# 科技部補助專題研究計畫成果報告

**（□期中進度報告/■期末報告）**

Develop a Standard Web Solution for Medical Images and Annotation Sharing

計畫類別：■個別型計畫　□整合型計畫

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| 本研究具影響公共利益之重大發現：■否　□是 |

# Abstract

Recently, both DICOM and HL7 have published web specifications, DICOM web and HL7 Fast Healthcare Interoperability Resources (FHIR), which is easier to be adopted by IT system developers and sharing medical image or related data across departments. This journal plans to develop a standard web solution for medical images and annotation sharing. The web solution has some essential functions such as zoom-in, zoom-out, and adjusting the contrast of medical images. The system could also be used for making annotations on medical images. According to the specification of FHIR observation resource, the annotations would be XML formatted and could be stored in FHIR server. The FHIR-based annotations could be referenced by FHIR-based image findings. This constitutes a FHIR-based web viewer solution that can be integrated with DICOM web server for retrieving and viewing medical images. FHIR uses HTTP protocol as an exchange protocol which is a developer-friendly method for sharing and accessing clinical information. Using FHIR as a standard for a more clinically integrated system in the field of radiology would be easier for implementation, understanding, and management.



**Key word**: FHIR, Digital Imaging and Communications in Medicine (DICOM), Picture Archiving and Communication System (PACS), SVG, web viewer, medical imaging, image annotation



# 摘要

最近，DICOM和HL7發布了Web規範，DICOM Web和HL7 Fast Healthcare Interoperability Resources（FHIR），使IT系統開發人員更容易採用它並可以在部門之間共享醫學影像或醫療相關資料。本計劃想要開發用於醫學圖像和註釋共享的標準Web解決方案。

影像顯示系統具有一些基本功能，包含放大，縮小和調亮度。本系統也可以在影像上畫標記。根據FHIR Observation資源的規格，標記將採用XML格式並可以存在FHIR服務器中。基於FHIR的標記可以被FHIR的影像發現參考。這構成了一個基於FHIR標準的影像顯示系統，可以跟DICOM Web服務器做整合以方便存取以及顯示醫學影像。

FHIR使用HTTP通訊協議作為交換協議，這是一種開發人員友好的方法，可以用來共享和進行臨床上資料的各項操作（增，刪，改，查）。以 FHIR 當作放射學領域中臨床上更完整的系統的標準將更易於執行，理解以及管理。

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# Chapter 1: Introduction

Picture Archiving and Communication System (PACS) is a system for managing and archiving medical images created in radiology department. More specifically, PACS is used in radiology as a system for filing and sending images that come from specialized imaging/ radiological equipment such as Plain X-Ray, CT, or MRI. Hospitals that already have constructed PACS, all devices are connected via a computer network to the PACS server. And the imaging results of the devices would be stored on the server. Consequently, radiologists can use PACS viewer and analysis applications to query and access the medical images that were stored in PACS server.

However, PACS follows on Digital Imaging and COmmunication in Medicine (DICOM) standard to support the process, transmit, store, retrieve, print and display of medical imaging data. Most of IT system developers are not familiar with DICOM specified protocol and data format, also conventional DICOM standard is not appropriated for sharing images across medical department. It is a huge overhead for those developers to handle DICOM standard images, presentation object, and structure report. And next problem, although security specifications has addressed in DICOM standard, most of PACS used in hospital do not support those security specifications. PACS usually confined in internal network inside hospital and cannot be accessed by others outside of the hospital. This will make doctors of a hospital unable to access the past imaging records of patients from other hospitals.

The imaging viewer system used to access the patient's imaging results were also not able to save the results of the analysis to a server, making it difficult for doctors in making clinical reports. Recently, both DICOM and HL7 have published web specifications, DICOM web and HL7 Fast Healthcare Interoperability Resources (FHIR). FHIR is a standard for exchanging healthcare information electronically. To ensure that medical images have the same standard in each hospital, medical images can be uploaded to the FHIR server according to the standard. This enables hospitals to access a patient’s past medical image, by using an understandable international standard, FHIR standard, easily. To integrate the DICOM Web System, the hospital’s PACS system, and the FHIR server, we are planning to develop a web solution for medical images that can be uploaded to the FHIR server for a standard image sharing.

