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Tablet Computer as a User Interface: Intelligent Solutions for Multifunctional Hardcopy Devices

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***Abstract*—**Tablet computers and Multifunctional Hardcopy Devices (MHDs) are common devices in daily life. Though, many scientific studies have not been published. The tablet computers are straightforward to use whereas the MHDs are comparatively difficult to use. Thus, to assist different levels of users, we propose combining these two devices to achieve straightforward intelligent user interface (UI) and versatile What You See Is What You Get (WYSIWYG) document management and production. Our approach to this issue is to design an intelligent user dependent UI for a MHD applying a tablet computer. Furthermore, we propose hardware interconnection and versatile intelligent software between these two devices. In this study, we first provide a state-of-the-art survey on MHDs and tablet computers, and their interconnections. Secondly we provide a comparative UI survey on two state-of-the-art MHDs with a proposal of a novel UI for the MHDs using Jakob Nielsen's Ten Usability Heuristics Evaluation.

***Keywords*—**Computational intelligence, hardcopy device, tablet computer, user interface.

I. Introduction

THERE is a variety of Multifunctional Hardcopy Devices (MHDs), for example, Multifunction Printers/Products (MFPs), Multifunction Copiers (MFCs) and Multifunctional Devices (MFDs) on the market. The commonality between these devices is copying, scanning, and printing properties [1] - [3]. In addition, the MHDs may include facsimile and email functions, and even file server properties [1], [3].

The MHDs are regarded as comparatively difficult to use. Thus, these devices have producer dependent non-standard user interfaces (UIs), many different functions, a variety of software and many intricate procedures for operators concerning mechanics. In addition, the MHDs are often considered to be broken, though any user might easily solve the existing problem with proper guidance. We admit that 'multifunctional' is a synonym to 'complicated', but in our opinion it is possible to hide dispensable properties from users who do not really need them and guide users to solve most of the temporary errors by themselves. Therefore, we think that our research is significant for many individuals and society.

To assist different levels of users, we propose an almost effortless UI on the MHD by replacing the original UI with a tablet computer. The tablet computers have gained success in the market. They have become part of our everyday life and the number of users increases exponentially. In addition, tablet computers are moderately prized, user-friendly and have an extensive assortment of applications. The applications we are interested in are scanner and printer drivers, and image processing software [4].

In our study the scanning and printing functions require no additional software and connections, whereas the copying function does. Our approach to the copying issue is to propose an intelligent universal What You See Is What You Get (WYSIWYG) interface [5] with sophisticated image processing features. However, these features are also available for scanning and printing. The intelligence in this case may appear in user dependent behavior and universality in producer independent transferable solutions.

The results of this paper are that by combining a tablet computer with a MHD we may achieve an almost effortless UI for different levels of users including all the sophisticated features included in both of the devices. The comparative survey on two state-of-the-art MHDs with proposal of novel UI in the means of the Heuristic Evaluation of Nielsen [6] clearly shows that the two state-of-the-art MHDs' UIs need development to become easier to use and satisfy users.

The rest of the paper is organized as follows. In section II, we provide a state-of-the-art survey on the MHDs graphical UIs and tablet computers concerning their display, usability and image processing features, and interconnections between these devices. A comparative UI survey on two state-of-the-art MHDs with design proposal of a novel UI for the MHDs is provided in Section III. Related work is given in Section IV, followed by conclusions and future work in Section V.

II. State of the Art Survey

In this section, there is first a state-of-the-art survey on MHDs graphical user interfaces (see Sect. II-A). Secondly, there is a state-of-the-art survey on tablet computers concerning their display, usability, and image processing features (see Sect. II-B). Thirdly, there is a survey on available interconnections between tablet computers and MHDs (see Sect. II-C).

A. Office Multifunctional Hardcopy Device User Interfaces

There are very sophisticated features in different manufacturers' MHDs' UIs. However, there is a lot to develop to make users satisfied. Continually, more features and functions have been applied to MHDs. This may have been lead to over-complexity [7]. Thus, all manufacturers pay attention to their UIs and claim that they are easy to use. Even

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though, some of them admit that with many features and functions these devices may be complicated to use. Thus, to ease users' work, most of these devices have some kind of templates or shortcuts for many complicated tasks [7]-[10]. With these shortcuts and templates there is still the requirement that someone has to learn how to make them work and have them updated.

The basic operations, such as 1-sided copying, scanning and printing are usually easy to find and use. However, the more complicated tasks, such as booklet copying or printing with cover page, folding and saddle-stitch stapling or scanning and editing scanned images, may be inaccessible for many users. To make this feature "match between system and real world", which is one of the Nielsen's heuristics [6], few manufacturers have already a preview feature with some limited image processing [7], [9], [11]. One manufacturer has already a flick-tab-slide touch screen UI where a copy or scan job may be checked, rearranged and edited with flick, tab and slide of a finger before the job is printed or saved. User may also review two-sided documents and correct upside-down scanned pages [7]. Other manufacturers have touch screen UIs with tab feature (see Table I).

