background	9	Load Object Targets on Detect	
Projection Perspective Field of View 60 Clipping Planes Near 0.05 Far 2000 60 Viewport Rect X0 Will H Depth 1 Rendering Path Use Graphics Settings Target Texture None (Render Texture) Occlusion Culling Allow HDR Allow HDR Allow HDR Allow HDR Contact Behaviour Yuddo Listener Contact Settings Video Background Video Background Video Background Shader Hidden/VR/VideoBackground Video Background Hidden/VR/ClippingMask Openviring is prove in angle Hidden/VR/ClippingMask	Culling Mask	Everything +	Camera Direction CAMERA_DEFAULT	1
Projection Pried of view Clipping Planes Par Oopth Depth Rendering Path Uise Graphics Settings Target Texture None (Render Texture) Occlusion Culling Allow HDR Allow MSAA O Yuforia Behaviour (Script) Script Vuforia Behaviour (Script) Script Vuforia Behaviour (Script) Script Vuforia Behaviour (Script) Script Open Vuforia Configuration Vide Default Initialization Error Handler Add Component Script Add Component Script Add Component Script Default Initialization Error Handler Wate Shader Prover Tracker Enable device pose tracking Wate Shader Wate Shader Inder/VR/VideoBackground Video Background Shader Wate Shader Script Default Initialization Error Handler Wate Shader Italized Store Belie Video Background Shader Video Background Shader Video Background Shader Video Background Shader Inder/VR/VideoBackground Video Background Shader Inder/VR/VideoBackground Video Background Shader Inder/VR/VideoBackground Video Background Shader Inder/VR/VideoBackground <	Duciestien	(Perspective t)	Mirror Video Background DEFAULT	
Inclusion View Clipping Planes Far 2000 Viewport Rect X 0 Y 0 Depth 1 Target Texture None (Render Texture) Occlusion Culling Allow HDR Allow HDR Allow HDR Allow HDR Allow HDR Allow HDR Script Script Vuforia Behaviour Voria Behaviour Open Vuforia Configuration Video Background Video Background <td>Field of View</td> <td>Feispective 60</td> <td>T Digital Evewear</td> <td></td>	Field of View	Feispective 60	T Digital Evewear	
Viewport Rect Viewport Recttor V	Clipping Planes	Near 0.05	Evewear Type None	:
Viewport Rect X 0 Y 0 W1 H 1 Depth 1 Endering Path Use Graphics Settings 1 Target Texture None (Render Texture) Occlusion Culling C Allow HDR Allow MSAA C Target Display 1 Target Display 1 Display 1 Script Open Vuforia Behaviour Wed Croter Made Elest TABORT Open Vuforia Configuration Open Vuforia configuration Open Vuforia configuration Cole Vuforia Configuration Open Vuforia configuration Cole Vuforia Cole Vuforia Cole Vuforia Cole Vuforia Cole Vuf	company ratios	Far 2000		
Wi Hi Depth 1 Rendering Path Use Graphics Settings Target Texture None (Render Texture) Occlusion Culling Image: Control of the set of the	Viewport Rect	X 0 Y 0	▼ Datasets	
Depth 1 Rendering Path Use Graphics Settings Target Texture None (Render Texture) Occlusion Culling Image: Control of Contro		W 1 H 1	Load Thyroid Database	
Corpor Rendering Path Target Texture None (Render Texture) Occlusion Culling Allow HDR Allow MSAA Target Display Display <t< td=""><td>Depth</td><td>1</td><td>Load VuforiaMars, Images Dat</td><td></td></t<>	Depth	1	Load VuforiaMars, Images Dat	
Target Texture None (Render Texture) Occlusion Culling Allow MSA Allow MSA Target Display Display 1 Image Control Contr	Rendering Path	Use Graphics Settings	Activate	