# Chapter 2: Purpose

The main purposes of this research are to;

- Ensure that medical images have the same standard in each hospitals. Medical images can be uploaded to the FHIR server according to the standard, this enables hospitals to access a patient’s past medical images by using an understandable international standard, FHIR standard, easily
- Improve radiologists’ performance in practice by developing a standard web solution for medical images and annotation sharing
- Provide guidance in the process of creating medical image exam workflow and image related clinical researches. The related documentation for image annotation guideline is available on Github, with following URL:
  Homepage: https://github.com/victoriatjia
  Guideline Repository: https://github.com/victoriatjia/Guideline

# Chapter 3: Literature Reviews

This chapter focuses on the concept of the new FHIR standard, including the importance of FHIR solution in showing clear impact on the quality of radiologic interpretation by reducing the amount of time needed for radiologists to make a diagnosis. Furthermore, the importance of new standard specifications used for image annotations, like; W3C SVG and FHIR are also discussed. Since this paper will focus on providing a guidance in the process of creating medical image exam workflow through the new FHIR standard, the differences between the current radiologic interpretation process and the FHIR standard radiologic interpretation process also considered in this chapter.

## 3.1 Current Radiology Interpretation Process

The field of radiology has been increasingly challenged by balancing multiple software platforms which often separate the picture archiving and communication system (PACS) from the electronic medical record (EMR). In a national survey conducted in 2016, more than half of academic hospitals reported no integration between the PACS and the EMR. Another study concluded there is “an alarming lack of communication of pertinent medical information to the radiologist,” requiring the radiologist to be able to access the EMR since awareness of important clinical information demonstrates a clear impact on the quality of radiologic interpretation. For certain diagnostic studies, as low as 34% of the time would a radiologist review the EMR for clinical information.

The typical radiology interpretation process often starts with viewing images without reviewing supporting clinical information to avoid framing bias. After initial review, depending on recognition of the need for additional information, will the radiologist search into the EMR for the patient’s history of present illness, medical history, or relevant laboratory work. These explorations into the medical record often require opening and authenticating with additional software, querying for and selecting the patient, and clicking and scrolling to identify the relevant note and find relevant lab work. Not only can this be time-consuming for radiologists, but information is presented in fragmented pieces. Important information may be missed or information may be taken out of context.

Radiologists having access to relevant information in the EMR, can improve value of patient care. With the advent of new application program interfaces (APIs), typical barriers for external software to integrate with clinical systems have been greatly reduced. Tools like DICOMWeb, the Society for Imaging Informatics in Medicine (SIIM) Workflow Initiative in Medicine (SWIM), and Fast Healthcare Interoperability Resources (FHIR) are a variety of upcoming APIs that encourage developer integration of medical images, workflow data, and clinical information respectively.

## 3.2 FHIR

FHIR is an interoperability standard developed by Health Level Seven (HL7) that functions as an API for developers to access needed clinical information from the EMR. The service-oriented system which permits external software to ask specific clinical questions and obtain an immediate response.

A second key advantage of FHIR is the World Wide Web Consortium (W3C) compliant format that follows a language and structure well-established and commonly utilized in the web development community. The structure is called a representational state transfer (RESTful) architecture which standardizes methods to search for, update, and delete data. This also differs from HL7 which required creation of its own transport mechanism when first developed in the 1980s.

One clear benefit with FHIR for the field of radiology is the ability to quickly probe for relevant clinical information. The power of FHIR comes from the simplicity of the queries to fetch specific data, eliminating the need for complex searches in the EMR. fhir api 比 dicom 資訊 (query retrieve)

### 3.3 Standard Specification for Image Annotation

A number of different image types are part of the multimedia patient record. These include scanned patient record documents, waveform data such as electrocardiograms, stereo image pairs, and the other. Any of these image types can be annotated with text, measurements, circles, and other markings. Annotations can be stored in a separate file and applied to the original image file.

DICOM Presentation State (PS), Structured Report (SR), and Radiotherapy (RT) Structure Set are the objects used in the DICOM standard for annotation information. DICOM PS is a specification for image presentation, it can be applied to an image so that the image is displayed with all the visual specifications defined by that PS. The PS may be used to describe annotation, containing windowing values, zoom value, scrolling (panning) values, rotations or any other visual display element that is defined within the DICOM standard. Meanwhile, DICOM SR has defined a standard way for including contour annotation within the imaging report. And the last, DICOM RT structure set is used in radiotherapy department, and it contain graphic outlines defined as contours with patient relative (3D) coordinates. Actually, there are many kinds of non-standard annotation. Many vendors provide proprietary image annotation solutions. Therefore, we provide a new standard specification for image annotation information based on W3C SVG and FHIR specification.