TABLE I
MHD CUSTOMIZABLE COLOR DISPLAYS

Manufacturer	Model	Size/type	Resolution	Control
Canon	C5051/ C5045/ C5035/ C5030	8.4 inch / TFT	SVGA (800x600)	tab
Hewlett Packard	LaserJet M9040/ M9050	8.1 inch / not available	not available	tab
Konica Minolta	Bizhub C452	8.5 inch / not available	not available	tab
Kyocera	TASKalfa 7550ci	10.2 inch / not available	not available	tab
Lexmark	X954dhe	10.2 inch / not available	not available	tab
Ricoh	Aficio MP C3001/ C3501/ C4501/ C5501	8.5 inch / LCD	not available	tab
Sharp	MX-3610N/ 3110N/ 2610N	10.1 inch / LCD	WVGA (1024x600)	flick-tab-slide
Toshiba	e-STUDIO 2040c/ 2540c/ 4540c	8.5 inch / LCD	WVGA (800x480)	tab
Xerox	WorkCentre 7525/ 7530/ 7535/ 7545/ 7556	8.5 inch/ not available	WVGA (800x480)	tab

In Table I are examples of small and medium work group, office and department MHD graphical UIs including several manufacturers' color laser or light emitting diode (LED) printing devices from 20 to 60 pages per minute (ppm) speeds including data of display sizes, types, resolution and control. All the manufacturers have a large color touch screen display; though some manufacturers do not publish exact specifications of their displays (see Table I).

To assist users, all manufacturers have published some user documentation and most of them have online support and training on their websites as well [2], [3], [7], [8], [12], [13]. The most sophisticated solutions of the online training have flash videos or interactivity guiding users step-by-step all the phases needed for specified functions, models and configuration [12], [13]. Onboard user guides may be found on many MHDs under a help or info button. They are text-based instructions or descriptions of functions and in best cases they are about the specific task going on [8], [9], [11]. Though, many devices have a web browser application installed or applicable. Thus, users may access the online support and training through the devices touch screen [7], [13], [14].

B. Tablet Computer

A tablet computer is a general-purpose mobile computer integrated into a flat touch screen and primarily operated by touch screen. Tablet computer provides internet capabilities, wireless data interfaces, such as Wi-Fi and Bluetooth, GPS location services and camera. Tablet computers are designed to be portable, with small dimensions and a lightweight design [15]-[17].

Modern tablet computers offer many features which are also in laptop computers, such as high screen resolution, video chat capabilities, multitasking capabilities, multiple inputs and ways of connecting to the internet. Tablet computers offer also features that are not included in basic laptop computers, such as cellular phone, touch screen and voice recognition. Respectively tablet computers do not have some input methods, such as mouse and separate keyboard.

Tablet computers may be evaluated and compared by several criteria such as main functionalities, ease of use, screen features, video and image processing capabilities, operating system and operating time. Next chapters provide information about basic features of tablet computers and information about state-of-the-art modern UI and input methods in tablet computers.

Tablet computer operating system is a set of software that manages tablet computer hardware resources and provides common services for programs. It performs basic tasks, such as recognizing input from UI, keeping track of files on file storage, sending output to the display screen and controls the internal and peripheral devices [18]. The operating systems for mass-market tablet computers are Android, Apple iOS, Windows Mobile and Windows 7.

When evaluating different tablet computers from hardware aspect user should evaluate the Central Processing Unit (CPU) and validate that tablet computer offers the needed performance for intended function. Also evaluation of the amount of Random Access Memory (RAM) and file storage is essential. Battery capacity and power saving capabilities are issues when evaluating the operation time of the tablet computer. Some tablet computers provide up to 12 hours of operation time. Modern tablet computers contain 1 to 4 processors and processor clock speed up to 1.66 GHz.

Weight and dimensions of a tablet computer is one of the evaluation criteria especially when portability and ease of use has high significance. When evaluating the latest tablet computers with over 8 inch screen size, there are weights from under 500 grams up to 990 grams and thickness as low as 8.8 millimeters. Modern tablet computers have versatile built-in devices and functionalities, such as music player, camera, video recorder, Wi-Fi, Bluetooth and GPS receiver.

To improve the user experience tablet computer manufacturers have developed many UI features and input methods which can apply only in tablet computers. These usability improvements are, for example, that tablet computers are designed to include a built-in stand to hold up the product for easy viewing. Others provide additional digital pen for UI navigation. Most of the tablet computers adjust screens from portrait to landscape automatically if user turns the tablet computer accordingly. Tablet computers also include multi-point touch screen which allow user to make sweep, zoom and pan actions with tablet computer applications which improves usability, for example, for web browsing and for image manipulation [19], [20].

