Aegean Pathology Journal **1**, 90–102, 2004
Available on line at www.epd.org.tr/apj.php

Ideal computing equipment in an anatomical pathology department

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Accepted for publication on 1 November 2004

Modern information systems of pathology are facilitating the work of the pathologists and of the whole health personnel. They have become an essential part of the electronic health record. Whereas the management of reports has advanced significantly, image dgitization in Pathology has received very little attention from hospital information systems managers.

In this article, the ideal computing equipment for a department of pathology is analyzed, with descriptions of the type of computer, printers, and scanners, more suitable for every user; the utility of pocket PCs or tablet PCs; the use of videoconference and of communications networks in general; the advantages of the total digitization of slides and of the integration of devices is also discussed. As for the computer programs, solutions for image analysis are described.

Key words: computer systems, pathology digital image, virtual slides, communication networks.

Introduction

National and Regional Health Services have been investing for several years in electronic medical record projects, including pathology records, to achieve a "unified health record". Significant advances have been done in digitization of Radiology images and management of clinical pathways, as in Critical Care, although the achievements are very unequal between different countries. Unfortunately, there is a uniform underdevelopment of digital image in Pathology, compared with other medical specialties.

Computing systems in Pathology departments have already solved problems in reports editing, laboratory management, patients and diagnosis searches and statistical analysis. This has been possible to a broader offer of modern commercial systems, which are becoming stable, flexible and complete solutions.

We are still learning to ask for improvements in our pathology information systems (PIS), and we are realizing of the importance of integration with the rest of the information systems in the hospital.

However, there is little improvement in the integration of digital image in pathology systems.[1,2] We can turn this delay into an advantage if we learn from what have been implemented and invested in Radiology, Endoscopy, Laparoscopy Surgery or Robotic Surgery imaging. Therefore, our aim can not be the acquisition of digital cameras for our microscopes, but defining a complete project of image digitization in Pathology, with a central repository of images and an automatic management of all images the pathologist work with.

The objective of this work is reviewing the computing hardware and software that could make possible a complete automation of pathology departments, with special attention to management of digital images.

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Desktop Computers (PC)

This is the main component of a pathologist's workstation. The specifications of personal computers may vary between different roles in the Pathology department (registration, laboratory management, reports editing, image editing, voice recognition …), the following specifications can be considered as adequate (Sept, 28th, 2004):

- Microprocessor Intel Pentium 4 3.0 GHz (530 series with HT technology) or AMD Athlon XP 2800+.
- Motherboard must be coherent with microprocessor. For instance, for mentioned Pentium 4 processor a bus 800 MHz bus is necessary and motherboard should contain a chipset Intel 925X or better.
- RAM: 512 Mbytes dual channel, type 400 MHz DDR2.
- Hard disk: 250GB Serial ATA, with 7,200 rpm.
- Graphics card 128 MB PCI Express x16.
- DVD 16x recorder (if used for image storage)
- CD-ROM (CD-RW) 48x recorder
- Network adapter Fast Ethernet (at least 100 Mbit/s) or Gigabit
- Frontal USB 2.0 ports
- Sound card and speakers
- Wireless optical mouse
- Wireless keyboard
- 17 inches TFT screen

The price for a system with those characteristics is around 1,500 to 2,000 euros.

Design innovations are also affecting desktop computers. Central units used to be an ugly and noisy metal box with square borders. New cooling systems allow for the existence of silent systems. Methacrylate and aluminum boxes are becoming popular; with small sized boxes with elegant design. So called barebones (Soltek QBI) and integrated CPU-Monitor systems (Elitegroup Aio, 1,500 euros) are some practical solutions.

Apple, leader in vanguard design with Macintosh computers, has solutions for every kind of user, from notebooks with wide screens, like PowerBook G4 17 to powerful two processors units like PowerMac G5. Software programs in Macintosh computers are often superior to PCs equivalents in image edition and graphical areas, but unfortunately these programs are not compatible with PC computers, and different versions for each platform need to be acquired.

Computer screens

Nowadays, flat panel TFT screens are widely used, and they are replacing rapidly traditional CRT monitors. We should be aware of the difference between TFT monitors and plasma screens, which we shall describe below.

The size of TFT screen should be 17 inches for general purposes. A 15" monitor should suffice for input of small amount of data, like terminals used for requesting techniques. For computers used in digital image edition or review, a larger screen size is recommended, with special screens, preferably 21 CRT monitors with high resolutions (2,048 x 1,536) and a high horizontal and vertical refresh rate (140 kHz) and smallest dot pitch (0,24 mm). Some examples are LaCie electronblue IV, (800 euros) or Sony Trinitron F520, with 0.22 mm dot pitch (1,600 euros), and IBM ThinkVision C220p with a 0.24 mm stripe pitch (650 euros).