# Chapter 4: Methodology

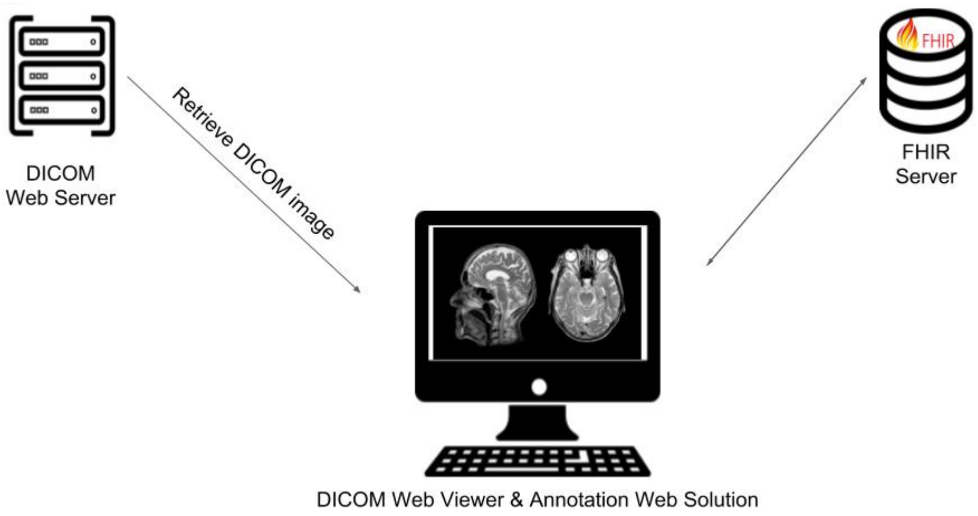



*Figure 1. A framework in medical imaging web system*

## 4.1 DICOM Web Server

All the medical imaging files will be retrieved from DICOM Web server. DICOM (Digital Imaging and COmmunications in Medicine) is the standard for the communication and management of medical imaging information and related data. DICOM is used for storing and transmitting medical images enabling the integration of medical imaging devices such as scanners, servers, workstations, printers, network hardware, and picture archiving and communication systems (PACS) from multiple manufacturers. PACS provides the electronic platform for radiology images. The medical image can only be seen in the hospital's radiology department because it only exist in the hospital's PACS system.