The main UI in a tablet computer is a touch screen. A touch screen of tablet computer is the main difference when compared to other computing devices, such as laptop computers. Touch screen contain touch keyboard for text input. For modern tablet computers a responsive touch screen is widely adopted by different manufacturers, along with display resolution from 800 x 600 pixels to 2048 x 1536 pixels. Tablet computer size is directly related to tablet computer portability and tablet computer display size is nearly equal to tablet computer size because tablet computer frames (area between tablet computer display and tablet computer margins) are made narrow in modern tablet computers. Modern tablet computers have screen sizes from 7 inch to 12.1 inch.

The Table II contains data about different tablet computer manufacturers' latest models including display size, resolution and type. There are several display types for tablet computers, such as Thin Film Transistor Liquid Crystal Display (TFT-LCD), In-Plane Switching LCD (IPS-LCD), Plane Line Switching LCD (PLS-LCD), Multi-Domain Vertical Alignment LCD (MVA-LCD) and Active Matrix Organic Light Emitting Diode (AM-OLED) (see Table II). Main differences between screen technologies are that some technologies have better visibility in outdoors or indoors and difference in color depth. Differences between display technologies can be measured in viewing angles, brightness, black and white contrast, color contrast, power efficiency and in response time [21]-[23].

TABLE II
TABLET COMPUTER DISPLAYS

Manufacturer	Model	Size	Resolution	Type
Apple inc.	iPad 3rd Generation	9.7 inch	2048x1536	IPS LCD
Archos	80 G9 SSD	8.0 inch	1024x768	MVA LCD
Asus	Transformer Pad Infinity LTE	10.1 inch	1920x1200	IPS+LCD
bModo	12	11.6 inch	1366x768	TFT LCD
ExoPC	ExoPC	11.6 inch	1366x768	LCD
HannSpree	HANNS pad SN10T1	10.1 inch	1024x600	TFT LCD
Hewlett Packard	TouchPad	9.7 inch	1024x768	TFT LCD
Lenovo	ThinkPad	10.1 inch	1280x800	IPS LCD
LG	Optimus Pad (G-Slate)	8.9 inch	1280x768	TFT LCD
Motorola	Droid XYBoard (Xoom 2)	10.1 inch	1280x800	TFT LCD
MSI	Winpad 100W	10.1 inch	1024x600	TFT LCD
Notion Ink	Adam	10.1 inch	1024x600	TFT LCD
Prestigio	MultiPad PMP7100C	10.1 inch	1024x600	TFT LCD
Samsung	Galaxy Tab 8.9	8.9 inch	1280x800	PLS LCD
Sony	Tablet computer S	9.4 inch	1280x800	TFT LCD
Toshiba	Excite AT305	10.1 inch	1280x800	LCD
ViewSonic	ViewPad 10	10.1 inch	1024x600	TFT LCD

Video processing capabilities in modern tablet computer provide high definition video playing and fast image processing for video recording and photography needs. The state-of-the art UI provide resistive and responsive touch screen with multiple concurrent touch points. Tablet computers contain also specific input methods, such as speech recognition for commands, gyroscope and acceleration meter for movement input methods [19], [20].

With all these mentioned features the modern tablet computers may offer comfortable user experience and give software designers the opportunity to develop applications to meet the most demanding user needs.

C. Related Interconnections

Both MHDs and tablet computers have standard interconnections. Some present in both devices and some does not. Most MHDs have at least Universal Serial Bus (USB) and Ethernet connections with 10 Mb/s and 100 Mb/s. Some of them have Gigabit Ethernet and Wireless Local Area Network (WLAN) connections installed as standard. Other interconnections, such as Bluetooth require usually some optional accessories [3]. Most tablet computers have USB, WLAN and Bluetooth connection. Other connections may exist and some new connections, such as Ultra-wideband (UWB) and ZigBee may be proposed for connecting these devices together and to enable novel usability.

USB is a standard bus to interconnect peripheral devices with computers. These devices may connect directly or through USB hub with each other. There are different versions of USB, which have differences in performance. The original USB 1.0 transfers data at the rate of 12 Mb/s (full speed) and 1.5 Mb/s (low speed) [24]. Though, the improved USB 1.1 version became general.

Hi-Speed USB (USB 2.0) extended USB bus performance up to 40 times faster. The speed is specified to 480 Mb/s. Hi-Speed USB is both forward and backward compatible with USB 1.1. [25]

SuperSpeed USB (USB 3.0) is the next advancement in USB technology with 10 times increased performance compared to Hi-Speed USB. The SuperSpeed USB has a 5 Gb/s transfer rate and it is backwards compatible with Hi-Speed USB. [26]

Wireless USB (WUSB) is the new wireless extension to USB that combines the speed and security of wired technology with the ease-of-use of wireless technology. It will support robust high-speed wireless connectivity by utilizing the common UWB and is capable of the same speed as Hi-Speed USB (480Mb/s) at 3 meters and 110Mb/s at 10 meters. [27]

UWB (also referred to as High Band UWB) is a technology for short range wireless data transfer. High Band UWB operates at 3.1-10.6 GHz and uses a large portion of the radio spectrum (>500 MHz) in order to provide very high data rates (up to 1 Gb/s). Low Band UWB, on the other hand, operates at 100-960 MHz and supports lower data rates (up to 1 Mb/s) and higher ranges (up to 100 meters). [28]

UWB can be used, for example, in the following applications: wireless cable replacement between devices, non-cooperative radar imaging, sensor data collection, and extremely accurate positioning.