Certain TFT monitors have and exceptionally high resolution, like IBM IntelliStation T221, a 22.2" screen with a pixel pitch of 0.1245mm, and a maximum 3,840 x 2,400 addressability.[3] However, its price is above 8,500 euros (Fig. 1).

Figure 1. IBM IntelliStation T221-DG5 Black 22" LCD is considered the word's finest monitor. It allows for a detailed analysis of digital images.

Where should we install a PC?

Each pathologist should have his/her our computer at the office. It is also necessary to install a terminal in each position of the gross study room, preferable accompanied by a digital image system. A computer will be also useful in each section of the laboratory (cytology reception, biopsies reception, general techniques, special techniques, immunohistochemistry, and molecular biology) and at autopsy room. The meeting room should also have at least one computer and an additional system should be installed for digitizing and editing images, and this one should also equipped with a DVD recorder.

PC at grossing room

Grossing room and autopsy room have been considered "not a particularly friendly site for a computer"[4], due to the use of bloody specimens, small organic or chemical products. However, there are solutions for these problems, like washable keyboards that can be used directly with gloves on, systems that can be manipulated with a foot pedal control, or slash-proof computers and monitors for use under these extreme environmental conditions.[5] Foldable keyboards like Adesso Fold-2000W (30 euros) can be washed and disinfected after use together with the rest of the material (Fig 2); formalin-resistant and water-proof monitors and computers can be used at the grossing station, preferably with touch screen (Fig. 3), and optical wireless water-proof mouse. Water resistant and washable keyboards, like Logitech KeyCase can also be connected to pocket computers or PDAs.

Figure 2. Starcover Flexboard was one of the first washable keyboards.

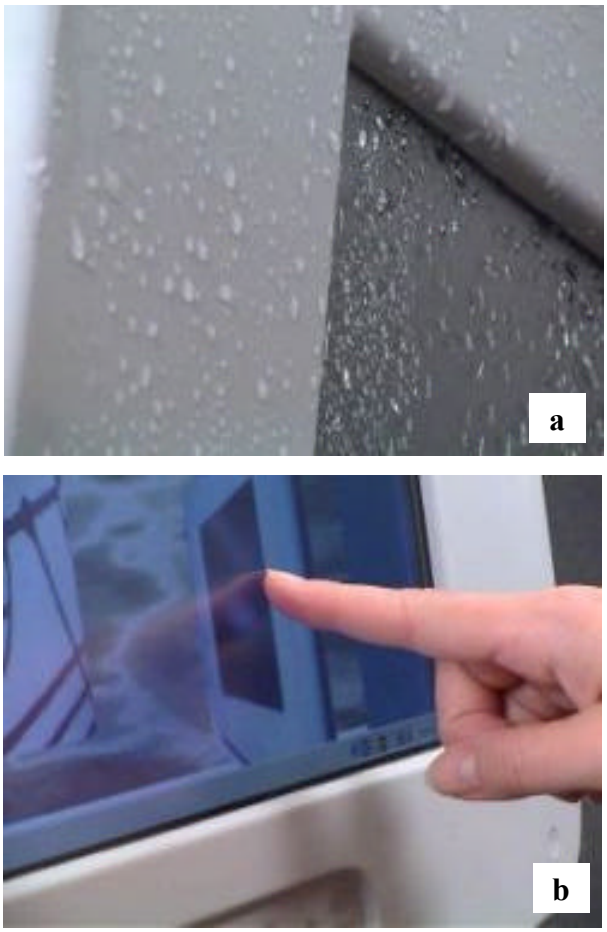

Figure 3. Water-proof monitors (a) can also work as touch screens for data input (b).

Automated grossing systems

Milestone company has designed systems for grossing and autopsy study. Argos was one of the first digital imaging systems for the grossing station. It was equipped with a calibrated video camera for measuring specimens, a voice recorder for descriptions and comments, and water resistant mouse and keyboard. A foot pedal allowed for a complete control. Images could be stored in JPEG format. A complete integration was possible with PathVision digital image management software.[6]

Modern systems include digital cameras and/or high resolution digital video cameras (3.4 Mpixels or better), like Photodyne Technologies or Milestone MacroPath.[7,8] The cost of these complete automated systems is from 8,000 to 15,000 euros.

Figure 4. Milestone Macropath. This system allows integration of clinical data, pathology description and digital image during gross study

Notebooks

Notebook specifications should include, at least, a Pentium 4 2.4 GHz microprocessor (or Intel Pentium M 1,6 GHz) or AMD Athlon XP 2000+; 512 RAM, 40 GB hard disk, combo DVD/recorder CD-RW combo unit, video card of 64 MB, USB 2.0 connectors and IEEE 1394 (for digital video) and TV or S-video output. The price for this computer is between 1,500 and 3,000 euros. More powerful solutions include Pentium 4 3.06 GHz processors.

