Comparative Study of Operating System Quality Attributes

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Abstract-
An Operating System is an interface between a user and computer hardware. It's a piece of software that handles hardware devices and acts as a bridge between an application software and hardware of the computer. Everything the user does is done in the user mode and what the system does is done in the kernel mode. The kernel is a computer program at the heart of the operating system, with absolute control of everything. Operating system concepts have been developed by many manufacturers over the years and a few quality ones to match with user demand and preferences. This paper helps compare operating systems by their quality attributes and using four of the most influential operating systems – Windows, Linux, Mac and Android OS, along with other technical details in assuring user guide when deciding what operating system to choose based on their requirements. The research uses factor analysis to obtain aggregate score based on selection criteria, with first choice at 50%, second choice at 42%, third choice at 6%, fourth choice at 2%. Windows 10 has highest GUI, Hardware Compatibility, Portability and Process Management features. Also it has high Memory Management, Text Mode Interface and file system features. However, Security feature on Windows 10 was least only 2% as fourth choice. Mac OS X has high percentage for Memory Management, GUI, Security and Architecture features. However, Hardware compatibility, Text Mode Interface, File System and Portability features was least only 2% as fourth choice. Linux Ubuntu 17.4 has highest Security, Text Mode Interface, Architecture and File System features. Also having high Portability and Process Management features. However, GUI and Memory Management was least only 2% as fourth choice. It was observed for latest version of operating system all have quality attributes but selecting most preferred choice of operating system would require proper analysis of the user. Windows with a percentage of 37% was first choice, followed by Linux having 33%, Mac with 23% and finally Android with the lowest score of 7%.

Key words: Operating System, Quality Attributes

1. Introduction

A computer system has various devices and software that help to complete the process or task. Computer Memory (RAM, ROM), Storage System (HDD, FDD, SDD), CPU (Central Processing Unit), Processors, and Other Input / Output System are widely used and essential in

computer operating system [1]. Operating system (O.S) is defined as a collection of software that handles the resources of computer hardware and provides basic computer program services. It is an interface system between the device hardware and the user [2]. This is an essential software that interfaces a computer user with computer hardware in such a way that it manages the running of all sorts of programs and guarantees the effective and easy usage of computer hardware and resources [3]. All computer devices have an operating system in them from video games consoles, mobile phones, to personal computers and web servers [2]. There are several operating systems built around the world, some for private or school usage, some for government use and users select operating systems based on professional guidance, context knowledge and need [4].

Operating systems manage data and can be thought of as an index of logic rules to determine the structure of files. Specifically, file systems are used to manage how data is processed, retrieved and updated [5]. A file system may be a database holding every piece of data on the hard drive or another storage unit [6]. The operating system maintains a file system in order to perform its file management functions to keep track of where information is stored, status of every file, and access user settings etc. [7]. The operating system utilizes memory management techniques to efficiently assign parts of the memory named blocks to several running programs and de-allocate them to improve overall machine output during usage [8]. Operating systems are able to restrict access to files and other system objects using DAC – Discretionary Access Control. In order to allocate resources to processes and protect the resources of each process from other processes, the operating system allows processes to share and exchange information. It strengthens an operating system's capacity to operate on different hardware architectures and to be flexible with relative ease to modern systems [9]. The benefit lies in the simplicity with which new architectures will support the operating system. However, there is usually a tradeoff between the desire for portability and a highly customized, optimal code [10].

[5] Carried out a comparative study using online survey to arrive at criteria that describes the most powerful and giant operating systems. The study suggests proper analysis of the user in choosing an operating system among the three most stable and famous version of operating systems - Windows, Linux and Mac. [6] Compares technical and general information for some widely used and current operating systems, including tablets devices and smart phone. The result from the study suggest that the complex and powerful operating system had to include system functions as well as the main purpose of the computer. Additionally, [2] provided wider overview of operating systems that includes supercomputers, mainframes and servers. They noted also that server and desktop OS development is growing faster than other operating systems today.