## 4.2 Viewing System

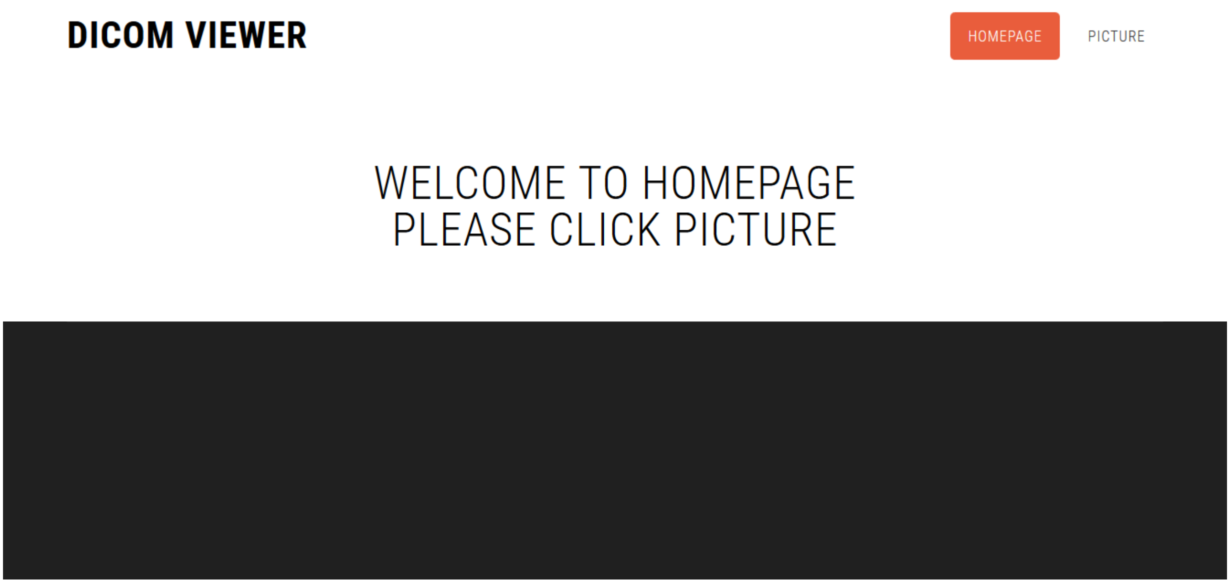



*Figure 2. Viewing System website page*

Our website provides services related to imaging such as zoom in/out, adjusting brightness, and annotation.

### 4.2.1 Zoom In/Out

We use the implementation of WADO-RS Viewport. Viewport is a rectangular area on screen where image coordinates are mapped to be displayed. It is used to display selected portion of image onto the screen. Its parameter specifies a rectangular region of the source image to be cropped and a rectangular region corresponding to the size of the cropped image should be scaled.