Notebooks are especially useful in teaching sessions, clinicopathological sessions, meetings and congresses, but they can also be used as data input devices.

Tablet PC

Tablet PCs have similar dimensions of a notebook, with a lighter weight of less than one and a half kilogram. These devices have tactile screen and screen keyboard and they incorporate wireless connections. The price is around 3,000 euros.

One of the main applications of Tablet PC in Pathology is replacing paper forms with electronic forms, for instance, grossing lists. Due to the total mobility capacity, they allow and easy management of stores, controlling existences of products, annotating incidences in archives, or as a general purpose notepad.

Handheld computers (PDAs)

A personal digital assistant (PDA) is a small computer (less than 150 grams) with an easy interface that allow pathologist a simultaneous work with microscope and knowledge facilities like staging software, tumor classification guides or reference images. They can also be used as voice recorder in specimen gross or microscopy descriptions. Some models also have built-in medium resolution digital camera, up to 1.2 megapixel, like Palm Zire 72, (300 euros), PalmOne Treo 600 Smatphone (400 euros), or HP iPAQ h6315 Pocket PC (700 euros).

There are two main types of handheld computers: Palm devices with Palm OS, manufactured by PalmOne or Sony; and those using Windows Mobile/Pocket PC operating system, available from many manufacturers like HP, Dell or Acer.

Palm devices used to be smaller, cheaper systems, but new Palm models are becoming quite similar in price and specifications to Pocket PCs.

Palm Zire, and Acer n10 or Dell Axis series are cheap systems of each platform, available from less than 100 euros and 200 euros, respectively. HP iPAQ systems are well known for their excellent display and expansion capabilities. Handhelds can replace notebooks in slides shows in congresses or clinicopathological sessions, because there are programs for those devices that allow working with PowerPoint slides, both in Palm platform (Documents To Go) and in Pocket PC systems, such as Conduits Pocket Slides (35 euros), CNetX Pocket SlideShow (15 euros), or IA Presenter (20 euros). Expansion cards with VGA adapter are available as PC card, CompactFlash, Memory Stick or SD cards, like Margi Presenter to Go (180 euros), ColorGraphic's Voyager (150 euros), Lifeview Flyjacket i3800 (180 euros), Lifeview FlyPresenter-CF (120 euros), or FlyPresenter (80 euros).

Recent powerful models like HP iPAQ hx4705 or Dell Axim X30 with a 624 MHz processor or Palm Tungsten C with a 400 MHz processor, also include built-in wireless network (Wi-Fi) adapter that allow an easy connection to Internet to visit web pages and receive e-mails anywhere. They can also be used as a terminal of the pathology information system of the department.[9]

Direct printing from handheld devices is also possible using Bluetooth technology, and it is also possible with small infrared printers like Canon i70 (250 euros).

Uninterruptible power supply (UPS)

Those computers with a continuous use (report transcription or digital edition) should be connected to a UPS system to maintain power in the event of a power outage. They allow for an normal shutdown of the computer or to perform an automate backup and shut down procedures in case there is a power failure while no one is working at the computer. These systems prevent from loss of data, and they are available from 150 euros with a power of 1,000 VA. UPS should provide constant power from its own inverter (on-line UPS) and include RS-232 ports or USB interface with the computer to protect.

Printers

Monochrome laser printers are most suitable for report printing, due to the high volume of reports to be printed daily. They are also commonly used to for general printing purposes, like scientific articles or web pages. In a pathology department reports should be printed in network printers like Lexmark T632 (38 ppm), Dell M5200n (35 ppm) or HP LaserJet 4200N (35 ppm) with prices ranging from 1,000 to 1,500 euros.

Those computers that are not so often used for printing documents (letters, reports), with a low workload, using an entry-level monochrome laser is a better option. Available models include Brother HL-5030, HP LaserJet 1150, HP LaserJet 1300 o Epson EPL-6100L, from 16 to 19 ppm, with prices around 400 euros.

Inkjet printers are the best price worth option for color printing. There are two available technologies: thermal technology, whereby heat is used to put ink onto the paper; it has been adopted by manufacturers like Brother, Lexmark or HP; both ink and printhead and included in the cartridges. On the other side, piezoelectric technology is used by Epson and some Canon printers, in which cartridges are cheaper, since they are just ink reservoirs. Some basic models are so cheap – 60 euros –, like HP Deskjet 3745 with 1,200 x 1,200 dots per inch (dpi), and 14 pages per minute (ppm), and Epson Stylus C46 (2,880 x 720 dpi, 12 ppm) that it is worth replacing the complete printer instead of replacing ink cartridges.