Occlusion Culling Allow HDR Allow MSAA Target Display Display 1 Target Display Display 1 Vuforia Behaviour (Script) Script Open Vuforia configuration Video Background Video Background <td>Target Texture</td> <td>None (Render Texture)</td> <td></td> <td></td>	Target Texture	None (Render Texture)		
Allow HDR Allow MSAA Target Display Display 1 * Activate Activ	Occlusion Culling	v	Load VuforiaMars_Object_OT [
Allow MSAA Target Display 1 Cather Made Control Made Display 1 Control Made Control	Allow HDR	õ	Activate 🖌	
Target Display Display 1 Image: Di	Allow MSAA			
Activate Activate Activate Activate Activate	Town Direl	-	Load VuforiaMars_VuMark Dat	
● Audio Listener ● Add Database ● Script ● VuforiaBehaviour Wodd Center Mede FLEST TARGET ● Open Vuforia configuration ● Video Background ● Open Vuforia configuration ● Video Background ● Open Vuforia configuration ● Number Divisions ● Open Vuforia configuration ● Video Background ● Open Vuforia Play Mode ● Video Background ● Open Vuforia Play Mode ●	Target Display	Display 1	Activate 🗹	
Vuforia Behaviour (Script) Video Background Script Itest TABORT World Caster Mode FIRST TABORT Open Vuforia configuration Video Background Shader Video Background Shader Itelden/VR/VideoBackground Open Script Overflow geometry CLIP Itelden/VR/ClippingMask Add Component Start Automatically Vetoce Tracker Start Automatically Vetoce Tracker Enable device pose tracking Disable Vuforia Play Mode Disable Vuforia Play Mode	🥥 🗹 Audio Listener	Q 0.	Add Databa	ise
Script VudoraBehaviour • Wadd Center Made [Itest Tasker] • Open Vuforia configuration • • • • • Script • • Add Component • • Add Component • • • •	🔻 📚 🗹 Vuforia Behavio	our (Script)	Video Background	
Open Vuforia configuration Video Background Shader Image: Script DefaultInitializationErrorHandler Add Component Image: Start Automatically Image: Start Automatically Image: Start Automatically </td <td>Script</td> <td>SuferiaBehaviour</td> <td>Enable video background</td> <td></td>	Script	SuferiaBehaviour	Enable video background	
Open Vutoria configuration Number Divisions 2 Script DefaultInitializationErrorHandler Overflow geometry CLIP # Add Component Start Automatically Image: ClippingMask I			Video Background Shader	ackground
Script DefaultInitializationErrorHandler Add Component Matte Shader Start Automatically Image: Component Component Below Sector Start Automatically Image: Component Component Image: Component Component Component Image: Component Component Component Image: Component		Open Vutoria configuration	Number Divisions 2	
Script DefaultInitializationErrorHandler Matte Shader Midden/VR/ClippingMask Matte Shader Add Component Smart Terrain Tracker Start Automatically Device Tracker Enable device pose tracking Webcam Disable Vuforia Play Mode Disable Vuforia Play Mode	V 🕑 💌 Derault Initializ	ration Error Handler (Script)	Overflow geometry CLIP	
Add Component	Script	DefaultInitializationErrorHandler	Matte Shader	ngMask O
Add component Smart Terrain Tracker Start Automatically Image: Component of the start Automatically Device Tracker Enable device pose tracking Webcam Disable Vuforia Play Mode		Add Component		
Start Automatically V Device Tracker Enable device pose tracking Vebcam Disable Vuforia Play Mode		Add componenc	V Smart Terrain Tracker	
Device Tracker Enable device pose tracking Webcam Disable Vuforia Play Mode			Start Automatically	
Enable device pose tracking Webcam Disable Vuforia Play Mode			▼ Device Tracker	
▼ Webcam Disable Vuforia Play Mode			Enable device pose tracking	
Disable Vuforia Play Mode			▼ Webcam	
			Disable Vuforia Play Mode	