Figure 3. Default

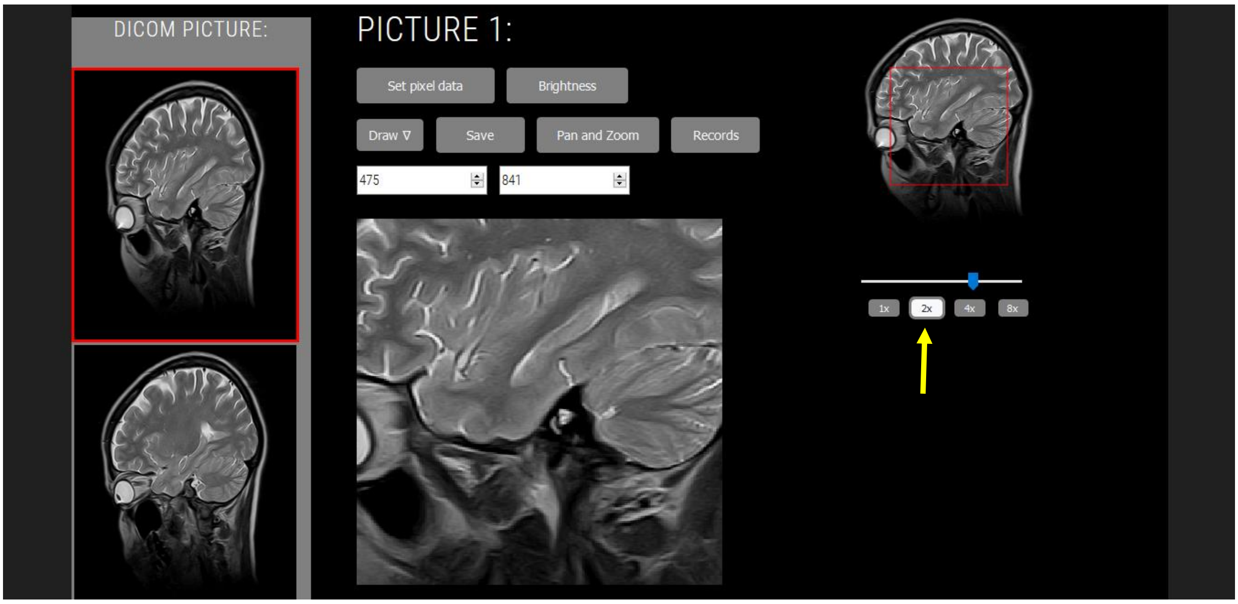



*Figure 4. Zoom in*

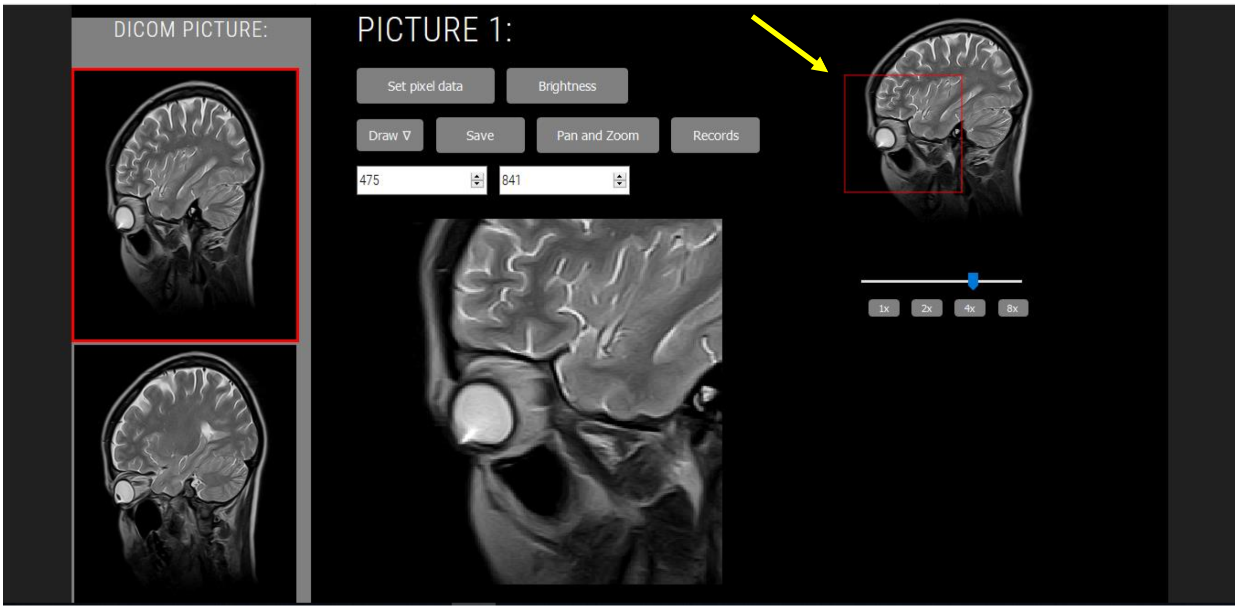



*Figure 5. Analyze the other part of images by moving the red box*

### 4.2.2 Window Width and Window Center

We use the implementation of HTML DOM Mouse Events (Onmousedown, Onmousemove, Onmouseup) to adjust the brightness of the image. Each time a new window center/width is set, a WADO HTTP request with window width/center parameters is sent back to the Web server, which then generate a new image that is displayed in the browser.

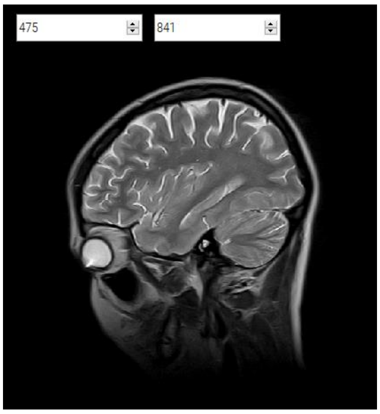



*Figure 6. Default*

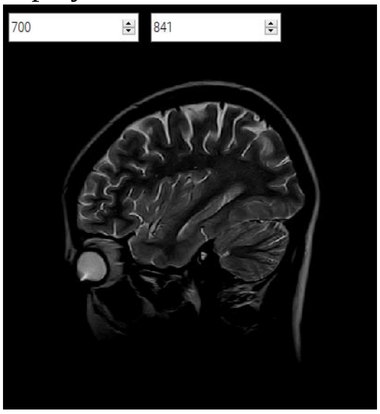



*Figure 7. Increase window center*

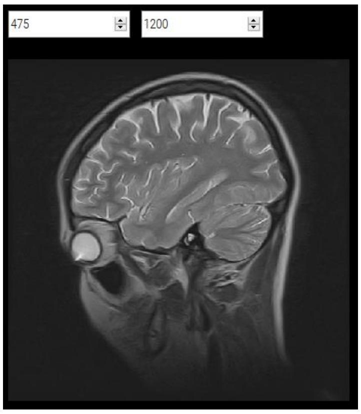



*Figure 8. Increase window width*

*notes: The window center value is displayed on the left textbox in the image, meanwhile the right one means the window width value