ZigBee is a technology for short range wireless data transfer especially designed for wireless low-power devices providing battery lifetimes up-to several years with a single AA battery. ZigBee is based on IEEE 802.15.4-2003 standard: it adds the network and application layers on top of the Physical layer (PHY) and Medium Access Control layer (MAC), which are defined by 802.15.4-2003. ZigBee also provides enhanced security control and support for mesh networks. [29], [30]

The first version of ZigBee specification, simply called as ZigBee (also referred to as ZigBee 2004), was released in 2004: nowadays this version can be considered obsolete and thus it is not supported anymore in new ZigBee devices. The second version of ZigBee specification, also called as ZigBee (also referred to as ZigBee 2006), was released in 2006: this version is used when the ZigBee network should be as cheap as possible. The latest version of ZigBee specification, ZigBee Pro (also referred to as ZigBee 2007), was released in 2007: this version is used when the size of the ZigBee network is very large and enhanced security features are needed to protect the network. Even though the IEEE 802.15.4-2003 was updated to IEEE 802.15.4-2006 in 2006, the current versions of ZigBee (i.e. ZigBee and ZigBee Pro) still use IEEE 802.15.4-2003 as their basis. [29]-[31]

ZigBee’s main scope and purpose is "home automation" including sensors and actuators, such as rain/light/smoke sensors, locks, and windows. ZigBee operates at 2.4 GHz frequency supporting theoretical data rate of 250 kb/s, at 915 MHz frequency supporting theoretical data rates of 40 kb/s and 250 kb/s, and at 868 MHz frequency supporting theoretical data rates of 20 kb/s, 100 kb/s, and 250 kb/s. ZigBee is based on Direct Sequence Spread Spectrum (DSSS) technique and Offset Quadrature Phase Shift Keying (O-QPSK) modulation. [29]

Bluetooth is a technology for short range wireless data and real-time two-way audio/video transfer providing data rates up to 24 Mb/s. Connection types define the ways Bluetooth devices can exchange data. Bluetooth has three connection types: Asynchronous Connection-Less (ACL), Synchronous Connection-Oriented (SCO), and Extended SCO (eSCO). [36]

ACL links are for symmetric or asymmetric data transfer. Retransmission of packets is used to ensure the integrity of data. SCO links are symmetric and are used for transferring realtime two-way voice. Retransmission of voice packets is not used. Therefore, when the channel Bit-Error-Rate (BER) is high, voice can be distorted. eSCO links are also symmetric and are used for transferring real-time two-way voice. Retransmission of packets is used to ensure the integrity of data (voice). Because retransmission of packets is used, eSCO links can also carry data packets. However, they are mainly used for transferring real-time two-way voice. [32]

Bluetooth operates at 2.4 GHz frequency in the free Industrial, Scientific, and Medical (ISM) band. Bluetooth devices that communicate with each other form a piconet. The device that initiates a connection is the piconet master and all other devices within that piconet are slaves. All communication within a piconet goes through the piconet master. The clock of the piconet master and frequency hopping information are used to synchronize the piconet slaves with the master. Two or more piconets together form a scatternet, which can be used to eliminate Bluetooth range restrictions. A scatternet environment requires that different piconets must have a common device, called a scatternet member, to relay data between the piconets. [32]

The first public version of Bluetooth specification, Bluetooth 1.0A, was released in July 1999. Many device manufacturers had difficulties in making their Bluetooth 1.0A compatible products interoperable. Therefore, the Bluetooth 1.0B specification was released later in the same year (December 1999) to fix the interoperability problems. The Bluetooth 1.1 specification was released in February 2001. It fixed many errors that were found in the Bluetooth 1.0B specification and added support for unencrypted communication as well as support for the Received Signal Strength Indicator (RSSI). The RSSI is a measurement of the received radio signal strength that is used for controlling power in Bluetooth devices. It can also be used for Bluetooth positioning purposes, for example. [32]

The Bluetooth 1.2 specification was released in November 2003. It included major improvements such as Adaptive Frequency Hopping (AFH) method, extended Synchronous

Connection-Oriented (eSCO) links, and optional Quality-of-Service (QoS) improvements. AFH further improves the original Bluetooth frequency hopping method Frequency Hopping Spread Spectrum (FHSS) by avoiding the use of channels that suffer from interference. A maximum of 59 "bad" channels can be switched off during the communication session i.e. only 20 different "good" channels are required. AFH also gives higher transmission speeds in practice by decreasing the need for retransmissions. eSCO improves the voice quality of Bluetooth audio links by allowing retransmissions of corrupted packets. QoS improvements further enhance the capabilities for error detection, flow controlling and synchronization. [32]