A general purpose inkjet printer (Epson Stylus series C and hp cp1700) can be used for text or low resolution graphics printing. They must be reasonably fast (12 to 24 ppm in black quality and 2 ppm in color quality). However, in order to print high resolution pictures, a photographic printer (Epson Stylus Photo R800 or HP Deskjet 6540) is a necessary option. Their prices are between 300 and 550 euros. They must be high resolution printers, at least 2,400 x 1,200 dpi. In Epson printers we can find resolutions of up to 5,760 x 1,440, and in HP printers, 4,800 x 1,200 dpi is the maximum resolution available. An interesting option in photographic printers is printing directly from built-in memory card slots (SD, SmartMedia, Compact Flash or Memory Stick), available, for instance, in HP Deskjet 450 and Epson Stylus Photo R300, without using a computer.

Figure 5. Epson Stylus Photo R800. High quality photographic printer with eight individual cartridges.

An interesting option is the use of printers with several separate color cartridges, like Epson Stylus Photo R800 (Fig. 5), with eight individual cartridges, including matte black ink and gloss optimizer, with a price of 16 euros for each one.

Laser color printing does not seem to substitute inkjet color devices in high quality photography,

because it is still difficult to obtain a photographic quality with laser technology. However, it can be very useful for high volume color printing. The prices are still going down and they can be found starting from 1,500 euros. Maintenance is more expensive than other options and their toner cartridge allows printing 5,000 pages, and what it is worse, drum cartridge needs to be replaced every 12,000-17,000 printings, fuser cartridge every 45,000 pages, and transfer roll every 50.000 pages.

Label printing and bar code label solutions can be done with conventional laser printers, using label paper and making necessary adjustments in the pathology information system. In many cases, label printers are a preferable option. They may be installed at the reception desk or at the laboratory for printing slides labels. Small thermal label printers like Seiko Smart Label (230 euros) are good options for a small printing volume. See "Identification of specimens, blocks and slides" for specific solutions.

Scanner with transparency adapter and document feeder

Scanner works using a sensor of CCD (charged coupled device) type, which consists of small photosensitive diodes that extract the information from the image. Therefore, a scanner with an optical (real) resolution of 600 dpi has 600 photoreceptors. Another component to analyze in scanners is the light source, of which three types exists: hot cathode, cool cathode, and xenon. Hot cathode light is more usual and they allow a rapid warming, although they are a more expensive option than cool cathode light. Xenon systems are more stable and precise and it is only used in professional documental business. The recommended optical resolution in Pathology is 2,400 x 4,800 dpi. The time used for a color picture scanning should be less than 40 seconds. A conventional scanner with those specifications (Epson Perfection 2580 PHOTO or HP Scanjet 3970) is available at a price of 150 euros. If a high volume of scanning is necessary, for example, digital archiving of pathology study requests or pictures, professional scanners is a more appropriate solution. Their prices range from 1,000 to 2,500 euros. These products used to have a SCSI interface, but this is being replaced by an USB 2.0 or an IEEE 1394 connector.

A most valuable scanner accessory in Pathology is the transparency adapter, since it can be used for digitization of kodachrome slides, photographic negatives and x-ray films. In all these cases, light source should not be generated by the scanner but it should come from the transparency adapter. Usual flatbed scanners have a small transparency accessory with a capacity for scanning 3-6 kodachromes simultaneously.

Automatic document feeders permit a scanning speed of 8 to 25 pages per minute, with a resolution of 150 dpi, which is adequate for the digitization of pathology request paper forms.

Some professional scanners, like Fujitsu Document Station Advanced, Fujitsu *fi* series, or HP digital sender 9100c, with prices from 2,500 to above 3,200 euros, are complete solutions for document management because they can integrate digitized documents into the pathology or hospital information system, generate an automatic numbering for each file, create PDF documents, send them through the hospital network to the destination computers, compress files, and generate e-mails with attached documents. Similar functions have been incorporated in Fujitsu ScanSnap, a product for small volumes.

A possible use for these automatic devices is bar code reading, to identify patient (demographic data) without errors.

A conventional scanner is enough for digitization of pictures or slides that will be presented with video projectors or for Internet distribution, because a resolution of 100 dpi may be sufficient. However, for kodachrome digitization, a minimum resolution of 600 dpi is recommended. For optical character recognition (OCR) functions document should be digitized in pure black and white with a resolution of 300 dpi. All these parameters can be adjusted with the supplied software shipped with the scanner.

Scanner of slides and negatives

Kodachrome slides and negatives (35 mm) are still an invaluable source of information in all Pathology Departments. Not many pathologists are aware of the possibility of scanning of negatives using a

conventional scanner with a transparency adapter, as stated in previous section, or using fast specific slide and negative scanners. With this option we have the advantages of the two systems; conventional photography, an original support with an optimal definition, which is just being equaled by digital formats; and digital format prevents film developing of all pictures taken.