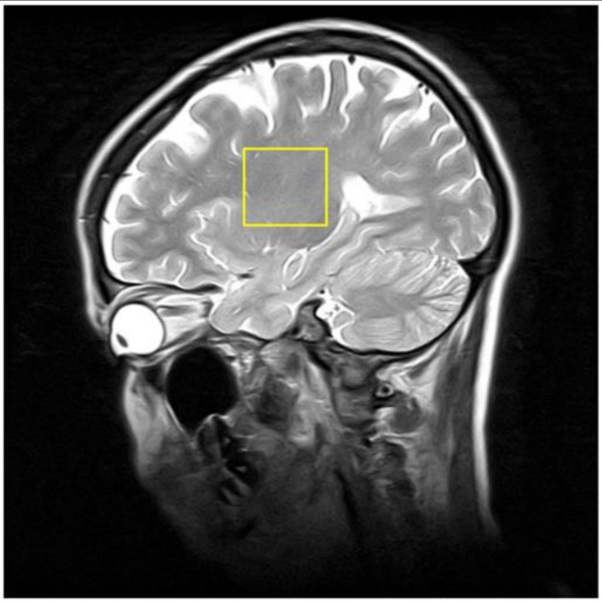
### 4.2.3 Annotation System

Users are provided with some options of shape (line, rectangular, round, and polygon). We use the implementation of HTML canvas for annotation and convert annotations from a HTML canvas drawing to SVG. After that, we merge SVG files with patient's data and their medical imaging. Finally, we return merged data from client server to web server.


**SVG Conversion of a Line**

<svg width="400" height="400">
<line x1="177" y1="232" x2="384" y2="102" style="stroke:rgb(255,0,0);stroke-width:2" />
</svg>

*Figure 9. Line annotation in image*



**SVG annotation example:**
<svg width="512" height="512" >
<rect x="207" y="124" width="71" height="66" style="stroke:rgb(255,255,0); stroke-width:2; fill:none " /></svg>

**Base 64 conversion result:**
PHN2ZyB3aWR0aD0iNTEyIiBoZWlnaHQ
9IjUxMiIgPjxyZWN0IHg9IjIwNyIgeT0iMTI
0IiB3aWR0aD0iNzEiIGhlaWdodD0iNjYiIH
N0eWxlPSJzdHJva2U6cmdiKDI1NSwyN
TUsMCk7IHN0cm9rZS13aWR0aDoyOyB
maWxsOm5vbmUiIC8+PC9zdmc+

*Figure 10. SVG annotation for medical image*

As demonstrated in graphic 4, a Scalable Vector Graphics(SVG) rectangle is presented on a MRI image. The medical images were stored in DICOMWeb server. And the images can be accessed through DICOM WADO protocol. A web base image viewer can use JavaScript to access the image that stored in DICOMWeb server. We can also make annotation on the image by our viewer. However, the annotation would not be stored into DICOMWeb server. According to DICOM standard the annotation should be DICOM Structure Reporting(SR) or Presentation State(PS) formatted for storing into DICOMWeb server. However, the DICOM objects are too complicated to handle by image viewing and reporting systems. Conventional DICOM specifications are very complicated, it would be a great challenge for system developers for handling SR or PS DICOM objects and designing a general purpose image viewing and report creating system. This paper suggests using W3C SVG to store medical image annotations. SVG is an XML-based vector image format for two-dimensional graphics. W3C SVG specifications have clear defined geometric graphics, such as line, ellipse, rectangle, polygon. And the SVG specifications can be easily comprehended by IT developers. We can create a simple SVG webpage that links to WADO image and contains geometric graphic annotation as demonstrated in following example:

```
<html><body>
 <svg width="512" height="512" >
  <image x="0" y="0" width="512" height="512" xlink:href=
  "https://DICOMWebServer.WADO/studies/1.2/series/3.4/instances/5.6"/>
  <rect x="207" y="124" width="71" height="66"
  style="stroke:rgb(255,255,0); stroke-width:2; fill:none" />
 </svg>
</body></html>
```
*Example 1. SVG web page with DICOMWeb image and a rectangle graphic*

If we open the example 1 on browser, we can see the result of figure 10 (left result). Example 1 is a WADO image and would be jpg formatted as the default WADO response result format specified in DICOM standard. And <rect x="207" y="124" width="71" height="66" style="stroke:rgb(255,255,0); stroke-width:2; fill:none" represent a rectangle that has 2 pixel width yellow border. W3C SVG standard has richful graphic specifications supported by most of browsers. Consequently, we can open example 1 by IE, Chrome, or Firefox that would have the same result as that presented in figure 10. However, the SVG annotation and WADO image might also be presented in an application based viewer. The self-developed viewer might not have the browser that support all SVG specifications defined in W3C. We must confine a sub-set of W3C SVG specifications that have simple and enough geometric graphics and styles that can be easily be supported by viewers. A simple sub-set of W3C SVG specifications for medical image annotation interoperability and display consistence would be discussed by another paper.