The Bluetooth 2.0+ EDR (Enhanced Data Rate) specifications were released in November 2004. The main improvement was the introduction of EDR, which provides data rates up to 3 Mb/s. The original Bluetooth data rate before the EDR was 1 Mb/s. According to the Bluetooth SIG, the EDR has the following effects on Bluetooth communication three times faster transmission speed (up to 10 times in certain cases), lower power consumption through a reduced duty cycle, simplification of multilink scenarios due to more available bandwidth and further improved Bit-Error-Rate (BER) performance. [32]

New Bluetooth versions are backward-compatible with the older versions. The Bluetooth 2.1+EDR specification was released in July 2007. It provides many improvements such as, Encryption Pause Resume, Extended Inquiry Response, Secure Simple Pairing (SSP), Near Field Communication (NFC) as an Out-Of-Band (OOB) channel, Sniff Subrating and QoS improvements. [32]

Encryption Pause Resume will further enhance the security by allowing encrypted links to change their encryption keys periodically. Master-slave role switches will also be possible on an encrypted link.

Extended Inquiry Response will provide more information, such as the name of the device and a list of supported services, during the inquiry procedure, allowing better device filtering before the connection is established.

SSP radically improves the Bluetooth pairing experience by simplifying the pairing process from the user's point of view. It will also increase the strength of security by providing the protection against both passive eavesdropping attacks and Man-In-The-Middle (MITM) attacks (active eavesdropping attacks). This feature has significantly increased the use of Bluetooth technology.

NCF as an OOB channel is in order to provide protection against MITM attacks, SSP either uses NFC as an OOB channel or asks the user to compare two six-digit numbers. Such a comparison can also be thought as an OOB channel which is not controlled by the MITM. However, when NFC radio interface is available, SSP supports the automatic creation of secure Bluetooth connections.

Sniff Subrating will further reduce the power consumption of Bluetooth devices. For example, it will increase the battery life of Human Interface Devices (HID) devices, such as mice and keyboards, by 3 to 10 times compared with the battery life times of older Bluetooth HID devices.

QoS improvements will further enhance the quality of audio and video transmissions.

The Bluetooth 3.0+HS (High Speed) specification was released in April 2009. It supports theoretical data transfer speeds up to 24 Mb/s, though not over the Bluetooth link itself: instead, the Bluetooth link is used for negotiation and establishment, and the high data rate traffic is carried over a 802.11 (WLAN) link. The major areas of improvement are Alternate MAC/PHY (AMP), Unicast Connectionless Data (UCD) and Enhanced Power Control (EPC). [32]

The main new feature of Bluetooth 3.0+HS is the AMP, the addition of 802.11 (WLAN) as a high speed transport. Two technologies had been anticipated for AMP, 802.11 (WLAN) and UWB, but UWB is missing from the specification. AMP enables the use of alternative Medium Access Control (MAC) and Physical layers (PHYs) for transporting Bluetooth profile data. The Bluetooth radio is still used for device discovery, initial connection, and profile configuration. However, when large quantities of data need to be sent, the HS AMP 802.11 (WLAN) will be used to transport the data. It means that the proven low power connection models of Bluetooth are used when the system is in idle mode and the faster radio is used when large quantities of data need to be sent.

The UCD permits service data to be sent without establishing an explicit Logical Link Control and Adaptation Protocol (L2CAP) channel. It is intended for use by applications that require low latency between user action and reconnection/transmission of data. This is only appropriate for small amounts of data.

ECP updates the power control feature to remove the open loop power control, and also to clarify ambiguities in power control introduced by the new modulation schemes added for the EDR. The EPC removes the ambiguities by specifying the behavior that is expected. The feature also adds closed loop power control, meaning the RSSI filtering can start as soon as the response is received. Additionally, a "go straight to the maximum power" request has been introduced. This is expected to deal with the headset link loss issue typically observed when a user puts their phone into a pocket on the opposite side to the headset.

The HS part of the specification is not mandatory. Thus only "Bluetooth 3.0+HS" devices, i.e. devices with "+HS" suffix, will actually support the Bluetooth over WLAN high-speed data transfer. A Bluetooth 3.0 device without the "+HS" suffix will not support High-Speed and thus needs to support only the UCD. [32]