If the number of kodachrome slides or negatives is high and a high quality resulting image is necessary, the most adequate solution is using slide scanners that are able to perform a complete scanning of excellent resolution (above 2,500 optical dpi), with 36 color depth in 40-60 seconds, with six images at the same time and automatic loading of slides and negatives. Some of the models that could be suitable are Konica Minolta Dimage Scan Dual IV, Acer-BenQ ScanWit 2750i, HP Photosmart S20, Nikon Coolscan V ED. The price is between 350 and 710 euros.

An economic option for kodachrome slide digitization is direct picture taking from a digital camera, preferably with a negative carrier accessory.[10]

Some special high resolution models have multi-format capabilities, special lenses and LED illumination that allow a minimum chromatic aberration. These high optical resolution products (4,000 dpi), like Nikon Super CoolScan 9000 ED have prices around 3,000 euros.

A complete review of film scanner models is available in Kodak web site.[11]

Multifunction devices

Multifunction printers include additional functions in the same device, like scanner, copier and, some times, fax capabilities. Inkjet multifunction devices have the best quality-price relation. Technical specification must be similar to those seen in printers and scanners sections. Optical resolution in copying functions must be at least 1,200 x 1,200 dpi.

The price of multifunction printers goes from 200 to 400 euros. In Spain, 50 euros of this price corresponds to a special tax of the General Society of Authors in Spain (SGAE).

If the number of copies is above 100/daily, a better option is using a conventional photocopier, and, if a high printing volume is necessary, laser multifunction devices like monochrome HP Laserjet 4100 mfp (2,000 euros) or HP Color 9850mfp (2,800 euros) can be an option.

DVD writers

DVD recorders are becoming a common electronic device in living rooms, but computer DVD writers have some characteristics that must be taken into account for a professional work.

Whereas there is only one standard in CD-ROM on time recording (CD-R) and in several times or "re-write" recording (CD-RW), in DVD devices, we can find two common different technologies (DVD+R/+RW on one side, and DVD-R/-RW), both allow writing a 4,7 GB DVD disc in less than 15 minutes. Since the unification of the two formats has not been possible, many devices adopt both of them. DVD+R/+RW seems to receive more attention from manufacturers. The price of an internal unit is around 300 euros, and external units, with USB or IEEE 1394 interface can be found parting from 400 euros. Some units allow also writing CD-R and CD-RW disks.

Double-layer recording technology use double-layer DVDs to record almost twice as much data (up to 8.5 GB) as it can be done on single-layer DVD+R DL disc. Unit recording speed are: DVD+R at up to 16x, DVD-R at up to 8x, DVD±RW at up to 4x, and double-layer DVD+R at up to 2.4x.

Digital photographic and video cameras

A most important characteristic to evaluate the quality of a digital photographic or video camera is resolution (in fact, size) of captured images, which depends on the size of the CCD incorporated. Nowadays, camera CCDs of most advanced digital photographic cameras, like Jenoptik ProgRes 3012, are up to 20 megapixels in size (4,608 x 3,480 pixels). More conventional models include 5.3 megapixel CCDs. In some digital microscopy cameras, a single 1.45 megapixel CCD chip, piezo shifted, can achieve effective image resolutions up to 4,080 X 3,072 pixels, that is, 12.5 megapixels. It takes approximately 3 seconds to capture a high resolution image. Olympus DP70 and Nikon DXM1200F are examples of these high resolution photomicrographic cameras.

A device similar to a stereo/dissecting microscope for low magnifications is Olympus MIC-D, which allows image size of up to 640 x 480 pixels. Some digital cameras can also be connected with a fireware (IEEE-1394) interface, like Sony DFW-X700 and DFW-SX900.

Leong et al (2004) have recently reviewed all the aspects of digital photography in anatomical pathology.[12]

Projectors

Digital projectors have become an essential element in all professional meetings, including clinico-pathological sessions, and every pathology department should have one. They are easy to use and image quality is very high. Prices are in a wide range, from 2,000 to 8,000 euros, depending on many features, of which the most important ones are brightness, since a big room where complete darkness can not be achieved, will need a projector of 2,500 to 3,000 ANSI lumens. In small dark rooms, 1,000 ANSI lumens will be enough. Other important features are contrast ratio, and indicator of sharpness; weight, resolution, and interfaces. Installed (fixed) projectors should have a contrast at least 1,000:1, weight is between 5 and 7 kilograms, display resolution of 1,024 x 768 pixels (XGA). Portable projectors should have a contrast of 2,000:1, weight between 1 and 2 kilograms, and display resolution of 1,024 x 768 pixels (XGA). Interfaces should include S-video, RCA, composite video, and DVD. Noise level should be less than 35 dB.