[7] Conducted a survey of the latest stable version of four of the foremost operating systems – OS Android, Windows, Linux and Mac. At the end, studies proved that all operating systems are working on new updates and releases yearly. [4] Acknowledged Window, Mac, UNIX, and Linux operating systems as the most popular set of operating system. However, each operating

system has a strong and weak side which makes it unique; these minute elements of diversity distinguishes them from their competitors. Furthermore, [8] examined that Linux working framework has created a Security-Enhanced Linux (SE Linux) which includes Mandatory Access Control (MAC) to the Linux piece, and is empowered of course, subsequently no need of antivirus to ensure it against the dangers.
[6] Linux is a UNIX-based operating system and being an open source, it is non-proprietary and free to download. Any changes to it are open for all to adopt, and as a result it has developed into a very powerful OS that has gained universal popularity, particularly among those seeking an alternative to Windows. Linux security is much stronger than other operating systems because one doesn't need home security systems to use a Linux operating system even over the internet. [1] Evaluates the functionalities in defining quality attributes of an operating system. The study comprises of well-known architecture that can be used to evaluate different operating systems. Furthermore, [9] categorised operating systems services. Four possible categories are device control, file manipulation, task control and information maintenance.

This paper evaluated the influential operating systems in use and also compares them based on certain quality criteria. It highlights their performances with respect to the reviewed quality attributes. The remaining part of this paper is divided as follows. Section 2 reviewed works that are relevant to our study. Section 3 discusses the evolution of selected operating systems while in section 4, comparison of quality attributes and discussion of this operating systems would be done, section 5 concludes the paper with recommendation.

2. Materials and Methods

2.1 Graphical User Interface

Android version 1.1 launched on February 9, 2009; it is equipped with a pretty good UI (User Interface) aesthetic appearance. Also, there are supporting applications such as clock, alarm, voice search, sending messages using Gmail and E-mail. The first product to use this version of the Android OS is the HTC T-Mobile G-1. However, this device with the OS version does not yet provide a system upgrade function. September 2013, Google announced that around 1 billion active mobile devices around the world use the Android OS. Windows is familiar and easy to use, and is considered by far the most user-friendly interface. Over 1.5 billion people in every country of the world use Windows and can be found in almost all the home user computers and for office use. With the release of Windows 10, the latest, from Microsoft with lots of similarities to Windows 7 including the Start menu. Purchasers of new laptops and desktops nowadays opt for Windows because of its brand recognition and acceptance.

The Macintosh operating system (also called Mac OS), has many intuitive and important features that make the system more usable. The Mac OS X includes Aqua, a GUI. It uses photorealistic icons of good quality in varying sizes up to 128x128, allowing for functionality including in-

place document preview and in-icon status indication. Ubuntu Linux is an easy-to-use version of Linux available with two types of GUIs - KDE and GNOME. Unlike OS Android, Windows and MAC, using Linux is not so easy for a general user because it was not developed as a GUI based operating system.

2.2 Security

The Windows security model is a collection of user-mode and kernel-mode processes that deliver, monitor, and manage the different OS security components, and ensures finer granularity among them [12]. Windows 10 has improved in-built security features and is also backward compatible. It is the most flexible of all Microsoft OS versions, but at the same time remains vulnerable to viruses, malwares and hacks [10]. The Linux security model is a series of many active processes, daemon utilities, and libraries that provide the Linux kernel with a stable environment to run in. It requires the user to authorize the execution of any file by entering password which ensures that no malware or viruses can be installed without letting the user know [15]. The OS X kernel which is restricted by Mandatory Access Control is where OS X sandboxing runs application from Trusted BSD project, for a stronger form of protection from malware and viruses. It makes resources accessible to only intended owners. Due to the fact that there are no third-party developers, this doesn't exempt Mac operating system from security threats [15].

2.3 Hardware Compatibility

Android is not the type of embedded kernel due to differences in standard utilities such as X-Window and GNU-C libraries. Android is an open source system like Linux due to market penetration for Android-based products and also makes it easier for users to access all Google and Android services as a new medium of ad serving that can increase Google's revenue, some of which is for the development of the Android OS itself. There is not so many software's that have Linux version and with development of the desktop versions, compatibility support will increase in the near future. Most software manufacturers make a Windows-compatible version of their software, which supports devices to be dynamically configured as the software evolves. Apple's MAC on the other hand tightly holds itself from external interfacing to increase its security, even though many people might think it is a very limited access [5].

2.4 Memory Management

The memory space adjustable to an operating system is shared by active and kernel programs. There has been a requirement for more memory than the actual memory within a system since the start of the computing operations. A Windows 32-bit process has a virtual address space which requires around 4 gigabytes of memory. In comparison, the 64-bit Windows machine has 8 terabytes of virtual address space and memory. All the threads may reach their virtual address space in a process. Nevertheless, threads are unable to reach memory that is reserved to other

processes. It saves one process from being manipulated by anyone else. Virtual memory of the Ubuntu Linux based system is known as swap. Swap describes the transaction between the physical RAM, the hard disk of moving memory pages and the region of a disk the pages are stored on. Ubuntu commonly uses a whole hard disk partition to switch. The partition is known as swap space. The system's virtual memory is provided by swap room. Swapping is a memory enabling a computer to run programs and process data files that are larger than its own physical memory.