The Bluetooth 4.0 specification was released in June 2010. It includes Classic Bluetooth (from versions 1.0A – 2.1+EDR), Bluetooth HS (from version 3.0+HS), and Bluetooth Low Energy (LE). Thus, the new improvement is inclusion of Bluetooth LE specification, which was formerly known as Wibree. Bluetooth LE is aimed at very low power applications running off a coin cell. Bluetooth LE allows two types of implementation: dual-mode and single-mode. In a dual-mode implementation, Bluetooth LE functionality is integrated into an existing Classic Bluetooth controller. The resulting architecture shares much of Classic Bluetooth's existing radio and functionality resulting in a negligible cost increase compared to Classic Bluetooth. Additionally, device manufacturers can use current Classic Bluetooth or Bluetooth HS chips with the new LE stack, enhancing the development of Classic Bluetooth and Bluetooth HS enabled devices with new capabilities. Cost-reduced single-mode chips, which will enable highly integrated and compact devices, will feature a lightweight Link Layer providing ultra-low power idle mode operation, simple device discovery, and reliable point-to-multipoint data transfer with advanced power-save and secure encrypted connections at the lowest possible cost. The Link Layer in these controllers will enable Internet connected sensors to schedule Bluetooth LE traffic between Bluetooth transmissions. Moreover, Bluetooth LE specification enhances the security by adding Advanced Encryption Standard (AES) encryption. [32]

The combination of a radio using little power in idle mode and a high data rate radio for transmitting bulk data could be the start of software radios. Therefore, Bluetooth 4.0 provides an excellent signalling channel for enabling the software radio concept. Software radio is the technique of getting code as close to the antenna as possible, i.e. radio hardware issues is turned into software issues. The main idea in software radio is that software defines the transmitted waveforms and it also demodulates the received waveforms. In traditional radios, the processing is done with analog circuitry or with analog circuitry combined with digital chips. [36]

Many kinds of Bluetooth devices, such as laptops, computers, mice, keyboards, printers, mobile phones, headsets and hands-free devices, are widely used all over the world. Moreover, in many countries, a hands-free device or headset connected to a mobile phone is mandatory in moving vehicles for safety reasons. Therefore, the markets for easy-to-use wireless Bluetooth headsets and hands free devices are huge! [33]

Already in 2006, the first billionth Bluetooth device was shipped. Less than five years later in 2011, the fourth billionth Bluetooth device was shipped, and the volume is expected to increase rapidly in the near future. According to In-Stat, the eighth billionth Bluetooth device is expected to be shipped by the end of 2013. [33]-[35]

The most popular WLAN versions currently, 802.11b, 802.11g, and 802.11n, operate in the 2.4 GHz band and 802.11n also in the 5.0 GHz band. In this paper, only 802.11g and 802.11n versions of WLAN are considered, because 802.11b is rather old, slow, and insecure standard, and therefore 802.11b networks are expected to be replaced by 802.11n networks in the long run. [36]

802.11b use DSSS technique with Differential Binary Phase Shift Keying (DBPSK) or Differential Quadrature Phase Shift Keying (DQPSK) modulation for transmission speeds of 1 Mb/s and 2 Mb/s. In addition, 802.11b and 802.11g use High Rate DSSS (HR/DSSS) technique with Complementary Code Keying (CCK) modulation for transmission speeds of 5.5 Mb/s and 11 Mb/s. Moreover, data rates of 802.11g are up to 54 Mb/s that can be achieved by using Orthogonal Frequency Division Multiplexing (OFDM) technique with 64-state Quadrature Amplitude Modulation (64-QAM). Other supported data rates of 802.11g using OFDM are the following: 6 Mb/s and 9 Mb/s with Binary Phase Shift Keying (BPSK) modulation, 12 Mb/s and 18 Mb/s with Quadrature Phase Shift Keying (QPSK) modulation, 24 Mb/s and 36 Mb/s with QAM or 16-QAM modulation, and 48 Mb/s with 64-QAM modulation. [36]

802.11n supports data rates up to 600 Mb/s at 2.4 GHz or 5 GHz frequency using OFDM and MIMO-SM (Multiple Input, Multiple Output – Spatial Multiplexing) as well as allowing more bandwidth per channel. The maximum data rate of 600 Mb/s can be achieved using four MIMO transmit/receive antenna pairings, 40 MHz channels, short 400ns GI (Guard Interval) and 64-QAM (64-phase Quadrature Amplitude Modulation). [36]

Support for 400ns GI (short) is optional and for 800ns GI (long) mandatory. The purpose of a GI is to introduce immunity to propagation delays, echoes, and reflections to which digital data is normally very sensitive. [36].

III. Novel User Interface

In this section, first a comparative UI survey on two state-of-the-art MHDs with design proposal of a novel UI for the MHDs is provided (see Sect. III-A) and secondly physical interconnection options presented (see Sect. III-B).

A. Usability of Multifunctional Hardcopy Devices

As mentioned earlier, the MHDs are comparatively difficult to use (Chapter I). Therefore we propose a large tablet computer UI to assist users to access all the sophisticated functions offered by MHDs and we also propose to entail more functions, such as easy user recognition, intelligent user dependent UI and many image processing features.

Here we approach this issue by the Jakob Nielsen's Ten Usability Heuristics. "They are called "heuristics" because they are more in the nature of rules of thumb than specific usability guidelines." [6] We also concentrate on two MHDs UIs, which may be accessed in online support, tutorial and interactive training, and compare our proposed novel UI with these [12], [13].