O Inspector

Services VuforiaConfiguration

Figure 6. Registering the license key.

A

0

Healthcare Informatics Research HIR

a target database. There are four target categories that can be selected: Single Image, Cuboid, Cylinder, and 3D Object as shown in Figure 3. After making a selection, enter the image's width (mm) in the 'Width' section. In this experiment, we selected 'Single Image' because we used a 2D image as a target.

② Click the 'Download Database', and set the development platform to 'Unity Editor' to download the unity package.

3. AR Process Using Unity and Vuforia

Run the Unity Editor and create a new project file. The Unity Editor workspace consists of the following four items as shown in Figure 4.

- Hierarchy: contains a list of every GameObject, asset file, and instance of prefabs in the current Scene,
- Scene: shows the image screen that is currently being worked on,
- Inspector: shows various types of properties and allows them to be edited,
- Project: contains the Assets folder.

1) Basic settings (Figure 5)

(1) To import the registered target file, select 'Assets' and then 'Import Package'. Subsequently, select 'Custom package' in the menu window and import the previously downloaded unitypackage file.

U Inspector Services							
VuforiaConfiguration		Q					
Vuforia		Open					
Vuforia Version	6 5 22						
vuloria version							
App License Key	AUMmk07////AAAAGbEcpnY6Ik6xvni DE+1X20jQfx1blFnunKrwyq+IUE5wUq fVaiDrko04G1N5GVtERa30S3cz+9m0	Qgy5b++8 j6wkbrnaa Moze9wJle					
	Add License						
Delayed Initialization			O Inspector Services				a -
Camera Device Mode	MODE_DEFAULT		MageTarget				Static *
Max Simultaneous Tracked Im	1		Tag Untagged	•	ayer Default		
Max Simultaneous Tracked Ob	1		▼↓ Transform				2
Load Object Targets on Detect			Position	X 0	Y 0	Z 0	
Camera Direction	CAMERA_DEFAULT		Rotation	X 0	Y 0	Z 0	
Mirror Video Background	DEFAULT	•	Scale	X 700	Y 700	Z 700	
			🔻 🗹 Image Target Beha	viour (Script)	and the second second		
* Digital Eyewear	(1)		Type	Predefined	getbenaviour		
Eyewear Type	None		Database	Thyroid			1
▼ Datasets			Image Target	thyroid			:
Load Thyroid Database	☑			Ad	d Target)	
Activate			▶ Advanced				
	100		🔻 🕼 🗹 Default Trackable E	vent Handler (Script)		24
Load VuforiaMars_Images Dat	- -	La	Script	@ DefaultTr	ackableEventHan	dler	C
Activate	2		🔻 💽 🗹 Turn Off Behaviour	(Script)	h a channa		
Land Victoria Marra Obient OT /	-		Script	C Turnombe	naviour		
Load Vutoriamars_Object_OT t			Lighting				
Activate	×		▶ Materials				
Load VuforiaMars VuMark Dat			Dynamic Occluded				
Activate	2		🔻 📃 (Mesh Filter)				0
	Add Database		Mesh				0
	Add Database		thyroidMaterial				0
♥ Video Background			Shader Unlit/Texture				
Enable video background	2						
Video Background Shader	S Hidden/VR/VideoBackground	0		Add Compo	nent		
Number Divisions	2						
Overflow geometry	CLIP						
Matte Shader	S Hidden/VR/ClippingMask	0					
Smart Terrain Tracker							
Start Automatically							
V Device Tracker							
Enable device pose tracking							
▼ Webcam							

Figure 7. Loading and activating the target datasets.

HIR Healthcare Informatics Research

② To use Vuforia SDK's AR features, go to the menu and select 'ARCamera' and 'Image' as follows.
 GameObject → Vuforia → ARCamera

GameObject → Vuforia → Image

③ Click the 'PLAY' button to augment the image of the webcam that is connected to user's PC.

2) Registering the license key (Figure 6)

To register the license key, select 'Hierarchy', and then select 'ARCamera' to open the Inspector menu. Click the 'Open Vuforia configuration' button at the bottom of the 'Vuforia Behavior (Script)' window. Copy and paste the issued license key into the 'App License Key' section.