## 4.3 FHIR Observation for Image Annotation

We adopted the openly licensed Health Level Seven draft standard called Fast Healthcare Interoperability Resources (FHIR) to store the healthcare information electronically. We use the HAPI FHIR server as the API. The HAPI FHIR library is primarily supported by the University Health Network (UHN), a large multi-site network of teaching hospitals in Toronto, Ontario, Canada.

In this medical imaging web system, the FHIR standard will be in an Observation type. Observations used to support diagnosis, monitor progress, determine baselines and patterns and even capture demographic characteristics. When user done inspecting the image, then the annotation and the other information of the image will all saved as the FHIR standard, which is in Observation type and then will be uploaded to the FHIR server. The image and all the settings can be retrieved again from the FHIR server.

The FHIR observation.valueString may be used for storing annotation information. However, FHIR observation should be XML or JSON formatted. And W3C SVG graphics should be XML formatted. If we put SVG data directly into XML or JSON FHIR observation.valueString that would cause error when we upload the annotation observation to FHIR server. To solve the problem, we suggest that the SVG data should be base64 encoded as demonstrated in figure 10. Consequently, we could put the SVG data into FHIR observation and upload the result to FHIR server. The FHIR annotation observation is demonstrated in Example 2.

```
{"resourceType": "Observation",

"status": "final",

"code": {"coding": [ {"system": "https://www.dicom.org.tw/SVG","code": "SVG.Annotation",

"display": "SVG Annotation"}]},
```

"focus": [ {"reference":
"https://DICOMWebServer.FHIR/ImagingStudy/imgSTDid4567_SOPInstanceUIO5.6"}],

"valueString":"PHN2ZyB3aWR0aD0iNTEyIiBoZWlnaHQ9IjUxMiIgPjxyZWN0IHg9IjIwNyIgeT0iMTI0IiB3aWR0aD0iNzEiIGhlaWdodD0iNjYiIHN0eWxlPSJzdHJva2U6cmdiKDI1NSwyNTUsMCk7IHN0cm9rZS13aWR0aDoyOyBmaWxsOm5vbmUiIC8+PC9zdmc+"

}

*Example 2. SVG base64 annotation contained in FHIR Observation.valueString*

Example 2 is a simple FHIR image annotation. The annotation data is base64 encoded and stored in FHIR observation.valueString. Decode the base64 string will restore SVG annotation data as that shows in figure 10. The FHIR observation has been uploaded to a FHIR testing server and can be access at following URL:

https://hapi.fhir.tw/fhir/Observation/4961

In example 2, observation.Focus reference to an URL that points to a DICOMWeb server. The URL was created according to FHIR reference data type requirement. Therefore, the observation can be stored into FHIR server without errors.

# Chapter 5: Conclusion

It is possible to upload medical images to the FHIR server for a standardized image sharing. Then we can retrieve the image from the DICOMWeb server and user can make annotations on the DICOM image in the web browser and save the annotations as an SVG file by using the web viewer. The DICOM image can be displayed on the HTML canvas element by implementing the WADO-RS to retrieve the image and the DICOM viewport concept. The displayed can be zoom-in or zoom-out by adjusting the viewport of the image on the canvas. Annotations also can be made on the image by making use of the HTML DOM mouse events such as “onmousedown”, “onmousemove”, and “onmouseup”. These mouse events can also be used for adjusting the window center and window width of the image. After annotation is drawn, the next step is the image and the annotations will be saved as the FHIR standard and uploaded to the FHIR server. The image and all the settings can be downloaded again from the FHIR server.