The first of these heuristics is "Visibility of system status", in which "the system should always keep users informed about what is going on, through appropriate feedback within reasonable time." [6]

In different MHDs this is not guaranteed. For example, the both devices [12], [13] provide too much information in one screen view, thus users may not be aware in which state the device really is. On both devices there is a main screen view where can be found the basic functions and when a user selects some special functions, the selected functions may be seen written on the basic function buttons and the selected special properties are darkened in their menus. Though, some special functions in the first device [12] end without visiting on the main screen view and the second device [13] has several main screen views depending on the job conducted, such as copying, scanning and printing. In addition, the second device [13] has also a Job Status hard button to show the system status on any situation desired.

On our proposed tablet computer UI, this issue is solved by simplifying all the functions and buttons minimum in all the screens and using all the sophisticated features of tablet computers' UIs. Thus, the system status may be seen as text based on the bottom of the screen, the job status may be selected in any phase and visual effects may be used activated on screen views as much as required.

The second of the heuristics is "Match between system and the real world", in which "the system should speak the users' language, with words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order." [6]

The issue with the MHDs is that manufacturers have their own names for the actions, functions, parts and supplies. Though, they have same names and similarity too, but sometimes the same words may mean different things. For example, double sided copies of double sided originals is "2-sided -> 2-sided" on the first device [12] and "2 -> 2 duplex" in the second device [13]. In addition, there are all human languages and dialects to consider too.

Another issue is that there is no standard for symbols of MHD functions. Though, few buttons are similar on most of manufacturers' devices, such as start and power buttons.

The state-of-the-art device to follow real-world conventions is the first device [12] concerning the preview and editing properties with flick-tab-slide touch screen function. A scanned job may be rearranged and separate scanned pages may be deleted, moved and rotated. The other device [13] has tab function in touch screen and has more limited editing properties with deleting and rearranging pages on a scanned job.

On our proposed tablet computer UI the "follow real-world conventions" is full tablet computer display size high resolution images which may be moved, zoomed, edited, twisted and rearranged freely. Thus, the visualization is as close to "real-world conventions" as possible. The scanned pages may be arranged in booklet format, the pages may be flipped like with real booklet and staples inserted, if needed, by pushing the points where they are intended to be.

The third of the heuristics is "User control and freedom ", in which "users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support undo and redo." [6]

Both devices [12], [13] do not have these functions. There is a cancel hard button and return touch screen button in the second device [12], though the return button is not always available. The first device [12] has several different exits, close and end methods to approve different functions, such as "edit end", "OK" and "X", which is not a consistent design. In addition, there is a cancel touch screen button in some screen views but not in all.

On our proposed tablet computer UI will be undo and return button always available in the left upper corner of the screen and they will be equivalent to most popular web browsers. In addition, there will be reset and home buttons as well.

The fourth of the heuristics is "Consistency and standards", in which "users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions." [6]

This kind of situation may appear if there have been several teams programming a UI or if there have been errors on translation. On both devices [12], [13] was not any this kind of errors detected on our study.

On our proposed tablet computer UI we use the same words, situations and actions on all screen views. Thus, we are going to make a contextual inquiry to gather information from the users [37] for our proposed tablet computer compared with some available state-of-art MHDs.

The fifth of the heuristics is "Error prevention", in which "even better than good error messages is a careful design which prevents a problem from occurring in the first place. Either eliminate error-prone conditions or check for them and present users with a confirmation option before they commit to the action." [6]

Both of these devices [12], [13] seem to be implemented the way that there is not this issue at all and we will implement our proposal tablet computer UI the same way.

The sixth of the heuristics is "Recognition rather than recall", in which "minimize the user's memory load by making objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate." [6]

This issue is concrete on both devices [12], [13]. For example, the editing function requires ten phases to delete and move one image on the first device [12] and at least seven phases to delete and move one image on the second device [13].

On our proposed tablet computer UI the "Recognition rather than recall" is implemented the way that preview is the primary view of the copied, scanned and printed documents. Then a user decides what to do with the job by flick-tab-slide UI. Thus the result of the job is all the time visible to the user.

The seventh of the heuristics is "Flexibility and efficiency of use" in which "accelerators -- unseen by the novice user -- may often speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users. Allow users to tailor frequent actions." [6]

The most of MHDs have some kind of templates or short cuts for many complicated tasks [7]-[10]. With these short cuts and templates novice users may access even the most demanding functions and expert users may learn how to make them work and have them updated.

We also propose our tablet computer UI to take account different levels of users. The UI may learn how a user acts and behave the best way to fulfill the user's needs. All the users do not need all the functions and we suggest that they may be hidden.

The eighth of the heuristics is "Aesthetic and minimalist design", in which "dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility." [6]

Both devices [12], [13] has the display filled with different buttons including many functions. The first device [12] has at least 12 buttons in the home menu and at least 31 buttons in copy screen view. The second device [13] may be chosen the copy screen view as home view. Though, there are 16 buttons and three tabs in the copy screen view. This may confuse occasional users, but regular users learn to select the right functions needed. Though, regular users may have problems trying to find some functions needed occasionally.

