The Virtual Microscope: a powerful tool for learning and teaching

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Summary

With the introduction of a problem-based learning curriculum at the Faculty of Medicine of the University of Geneva, the basic medical science curriculum has been reorganized in monthly, multi-disciplinary units dedicated to the main functions of the human body (reproduction, locomotion, etc.). Several disciplines including histology are therefore taught across these different teaching units. To optimise longitudinal integration and allow comparative analysis of histological sections, it became obvious that students should have a free and facilitated access to all histological specimen studied along the curriculum. To this end, carefully chosen specimens were digitalised at high magnification, stored in a database and made available dynamically through the web. This article describes the hardware and software infrastructure used, and the added values offered by a Virtual Microscope approach.

Description of the Virtual Microscope

The system that generates our virtual slide collection is based on two softwares developed for Nikon by Laboratory Imaging (http://www.lim.cz/): EclipseNet, an image archiving and networking software which includes image capture and organization as well as administration of databases and Web DB, an image web server which enables to search and view the virtual slides using a standard web browser.

In brief, the system configuration (figure 1) describes as follows: a Nikon Eclipse E600 microscope equipped with a Nikon DXM1200 camera and a Prior motorised stage, connected to a personal computer (Eclipse 1) running the EclipseNet software which drives the scanning of histological sections. A second computer (Eclipse 2) also equipped with EclipseNet, except for the modules controlling the microscope, the stage and the camera, allows the annotation of the virtual slides and management of the database.

Image capture

EclipseNet drives the motorised stage and the camera to take consecutive pictures of selected regions of histological sections at the highest wanted magnification. The hundreds to thousands image files are automatically assembled in a single large overview (figure 2). A high-performance shading correction ensures the evenness of the reconstituted images. Lower magnifications are then calculated and reconstructed from the high-resolution scan. This simple procedure contrasts with that of other digitalisation systems, which require a new scan for each magnification to be displayed.

EclipseNet also allows the annotation of the virtual slides after scanning. These annotations are reversibly removable: a non-destructive annotation layer is stored independently of the image data within a single file.

Image organizer and Database management

All the jpg files (“tiles”) and information (“vsl file”) of a given section are stored in a folder, which can be readily copied to the folder. The administrator of the system freely defines the set of metadata (“fields”) associated with each collection (“table”) of virtual slides. Most of the metadata are descriptive but also include links to other documents such as pdf, web sites or static images (“image gallery”). The user’s rights can be fine-tuned to fit defined roles, eg for first year students, teachers, or administrator of a collection. If authorised, a user can edit the metadata and also pre-select specific regions of interest (ROI) through a web interface.

Image Web Server

Web DB is an application on the web server that enables viewing and querying (sorting, filtering) the database via a Web browser (Mozilla Firefox or Microsoft Internet Explorer). It includes PHP scripts, Apache web server and MS-SQL database.

The content of the web database can be displayed according to 4 different modes (thumbnails with or without metadata, single slide or comparative
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display) (figure 2: single slide display; figure 3: comparative display).

The web server sends only the «tiles» required for the selected region of the slide to be displayed. Upon moving in the virtual slide, or when changing magnification, Web DB sends the new tiles corresponding to the other selected region. Web DB is therefore faster than the systems that require pre-loading of the entire image before display.

A powerful tool for learning

With the basic functions of the system, the students can:

– freely navigate the virtual slides, at any magnification, from anywhere and at any time, thus providing a unique tool for self-learning throughout the curriculum

– view the whole histological section at a glance, which is of great topographic help to bridge the gap between macroscopic and microscopic anatomy (figure 2)

– benefit from teacher annotations, which help the student to identify specific regions, tissues or cells (figures 2, 3). These annotations may be removed, thus allowing self-evaluation

– sort and filter the collection of virtual slides according to their needs

– have free access to rare, expensive and short-lasting specimens, eg immunolabelled sections

Several additional educational tools have also been specifically developed, to allow the students to:

– follow teacher-guided tours made of pre-selected regions of interest (ROI) (figure 2)

– display 2 slides side by side, thus allowing comparison of different staining procedures (figure 3), normal versus pathologic specimens, etc. This comparison facilitates the training of differential diagnosis

– consult attached documents, eg section’s drawing, handbook of the laboratory tutorials, etc.

– view a gallery of static images cognate with virtual slides, thus allowing further analysis of specific structures, comparison of different staining procedures, relationship with the ultrastructure revealed by electron microscopy, etc.) (figures 2, 3)

– monitor the regions of the virtual slide already scrutinised (“tracking”), thus allowing to control that large areas of each section have been properly screened

Figure 1. Diagram of the system used to generate and display virtual slides. The Eclipse 1 computer is equipped with the EclipseNet software that drives the Prior motorized stage and the Nikon DXM1200F camera of the Nikon Eclipse E600 microscope for the scanning of histological sections. The Eclipse 2 computer is also equipped with EclipseNet software (except for the modules controlling the microscope, the stage and the camera) and is used as a workstation to annotate the virtual slides and to manage the database. To accelerate transfer rates of the data, the Eclipse 1 computer is connected to the server (VSLSERV) through a Gigabyte LAN. The server is equipped with the Web DB software and is connected through an optic fiber (FO) to a high capacity and high availability storage array (SAN) where the virtual slides are stored. The server is connected to the network through two Gigabyte LAN ports, one of these being mainly used for the web access. The reverse proxy (Rproxy), used as an intermediate between the web clients and the server, treats all requests from the web and transmits them to the server which is only accessible through our intranet. UPS: Uninterrupted Power Supply.

Figure 2. Single slide display by the Virtual Microscope. Available metadata (database fields) are indicated in the menu on the left side of the main window. A small overview, the links to show or hide annotation and tracking layers, as well as the links to the available pre-selected regions of interest (ROI) are indicated on the right side.
A powerful tool for teaching

The teacher can:
- elaborate educational scenarios, to guide the self-learning student (teacher-guided tour)
- generate exercises on pre-selected ROI, to be screened and identified by students
- prepare teaching supports to be used in the classroom, such as on-line navigation of ROI, static images derived from the virtual slides, etc.

Current usages and future perspectives

The Virtual Microscope was introduced in our Faculty during the academic year 2004–2005, as a revision and self-assessment tool, complementary to the first year practical skill classes run on conventional microscopes. During their self-learning time, the students had to apply the knowledge acquired during the practical class to other unknown sections, eg to identify structures in pre-selected ROI. The feedback from the students was positive. Some of them have spontaneously saved images from the virtual slides, annotated them and requested teacher advice on these items.

We are currently pursuing the digitalisation of all the sections used in the teaching program of normal histology, aiming to extend the use of the Virtual Microscope to the second and third year of the medical curriculum for the next academic year. We are also planning to extend the application of the method to the teaching of histopathology, haematology and dermatology specimens.

In addition, an extensive virtual slide database should also prove useful in the continuing education of professionals, for the distance diagnosis of rare and complex cases which may require the confrontation of experts in different locations, as well as for multiple research purposes. Last but not least, the Virtual Microscope approach also provides an easy, ready-to-use teaching support for countries where access to conventional microscope is not possible.

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References