The procedures of viewer that queries previous image exam result and converts the result as portable web page are described as following:

1. Viewer system queries patient’s previous image diagnosticReports
2. Viewer gets FHIR annotation observation by references in finding observation and diagnosticReport
3. Viewing creates WADO URL according imagingStudy.endpoint and annotation observation.focus as demonstrated in example 2
4. Viewer retrieves and displays the WADO images
5. Viewer draws annotations on the images
6. Viewer export portable web page that contains medical image and annotation

Step 6 of the previous image exam query procedure has two methods to present the annotation on a web page. The first one is to put the SVG directly into HTML. The second method is through JavaScript to manipulate the DOM. With JavaScript, we can set the brush color or size, the thickness of the line, we can also mark some words on the annotation. SVG can be used to store those things mentioned above. In the process of retrieving the annotation, it’s possible that user doesn’t operate it on our web viewer, instead of processed in someone else's system. After we have combined so many things, for example, if the viewer is a mobile phone-based system where the code isn’t written in JavaScript code, after the annotation is retrieved, we supposed to show images and annotations on the phone at the same time. This is a good protocol solution if both of them can be shown on the mobile phone-based system. Show images actually is not a big deal, but for showing annotation, where this thing is fully supported by SVG is a big challenge for us.

The second method mentioned in paragraph above is implemented in our web viewer which require a more complex steps to be performed. To redraw the SVG, we need to change SVG format into JavaScript canvas element. The ability of JavaScript to redraw the elements of the SVG is constrained when certain style properties in SVG may not available in JavaScript. Suppose that the SVG is generated after the annotation is marked on the image, we recommend limiting the SVG graphics format, so that it will be more convenient for all kinds of program to process and present the annotation. The annotation specification should be designed as simple as possible. It may be limited to only lines, squares, and simple colors used only. Do not use too specific SVG specifications, for example, “linearGradient” elements.

Additionally, there are two coordinates referred in image annotation; The first one is original DICOM image coordinate, the coordinate would be suitable for making annotation on image processing, shown in example 1. The other one is viewer display canvas coordinate, such as the figure 3. We can use the viewer to make annotation on medical images. Annotations could be drawn on the canvas of viewer. However, we can use the viewer to do image rotation, flip, resizing, or shift the DICOM image for display before making annotations on display canvas. The coordinate relation between DICOM image and display canvas may be change, it corresponds to the range of zooming, panning, and other transformation done on the image. The coordinate of annotation should be in accordance with the coordinate of the displayed canvas. The coordinate conversion would be necessary when we store image annotations to FHIR server and display the annotations on viewer.

Solve the missed interpretation of annotation problem by using WADO viewport is recommended in this paper. Using WADO, we can scale the whole source image, and it’s also possible to scale a region of source images that we want to display on the viewer through viewport. The viewport parameter specifies a rectangular region of the source image(s) to be cropped, and a rectangular region corresponding to the size of the user agent's viewport to which the cropped image should be scaled. The parameter consists of “vw”, “vh”, “sx”, “sy”, “sw”, and “sh”, where ‘vw’ and “vh’ are positive integers specifying the width and height, in pixels, of the rendered image. ‘Sx’ and ‘sy’ are the top-left corner of the region of the source image(s) to be rendered. ‘Sw” and ‘sh’ can be used to define the width and height of the region of the source image(s) to be rendered.

We see that many of the problems actually are caused by our IT developer. The people who developed it may not have thought far, but they did too much, causing a lot of trouble. This is indeed a considered problem in the future when our annotation has become a standard specification used in radiology field.

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# 科技部補助專題研究計畫成果彙整表

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<tr><td colspan="3">計畫主持人：謝愛佳</td><td colspan="3">計畫編號：MOST 108-2813-C-320 -002 -E</td></tr>
<tr><td colspan="6">計畫名稱： Develop a Standard Web Solution for Medical Images and Annotation Sharing</td></tr>
<tr><td colspan="3">成果項目</td><td>量化</td><td>單位</td><td>質化<br>（說明：各成果項目請附佐證資料或細項說明，如期刊名稱、年份、卷期、起訖頁數、證號...等）</td></tr>
<tr><td rowspan="6">國內</td><td rowspan="6">學術性論文</td><td>期刊論文</td><td></td><td rowspan="2">篇</td><td>請附期刊資訊。</td></tr>
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<tr><td>碩士生</td><td></td></tr>
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<tr><td colspan="3">其他成果<br>(無法以量化表達之成果如辦理學術活動、獲得獎項、重要國際合作、研究成果國際影響力及其他協助產業技術發展之具體效益事項等，請以文字敘述填列。)</td><td colspan="3"></td></tr>
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