The remote control should allow pointer (mouse) movements. It is also possible to send the video signal remotely to the projector using wireless network connection from PC or handheld device.[13]

Plasma screens

Plasma/LCD monitors are big format screens, which may substitute old CRT monitors in clinicopathological session room. Image quality of these devices may not be as high as best CRT monitors, they have the advantage of the small room necessity for these large screens, since depth may be less than 14 centimeters. Comparing with projectors, they have the advantage of comfortable use. The price for 42 inches screens is about 4,000 euros.

Personal videoconferencing

The essential elements for computer video-conferencing between two users are a USB web cam, microphone and videoconferencing software, like MS Netmeeting. If more than one camera or high resolution video is necessary, special expansion cards will be necessary in the computer.

A resolution around 640 x 480 will be enough with a refresh rate of 25 frames per second (fps) and a luminance sensitivity of 1 lux or less.

Alfaro et al. (1998) have described a simple transmission method of pathology images and videos in Internet.[14]

Bandwidth for optimal videoconferencing is 256 to 512 kbps per second. In Spain, health services are implementing 1 Gbit/s computer networks, which makes an efficient videoconference possible.

If several participants from diverse sites make simultaneous use of multiconference sessions, a Multi-point Control Unit (MCU) will be necessary. This is a special central computer and communication system to which all users (from 4 to 256) connect.

Mobile data storage

Nowadays slide presentation is usually made with MS PowerPoint files with plenty of images, videos, animated images, and other complements that need several megabytes of storage room.

The usual solution is using a CD-ROM writer, storing those presentations in CD-R discs. In these cases, we should confirm that files have been copied correctly, executing them from CD-ROM, preferably from another computer. A practical advice is closing disc after recording session, to avoid future manipulation of the media.

USB flash drive is becoming an increasingly popular solution for mobile transportation of data (Fig. 6). These small units, with a weight of around 15 grams, also called portable USB hard drive, USB memory stick, pendrive, USB disc, or memory pocket have a storage capacity ranging from 32 MB to 2 GB, and they allow easy transportation of data between computers, above all if these are equipped with

Windows XP operating system (otherwise, we'll need to transport also the device drivers).

Figure 6. Several models of USB hard drive units (USB sticks)

Not only capacity, but also reading and writing (7 MB/s) speed are important factors to analyze in choosing between several models. Price is between 40 and 800 euros. Additional features include MP3 mode and card reading facilities.

When a larger amount of information has to be transported, we can find a better option in mobile hard disk units like LaCie Mobile Drive (240 euros) for up to 40 GB, or in card readers like Kingston's 2.0 ATA Reader/Writer (25 euros) for PC-Card hard drives of up to 5 GB (170 euros).

Memory card in Pocket PCs (also interchangeable with digital cameras) is an additional data transportation media. CompactFlash memory cards are usually up to 1 GB (350 euros), but models with 6 GB capacity can also be found. xD-Picture is a smaller card format that may soon reach 8 GB capacity.

Digital voice recorder in text transcriptions

In grossing room, autopsy room and pathologist's office, voice recording systems have been usual to store description of organs, microscopy descriptions, comments and diagnoses that later on are typed by secretaries.

Digital voice recorders like Olympus DS-3000 digital recorder (250 euros) or TecNet TDR-2016U, besides and excellent recording quality, they support removable cards (SmartMedia, CompactFlash, SD) for recording of speech or music files. These cards can be changed when necessary. A 64 MB card allows for more than 20 hours voice recording. These devices connect directly to a computer USB port and files can be stored automatically in the destination computer. In this way, digital pathology reports can be associated not only with gross and microscopy images, but also with pathologists' original voice files.

Computer networks

These years, we are living a real revolution in communication networks, because in local networks wired connections (RJ45 interface) has been expanded with a new protocol called Gigabit Ethernet, with a speed of 1,000 megabits per second (1 Gbps), that is, 10 times faster than usual 10/100 Mbps adapters in hospitals. There is also a 10 Gigabit Ethernet (802.3ae) standard for local networks for use in optic fiber networks.[15]

For less demanding bandwidth needs (Internet navigation, databases consultation, information systems without image transmission), a new transmission mode is emerging. The so called Wi-Fi (Wireless-Fidelity) networks became popular with the use of the IEEE 802.11b protocol that works at 11 Mbps. Wireless networks can transmit nowadays at 108 Mbps using IEEE 802.11g protocol. In most desktop computers it will be necessary to install a PCI card, USB adapter. Notebooks and handheld devices without a built-in wireless chip can also install a PC-Card (PCMCIA), or a Compact-flash or SDIO (Secure Digital) wireless adapter (50 to 90 euros). Wireless traffic between several computers is controlled by an access point (200 euros), a kind of hub that in some networks can also have additional functions as ADSL modem or router.

