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Digital Pathology: An Overview

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Introduction

Digital pathology (DP) is a sub-field of pathology that focuses on data management based on information generated from digitized specimen slides. Through the use of computer-based technology, digital pathology utilizes virtual microscopy.

Glass slides are converted into digital slides that can be viewed, managed, shared and analyzed on a computer monitor. With the practice of Whole-Slide Imaging (WSI), the field of digital pathology is growing and has applications in diagnostic medicine, with the goal of achieving efficient and cheaper diagnoses, prognosis and prediction of diseases due to the success in Artificial Intelligence and Machine Learning.

DP alters images from the microscope to the computer screen & storage media from glass slides to digitalized image files. Digitalized pathologic images stored in computer servers or cloud systems can be transmitted over the Internet. Whole-Slide Imaging (WSI), also known as virtual microscopy is a digital representation of an entire glass slide at microscopic resolution.

Discovery of digital pathology

The first mention of a methodology resembling digital pathology is over a century old. At this time, scientists were transferring images produced by microscopes onto photographic plates to capture the images and store them. In the late 1960s, the practice of telepathology emerged, where scientists began practicing pathology at a distance, gaining easy access to slide images produced at labs in other

locations. In addition to this, at that time National Aeronautics and Space Administration (NASA) was successfully monitor the health condition of their astronauts at a distance using telemonitoring systems.

On Oct 4th, 1993 Dr. Bhattacharya and Dr. Ronald S. Weinstein discuss the first telepathology diagnosis in china So, Ronald S. Weinstein has been recognized as the "father of telepathology. In the late 1990s Renato Ferreira from the University of Maryland Institute for Advanced Computer Studies and Joel Saltz from Johns Hopkins University designed the first software system to support whole slide images. This system used a robotic microscope and computer software to stitch together individual static images of a slide, captured in a tile-based mosaic pattern. At that time each focal plane created 7 GB of data, with individual slides reaching up to 210 GB of data. With advancements in digital cameras, objective lenses, robotics and computers, new whole slide images scanners (WSS) were built that produce high-resolution digital slides with manageable file sizes. By 2000, a variety of commercial Whole Slide Image (WSI) scanners were being manufactured. This included large instruments able to handle more than 100 slides to small footprint devices.

Components of digital pathology

The digital pathology ecosystem consists of three major components:

a) Information systems
b) Digital pathology system (DPS)
c) System tools

The information systems include the hospital information system (HIS), electronic medical record (EMR), laboratory information system (LIS) and radiology picture archiving and communication system (PACS).

The DPS consists of two connected subsystems: a device (e.g., whole slide scanner) used to acquire and manage digital images and a workstation (e.g., display cockpit) to view and/or share images.

The System tools (e.g., image analysis algorithms) that interact with the DPS allow digital images to be analyzed and manipulated for various applications such as computer-assisted diagnosis,.

Whole Slide Scanner (WSS)

A Whole Slide Scanner is an automated robotic microscope capable of digitizing glass slides. Each field of view (FOV) of the slide is imaged and stitched together to produce a whole slide image. Both low-volume (1–4 slide capacity) and high-volume (200–450 slides) scanners are available for laboratories to use. High-throughput scanners are typically used in clinical or research laboratories and have the facilities of continuous loading & removed the slides while others are still being scanned.

WSI instruments use different objective lenses such as 1.25, 2, 5, 10, 20, 40, 63, 80 or 100X. For routine surgical pathology, scanning glass slides using a medium magnification objective (e.g., 20X) and for identifying microorganism higher magnification (e.g., 40X or greater) lens are required.

To achieve whole slide scanning, these devices therefore use tile- or line-based scanning methods. With tile-based scanning, a slide is imaged in contiguous squares (tiles), which are subsequently merged into one large mosaic image. With line scans, the slide is imaged in consecutive strips that eventually get joined to form one whole slide image. Individual images are digitally stitched together using computer software algorithms. Most instruments can now scan slides in 1–3 min.

In WSS for image resolution micron/pixel is used rather than scan magnification (e.g., 0.5 mm/pixel vs. 20X or 0.25 mm/pixel vs. 40X). WSI scanners that offer lower micron/pixel values allow pathologists to get more information from the image which give more resolution and more detailed image with more image file size. The cytology slides contain thick smears or harbor three-dimensional cell groups that require to scan the slide in all X, Y and Z axis called as Z-stacking.

A typical file of one WSI scanned with a 200X magnification ranges from 400 to 650 Mb storage after compression and if we scan those slides at 400X magnification then required storage is multiply to factor 4 means 20-24 Tb per year.

Image analysis algorithms/ Software

Image analysis algorithm is the extraction of meaningful information from whole slide images. Many specialized image analysis software platforms are commercially available (e.g., Visiopharm, Definiens, Indica Labs, Virtuoso from Roche, Genie from Leica etc.). These software algorithms have been developed to identify rare events of body like nuclei detections, tumor cell detections, screening for microorganisms, counting mitoses, detecting micro metastases in lymph nodes, extent of tissue fibrosis etc.

Application of digital pathology

a) Education

Digital pathology is playing a major role in undergraduate pathology education and now a significant part of postgraduate education and research.

b) Diagnostics

Digital pathology is being used in consultation between two pathologists in two different settings. Digital consultation can be classified as local when that consultation is performed between colleagues in the same practice but at a different site and remote consultation when a distant consultation outside the practice is involved to give expert opinions.

c) Research

Digital pathology used in scoring tissue micro arrays (TMAs), it used in easy exchange of digital images between research institute, digital slides can be used for viewing, storing annotations and measuring pathological abnormalities, It can be used in basic medical research to quantify cells which express certain fluorescent proteins or cells that are labeled with colorimetric dyes for cell viability analysis.

d) Archiving

WSI are saved permanently with constant quality, easy retrieval of cases for teaching, research, clinico-pathological purposes, the same case can be accessed by different observers at the same time and Whole Slide Image can be integrated into the pathology report and the hospital information system.

Conclusions

Digital pathology has become a useful and valuable tool in clinical and research pathology. It can transform the glass slides in to digital images. Glass slides are scanned by various whole slide scanners and produce whole slide images. These digital images are analyzed by various image analysis softwares which quantify the whole slide and give the result. Digital images are easily stored in to cloud system and archived when necessary. Within minutes several hundred of slides are analyze by using digital pathology together. Digital pathology save the time required to analyze the slides, it reduce the man power required to perform the ordinary pathological processes.