However, the only disadvantage of Virtual Memory is that, heavy reliance on virtual memory may result in a significant drop in performance. The solution to this challenge is to provide sufficient RAM to simultaneously handle various operations [13]. Mac OS X on the other hand, comes with a fully integrated virtual memory system. It's often on and providing addressable space of up to 4 gigabytes per process. However, for the whole system few machines have that dedicated RAM, let alone for a single process. The virtual memory system allocates extra space for swap files on the root file system as a program uses space. Android, rely on automatic memory management which handled by garbage collector. However, the garbage collector can sometimes cause performance issues if memory allocation is not handled carefully. The Android SDK provides allocation tracker, a tool to avoid the frequent garbage collection.

2.5 Text Mode Interface

Android has ease of text input, with multilingual auto-complete features using the internal dictionary and select copy-paste control features. The principle that underlies the development of Android itself is openness of the system, all applications are created equal, and application development is fast and easy, breaking application boundaries. Each version of Windows has a single DOS interpreter that uses a shell command. However, UNIX commands are also supported by an optional PowerShell that was added recently. BASH, meaning Bourne Again Shell, is the default shell for Linux operating system and it supports several command interpreters. Linus Torvalds wrote the kernel which has a command line interface. Mac OS, which only runs on Apple Macintosh computers, has an interface that is always oriented towards icons and easy-to-use graphics. While MAC also has a simple interface on command line, it can take a while to get used to it before you appreciate the usability of Aqua.

2.6 Architecture

Most of the operating systems support 32-bit and 64-bit hardware architecture and they are backward compatible. Windows was meant to run on different hardware architectures. From Windows NT, which supported the x86 and MIPS architecture to newer versions of Windows now running on the ARM processor architecture, which has also advanced to ARM64 (64-bit) with an increasing number of devices running on it [5].

Linux was originally developed in C and assembly language to run on Intel i386 PCs only [14]. However, it has supported a number of architectures like the Alpha, ARM, MIPS, Sparc, x86 etc.

Most of its interfaces and core functions are architecture-independent C code, and kernel features are optimized for each architecture for performance critical pieces. Kernel interfaces which need to be architecture-dependent are implemented in separate functions and are named as appropriate. [14]. Linux and MAC OS both follows UNIX like file system.

2.7 File System

Windows, over the years, have supported a number of file allocation systems which includes FAT, NTFS (currently used by Windows for volume) and ReFS (the most recent of them). It can read from Ext2 and Ext3 file systems using Explore2fs. However, it cannot write to them. Windows uses rfstool and related programs to access ReiserFS [2]. Linux OS can read up to 100 types of partitions; but can modify only a few of them, it is known that it is possible to mount different types of filesystems on the same root filesystem which explains how compatible and interoperable Linux is with other systems. The list of the filesystem partition types can be obtained using Linux fdisk command. Filesystems include xfs, hfsplus, ext2, fat[15]. MAC OS 8.1 introduced the HFS Plus volume format, which is very similar to HFS architecture, although there have been a number of changes. The HFS Plus features is always available depending on the extent of the programming interface deployed. Although, it does not recognize programming interfaces for versions less than 9.0. [16].

2.8 Portability

Android was designed to be portable. This includes a long-term support (LTS) kernel branch of the Linux kernel. Because of the availability of the Dalvik virtual machine. Android is fast, and is independent of its hardware, making this portable. Windows is designed in multiple layers with lower-levels being processor-architecture-specific and other higher levels, who do not discriminate between architectures and hardware platforms. This comprises of a Kernel, Hardware Abstraction Layer (HAL), and Memory Manager. Architecture-discriminatory functions such as context switching, interrupt-handling are implemented in the Kernel. The Memory Manager also implements some architecture-dependent codes [20] . The chipset-dependent codes are isolated in the Hardware Abstraction Layer (HAL) [21]. Moreover, as with the UNIX operating system, Windows is mainly written in C (which aids portability on different hardware), C++ and assembly language [17].

2.9 Process Management

The operating system ensures seamless allocation, and sharing of resources to processes. The inter-process communication (IPC) of the Android based operating system varies according to the processing power and latency of the thread communication and the form of data being communicated. A fiber, which is a manually scheduled execution unit for the application, was created in earlier versions of Windows [18]. User-mode scheduling (UMS) was introduced in Windows 7 and are available only on 64-bit versions of Windows. They are an improvement over Fiber as they provide the same advantages as fibers and only a few of the disadvantages.