Wireless technology is not only changing rapidly data communication networks, but it will have an important effect in voice communications in new wireless IP voice networks.

Specimen, paraffin block and slide identification

The correct identification of specimen containers is done with bar coded labels that is read at the reception

desk with a bar code reader to identify univocally of each specimen with the corresponding patient (two bar codes, for patient identification and specimen identification can be included). If specimen comes with a request form paper, this must have the corresponding bar coded label with the identification of the patient (medical record number). In Pathology Department, an additional bar coded label with the accession (specimen) number is added. Theses labels can be printed with specific or general purpose printers.

Cassette printers are special printers for identification of paraffin blocks or cassettes. Some models use heated styluses form marking (Raymond A Lamb Cassette MicroWriter, Shandon MicroWriter I Cassette Labeler, Triangle Biomedical Sciences SHUR/Mark Cassette Marker), while recent models tend to use ink-jet technologies (Leica IP C, Sakura Tissue-Tek AutoWrite).

Slides printers can also be divided into ink-jet printers (Sakura Tissue-Tek AutoWrite Slide Printer, Leica IP S), and those based in diamond-tipped styluses (Shandon MicroWriter Slide Labeler, Raymond A Lamb Slide MicroWriter, Triangle Biomedical Sciences SHUR/Mark Slide Marker), and also some laser systems (Raymond A Lamb Slide Laser Writer).

DakoCytomation Seymour Glass Slide Labeling System and General Data Thermal are special printers for slides labels.

New products produce bar codes, alphanumeric characters, and customized logos on tissue cassettes and microscope slides. These printers can also be integrated with the Pathology information system.

Integration with Pathology information systems

Less than half of modern Pathology information systems are efficiently integrated with hospital information systems, although an increasing number of them are implementing health information standards like HL7. The situation with "internal" integration with the rest of electronic devices in the Anatomical Pathology department is even worse, probably because of the recent advent of automation in these departments.

Only 25% of pathology information systems have specific options for cassettes printers, and only a 10% can work with automated immunostainers, although half of these programs can work with some histology or cytology device, and 70% can work with bar coded labels (16).

Since automation is increasing in Anatomical Pathology, with automated glass coverslippers, stainers, and tissue processors information systems should adapt to this new automated environment, that in the near future will also include paraffin blocks and slides archiving.

This complete integration would allow a detailed follow up of each specimen, block of tissue, staining, or slide. Turnaround times could be calculated precisely for each phase of the process. In order this integration to be possible, it is needed that all devices and information systems follow the same information standards, like HL7 for messaging between systems, or DICOM for images.

In the meantime, manufacturer should facilitate the Pathology Department an easy and practical way to connect automated devices with computers of the department network. An increasing number of devices are controllable or programmable from computers, like Leica ST5010 stainer, which makes possible a diagnosis of the correct functioning of the system. Automated devices should be able to receive a list of specimens or slides processed.

Image analysis

Some computer systems make easier the quantitative study of microscopic images. Commercial software generally has several optional modules, sold separately. One of these systems is CHAMP (Cytology and Histology Analysis Modular Package) from the Danish firm Dimac that besides the corresponding software includes a last generation PC with a large monitor, a CCD digital camera with an appropriate adapter, scanner, CD-ROM recorder, color printer and XYZ motorized stage.[17]

Some examples of well-known image analysis software are Visilog (Norpix, former Noesis Vision)[18] and WinGrain[17], Media Cybernetics Image Pro Plus, Media Cybernetics Optimas or Soft Imaging System analySIS plus.

Automated image analysis systems using whole slide digitization are reviewed in the virtual slide section.

Cytological screening

A recent review of cytological screening automated systems is available in Spanish.[19] Nowadays systems are AutoPap Primary Screening System (TriPath Imaging), ThinPrep Imaging System (Cytyc), InPath (Molecular Diagnostics), and Aphrodite (Dimac, Denmark).

Virtual slides: Complete slide digitization

A complete review of virtual slides and virtual microscopy systems can be found elsewhere,[20,21] including initial projects and commercial solutions. Briefly, we must remember that the amount of information a unique histology slide contains, needs between 200 MB and 40 GB of storage space. For that reason, effective compression algorithms need to be used to handle this amount of information, and virtual slide can be obtained with a final 150 to 550 MB size.

Figure 7. Ariol SL-50 is a complete slide digitization and image analysis system, with plenty of modules for immunohistochemistry and tissue microarrays.