On our proposed tablet computer UI we consider simplicity and user dependent behavior with visual preview images. All the functions associate with tablet computers ease-of-use.

The ninth of the heuristics is "Help users recognize, diagnose, and recover from errors", in which "error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution." [6]

There are three levels of errors in MHDs. The first level errors may be recovered by users, the second level by system administrators and the third level errors by service technicians. The user recoverable errors are usually visual and text information, such as the second device [13] has a blinking message out of paper with blinking paper cassette symbol. Though, the service technician recoverable errors are code based in these devices. The system administrators may have both kinds of messages depending on the error and in case of code based error they may refer to technical documentation to solve the problem.

Our proposed tablet computer UI will be capable of showing all the errors in visual format. Thus, users may watch a video how to solve the specific error. In addition, service technicians have already now video courses how to assemble and disassemble these devices. Thus, it is possible to download these videos in our tablet computer UI and further develop them to correspond to the specific issue going on.

The tenth of the heuristics is "Help and documentation", in which "even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large." [6]

Both devices [12], [13] have an onboard text and image based help property and they both may access product specified online help in the Internet. Though, the text and still image based help properties are not always easy to search and carry out, and there is not always an Internet connection.

On our proposed tablet computer UI the "Help and documentation" is suggested to be onboard interactive function assistant. It provides help videos with interactive UI similar to the second devices [13] interactive online training manual inserted with active buttons to make choices concurrently.

B. Physical Interconnection

There are many options to implement physically our proposed tablet computer UI. One is to use off-the-shelf equipment using existing connections, such as USB and Ethernet connections. Though, tablet computers do not have Ethernet connection and some of them do not have any physical connections, thus wireless communication is one option. Tablet computers have at least WLAN interconnection and some of them have also Bluetooth and ZigBee interconnections. Though, tablet computers equipped with physical USB connection may use several USB technologies, such as Hi-Speed, SuperSpeed and Wireless USB. Though, SuperSpeed USB and WUSB with UWB are not yet very common interconnections.

Another option is to replace the MHD's original UI with a tablet computer. Thus, MHD's original UI have to be removed, tablet computer installed physically on the MHD and an adapter implemented between these devices.

IV. Related Work

There has not been studies about tablet computer based MHD UIs before, though several studies about tablet computers as UIs and MHD's UIs may be found. The most similar implementation to our novel UI, though, with remarkable limitations in hardware and software can be found from Sharp Corporation. Their solution is described and compared with our solution here.

Scanned data from a color-scan-capable Sharp MFP can be imported to the pen software for display on the LCD monitor and image data shown onscreen including notations can be saved to a PC or sent directly to an MFP for printout [38] as seen on fig. 1. In addition to this, our novel image processing features suggested are adjusting document skew by twisting a document with two fingers and rearrange page layout with WYSIWYG view, such as booklet format, and adding staples by pointing the spots. Then the processed images may be saved on a computer, server and cloud or printed directly with the sophisticated features processed on the images.

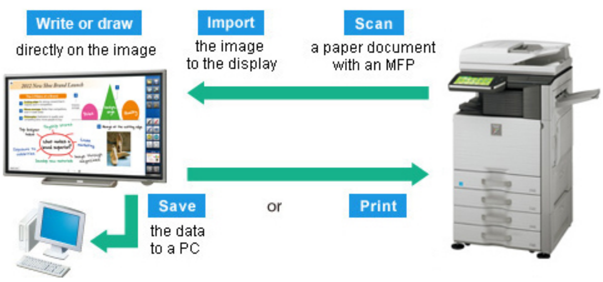

Fig. 1 Interconnectivity [38]

V. Conclusion and Future Work

At first, in this study we provided a state-of-the-art survey on MHDs and tablet computers displays, and the interconnections used in these devices. Secondly we provided a comparative UI survey on two state-of-the-art MHDs with a proposal of novel UI for the MHDs using Jakob Nielsen's Heuristic Evaluation. This evaluation clearly showed that the two state-of-the-art MHDs' UIs need development to become easier to use and make users satisfied. Especially, in the areas of visibility of system status, user control and freedom, recognition rather than recall, and aesthetic and minimalist design.

By combining a tablet computer with a MHD we may achieve an almost effortless UI for different levels of users including all the sophisticated features included in both of the devices. In the tablet computers the visual document processing capabilities and in the MHDs paper document processing properties are the most sophisticated features.

Our future work will include studies in intelligent solutions for MHDs which are comparatively versatile and therefore delicate to use. To assist different levels of users an intelligent user-dependent behavior of MHDs would be the solution.

The objectives of our research are to empirically implement a tablet computer based intelligent UI by using recent technology and integrate this device to our smart home and office platform.

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