Windows has a Windowing mechanism in kernel mode, whereas Linux has an X-Windowing system in user mode, but no threads per-se. The Completely Fair Scheduler (CFS) is the default scheduler for Linux since 2007 when it was integrated into version 2.6.23 of the Linux kernel [19]. Mac OS X applies the scheduling formula for the round-robin (RR) and a multilevel input queue.

3. Results and Discussion

Upon evaluating the literature on the four operating systems, their quality attributes are listed in Table 1 (see below), based on specified literature preferences, this is suggested by researchers and is useful to end-users in determining the operating system they need. 1 will become 4, being the most desirable according to criterion, 2 will become 3, 3 will become 2 and 4 will become 1 being the least preferred operating system. In this way, greater values will correspond with greater preferences. It illustrates the quality attributes for the most recent version of Windows, MAC OS and Linux. That is to estimate user preference and the features satisfied by each operating system. In case of Linux Ubuntu is chosen for desktop computers as there are large numbers of varieties of Linux flavors to choose, all of them cannot be compared.

Table 1: Most Recent Version of Operating Systems and Criteria

CRITERIA / **OS NAME**	GUI	Security	Hardware Compatibility	Memory Management	Text Mode Interface	Architecture	File System	Portability	Process Management
WINDOWS 10 [20] [7] [19] [18] [5] [11] [17] [8]	1	4	1	2	2	3	2	1	1
ANDRIOD 10.0 [7]	3	3	2	3	-	4	-	-	4
MAC OS X [7] [21] [22] [5]	2	2	4	1	3	2	3	3	3
LINUX (Ubuntu 17.4) [20] [7] [19] [15] [14] [23] [5] [8]	4	1	3	4	1	1	1	2	2

From the analysis of operating system in Table 1, we find out the latest version of operating system do all have quality attributes based on selection criteria that an operating system should meet. The quality attribute recommended shows different features for most influential operating system as seen in table, all quality attributes are considered for Windows, MAC and Linux version and some features of quality attribute was not considered for Android version. Some of those functional requirements may vary across both platforms (Desktop and Mobile). However, the weighting schemes vary depending on the features considered.

From the criteria selected in the table, GUI feature was highest for Windows 10 with 50%, followed by MAC OS X with 42%, while Android 10.0 and Linux Ubuntu 17.4 has low score of 6% and 2% respectively. This implies Windows is the most user friendly among other operating system. For Security, Linux Ubuntu 17.4 is first choice with 50%, followed by MAC OS X with 42%, Android 10.0 and Windows 10 has low score of 6% and 2% respectively. This implies Linux is the most secured. Also, Linux is open source, which means the system is getting modified and updated very rapidly than Windows. For Hardware Compatibility, Windows 10 is first choice with 50% followed by Android 10.0 with 42%, while Linux Ubuntu 17.4 and Mac OS X has low score of 6% and 2% respectively. So, Windows is more compatible than another operating system. For Memory Management, MAC OS X is first choice with 50% followed by Windows 10 with 42%, while Android 10.0 and Linux Ubuntu 17.4 has low score of 6% and 2% respectively. For Text Mode Interface, Linux Ubuntu 17.4 is first choice with 50% followed by Windows10 with 42%, while Mac OS X has lowest score of 6%. Also, Android is not considered as supporting platform. For Architecture, Linux Ubuntu 17.4 is first choice with 50% followed by Mac OS X with 42%, while Windows 10 and Android 10.0 has low score of 6% and 2% respectively. For File System, Linux Ubuntu 17.4 is first choice with 50% followed by Windows10 with 42%, while Mac OS X has lowest score of 6%. Also, Android is not considered as supporting platform. Finally, Process Management on Windows 10 is first choice with 50% followed by Linux Ubuntu 17.4 with 42%, while Mac OS X and Android 10.0 has low score of 6% and 2% respectively.

Figure 1 & 2 below gives a summarised diagrammatic representation of table 1 above and the results obtained from it.