Due to tissue microarrays development some efficient image analysis systems have emerged with specific modules for immunohistochemistry and molecular biology analysis, including total slide digitization. This has been the impulse that virtual slides needed to become better known, since that technology is complementary to what had been developing for conventional histological and cytological slides.

Ariol SL-50 is a complete automated image analysis system, which belongs to the OncoPath product lineage from the American company Applied Imaging (Fig. 7). This system has a completely robotized Olympus BX61 microscope, a slide dispenser, and a powerful computer and a large storage unit (DVD-RAM). Ariol SL-50 intended use is image analysis in immunohistochemistry, not only for nuclear markers but also for cytoplasmic staining (HER-2/neu) and FISH. Other interesting module allows comparisons between several markers of the same tissue area, synchronizing the movements in all markers when navigating into the slide.

ChromaVision ACIS (*Automated Cellular Imaging System*) is another image analysis system that consists of an automated microscope, a complete digital capture system, visualization modules, and automated interpretation, specially designed for immunohistochemistry and tissue microarrays.

General purpose virtual slide systems are now quite numerous. Some of these systems are robotized microscopes using special virtual slide software:

- Bacus - BLISS
- Dimac Nanoscan
- iPath
- MicroBrightField Virtual Slice
- Nikon Eclipse E600FN and EclipseNet VSL
- Olympus BX-61 and Media Cybernetics Image Pro Plus / Optimas
- Samba AcCell
- Syncroscopy Syncroscan
- vMic, Institute for Pathology, Basel.

Modified microscopes have been converted into digital image units, like Nikon Coolscope with EclipseNet VSL. Tiling and stitching are the usual techniques used by these systems to join together the captured images to preset them as a continuous virtual slide.

Recently, special slide scanners allow a faster and high quality complete digitization:

- 3DHistech Hi-Scope
- Aperio ScanScope
- LifeSpan BioSciences Alias II
- InterScope Xcellerator
- Trestle Medscan

Nanoscan (Dimac) can perform a complete scanning of a 20 x 20 mm slide area with a 1 micrometer resolution.

Aperio Technologies Inc. is a Californian company specialized in slide scanning. They have developed ScanScope II, a slide scanner that uses 20x and 40x lenses that scans continuously the slide, storing images in JPEG200 format. One of the main advantages of this system is the fast scanning method employed.

LifeSpan Biosciences, a company specialized in molecular pathology (antibodies, immuno-histochemistry services and localization databases) has developed a slide scanner (Alias II) whose main feature is the quality of obtained images.

Many of these virtual microscopy systems have special modules for tissue microarrays.

The price of virtual slide scanners goes from 70,000 to 200,000 euros, depending on configuration (web server, storage units, etc.). Commercial systems based on robotized microscopes can be found at the price of 50.000 euros. Some of these manufactures (Aperio Technologies, MicroBrightField) also offer scanning services for creating virtual slides of the sent specimens (20 to 80 euros per slide).

Nikon Instruments Europe distributes Eclipse Net the software of archiving and network transmission of images. The system can be used with digital cameras (Nikon DN100 and DXM1200) and Nikon Coolscope, and there is a module for virtual slide creation (EclipseNet VSL). This software makes easier the creation of image databases and stores images in JPEG200 format. LUCIA product lineage (Laboratory Imaging) also has modules for automatic classifying in immunohistochemistry, and can be used with automated microscopes like Nikon Eclipse E1000 (Fig. 8) and TE2000-E.

Other commercial programs that can be useful in Pathology are Web DB, a web server of images, or the module of three-dimensional images 3D Focus.

Telemedicine service of the Armed Forces Institute of Pathology (AFIP) also allows using commercial virtual slides systems, like ISSA/PHAROS (Vamstec, Zagreb), Trestle Corp, ASAP Imaging (Apollo Telemedicine), BLISS (Bacus Laboratories) and ScanScope (Aperio Inc.).[22]

Telepathology city is an excellent web site that compiles a large amount of practical information about digital image in Pathology.[23] The Florida State University has another excellent web with information about application of new technologies in microscopy.[24]

Figure 8. Automated Nikon Eclipse E1000 microscope. This model has been frequently used for virtual slide systems like LUCIA.

Conclusions

The budget needed for the acquisition of a complete virtual slide system can be as high or superior to what is needed for a full computing and digital imaging equipment of a medium sized Pathology Department that we estimate in 50.000 to 70.000 euros.

We have described conventional computer hardware systems and some image analysis software that can be of use in a Pathology Department, describing those features that can be of some help when choosing between systems. The usual price is also included for reference.

Although computer systems evolve very quickly and described systems will be old fashioned in a few months, the aim of this article was to compile some of the new technology that the pathologist must be aware of.

Acknowledgments

This work was made possible by a grant from the Spanish Ministry of Education and Science and ERDF (European Regional Development Fund), project number DPI2004-01346.

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