3) Loading and activating the target image (Figure 7)

 Select 'Hierarchy' and then 'ARCamera'. After that, click the 'Open Vuforia configuration' button. At the bottom of the Datasets menu, select the target file uploaded on the Vuforia homepage and check 'Activate'. ② Select 'Hierarchy' and then 'ImageTarget'. Click 'Inspector' and select the uploaded database folder name and the file uploaded in the 'Data Set' window and the 'Image Target' window below 'Image Target Behavior (Script)', respectively.

4) Loading overlay model file

① Select the basic overlay model provided by Vuforia as follows:

Hierarchy \rightarrow ImageTarget \rightarrow 3D Object \rightarrow Tree (example).

② Import downloaded files or files you have created to do overlays.

5) Play

- ① In the 'Scene' window, adjust the position, angle, and magnification to arrange the desired positioning between the target image and the model to be overlaid.
- ② Click the 'Play' button at the top of the Unity Editor to run it.



Figure 8. Build settings for PC and Android version.



Figure 9. Example of application of augmented reality technology: thyroid and internal organs on a robotic thyroidectomy training model through a smartphone display.

6) Android platform usage example (Figure 8)

① After the previous process, use the menu to select the following:

File Build Settings \Rightarrow Platform \Rightarrow Android. Next, click the 'Open Download Page' button to down-

load the 'Android Supporter' file and install it.

- ② After installation, click the 'Player Settings' button and set the 'Icon', 'API Level', and other settings in the Android menu window at the bottom of the Inspector.
- ③ Click the 'build' button to create an .apk file and download this file to an Android mobile phone. The AR functions that operate on a PC can now be implemented on the phone.

III. Results

In this tutorial, a 3D model of the thyroid and surrounding structures was created from a thyroid cancer patient's CT DICOM file using Seg3D open-source software [8]. Figure 9 shows the results of implementing AR using the PC version (Win 7, 64 bit) and a mobile phone running the Android OS. The constructed 3D model of the thyroid and surrounding structures was overlaid on 2D markers (around the neck) attached to a thyroid body model.

IV. Discussion

This paper described the overall AR process using the Unity Editor and Vuforia SDK and showed that AR can easily be used in medical applications, illustrated via an example in which AR was used in thyroid laparoscopic surgery. Even without expertise in image processing methods, such as registration techniques, this software can easily be used in AR research using various medical images. This tutorial is for beginners, and more detailed and in-depth usage guidelines and suggestions will be presented in the future.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

Acknowledgments

This work was supported by research fund of Chungnam National University. The authors thank Hyoun-Jin Joo for his technical assistance in developing the AR application.

References

- Chang H, Choi M. Big data and healthcare: building an augmented world. Healthc Inform Res 2016;22(3):153-5.
- Bernhardt S, Nicolau SA, Soler L, Doignon C. The status of augmented reality in laparoscopic surgery as of 2016. Med Image Anal 2017;37:66-90.
- 3. Khor WS, Baker B, Amin K, Chan A, Patel K, Wong J. Augmented and virtual reality in surgery-the digital surgical environment: applications, limitations and legal pitfalls. Ann Transl Med 2016;4(23):454.

HIR Healthcare Informatics Research

- 4. Kim Y, Kim H, Kim YO. Virtual reality and augmented reality in plastic surgery: a review. Arch Plast Surg 2017;44(3):179-87.
- 5. Tang R, Ma L, Xiang C, Wang X, Li A, Liao H, et al. Augmented reality navigation in open surgery for hilar cholangiocarcinoma resection with hemihepatectomy using video-based in situ three-dimensional anatomical modeling: a case report. Medicine (Baltimore) 2017;96(37):e8083.
- 6. Soler L, Nicolau S, Pessaux P, Mutter D, Marescaux J.

Real-time 3D image reconstruction guidance in liver resection surgery. Hepatobiliary Surg Nutr 2014;3(2):73-81.

- Barsom EZ, Graafland M, Schijven MP. Systematic review on the effectiveness of augmented reality applications in medical training. Surg Endosc 2016;30(10):4174-83.
- 8. Hassan K, Dort JC, Sutherland GR, Chan S. Evaluation of software tools for segmentation of temporal bone anatomy. Stud Health Technol Inform 2016;220:130-3.