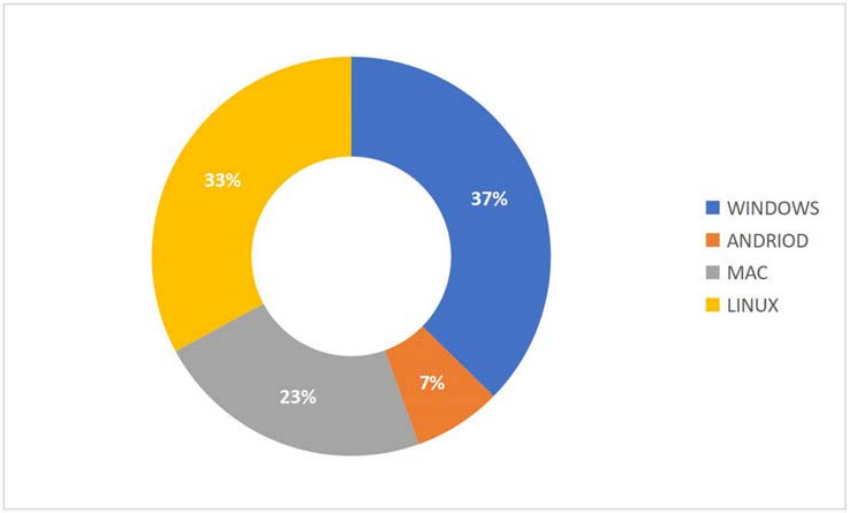

Figure 1: Pie Chart of Operating System User Preference

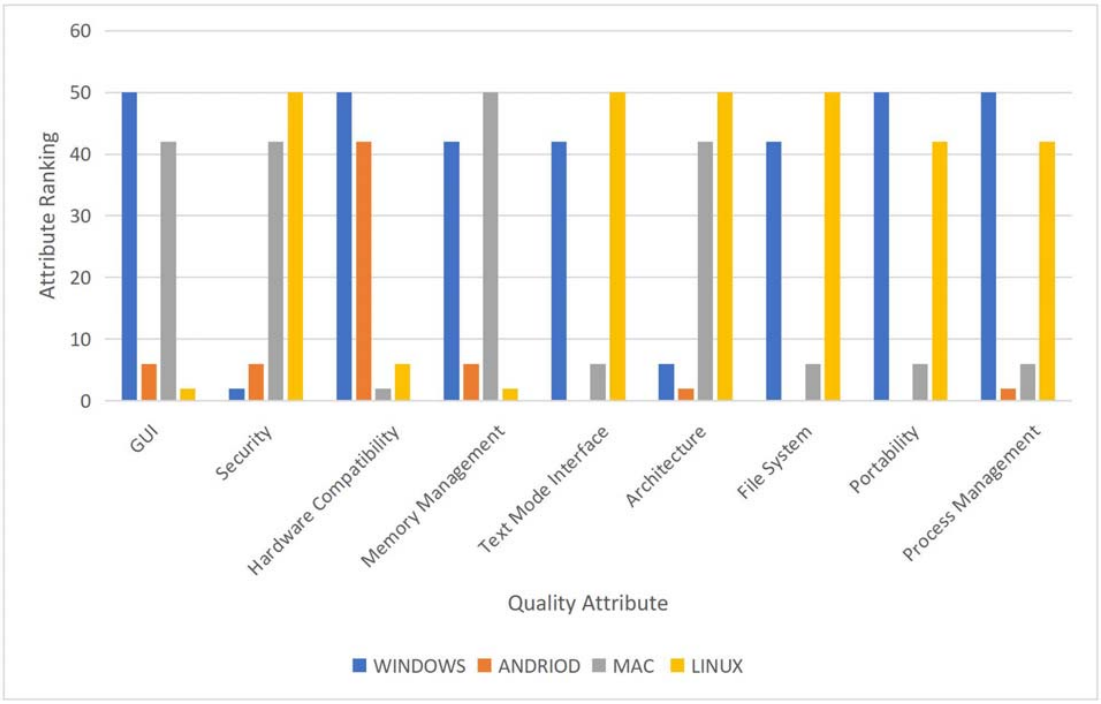

Figure 2: Bar Chart of Evaluation Metrics

As seen in table 1 above, the evaluated quality attributes show that Windows has more capabilities for GUI, Hardware Compatibility, Portability and Process Management features than another operating system, figure 2 also gives a summary of their strength and weakness. The four

operating systems are evaluated in (%) accuracy, with Windows having a total score of 37%. However, Linux is secured and is cheaper because it's open source.

4. Conclusions

We concluded that all the aforementioned operating system are the four most stable and influential operating systems. Every system all have quality attributes but selecting most preferred choice of operating system would require proper analysis of the user. Overall, Windows out performed Linux and Mac operating system in GUI, hardware compatibility, process management and is portable.

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