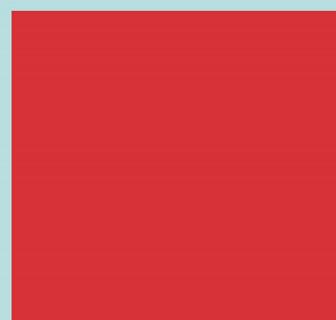


INTERNATIONAL JOURNAL OF
COMPUTER SCIENCE AND SECURITY (IJCSS)

ISSN : 1985-1553

Publication Frequency: 6 Issues / Year



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INTERNATIONAL JOURNAL OF COMPUTER SCIENCE AND SECURITY (IJCSS)

VOLUME 7, ISSUE 4, 2013

**EDITED BY
DR. NABEEL TAHIR**

ISSN (Online): 1985-1553

International Journal of Computer Science and Security is published both in traditional paper form and in Internet. This journal is published at the website <http://www.cscjournals.org>, maintained by Computer Science Journals (CSC Journals), Malaysia.

IJCSS Journal is a part of CSC Publishers

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INTERNATIONAL JOURNAL OF COMPUTER SCIENCE AND SECURITY (IJCSS)

Book: Volume 7, Issue 4, November 2013

Publishing Date: 01 - 11 - 2013

ISSN (Online): 1985 -1553

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Published in Malaysia

Typesetting: Camera-ready by author, data conversion by CSC Publishing Services – CSC Journals, Malaysia

CSC Publishers, 2013

EDITORIAL PREFACE

This is Fourth Issue of Volume Seven of the International Journal of Computer Science and Security (IJCSS). IJCSS is an International refereed journal for publication of current research in computer science and computer security technologies. IJCSS publishes research papers dealing primarily with the technological aspects of computer science in general and computer security in particular. Publications of IJCSS are beneficial for researchers, academics, scholars, advanced students, practitioners, and those seeking an update on current experience, state of the art research theories and future prospects in relation to computer science in general but specific to computer security studies. Some important topics cover by IJCSS are databases, electronic commerce, multimedia, bioinformatics, signal processing, image processing, access control, computer security, cryptography, communications and data security, etc.

The initial efforts helped to shape the editorial policy and to sharpen the focus of the journal. Started with Volume 7, 2013, IJCSS appears with more focused issues. Besides normal publications, IJCSS intend to organized special issues on more focused topics. Each special issue will have a designated editor (editors) – either member of the editorial board or another recognized specialist in the respective field.

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To build its international reputation, we are disseminating the publication information through Google Books, Google Scholar, Directory of Open Access Journals (DOAJ), Open J Gate, ScientificCommons, Docstoc and many more. Our International Editors are working on establishing ISI listing and a good impact factor for IJCSS. We would like to remind you that the success of our journal depends directly on the number of quality articles submitted for review. Accordingly, we would like to request your participation by submitting quality manuscripts for review and encouraging your colleagues to submit quality manuscripts for review. One of the great benefits we can provide to our prospective authors is the mentoring nature of our review process. IJCSS provides authors with high quality, helpful reviews that are shaped to assist authors in improving their manuscripts.

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An Empirical Study on the Security Measurements of Websites of Jordanian Public Universities

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Abstract

Most of the Jordanian universities' inquiries systems, i.e. educational, financial, administrative, and research systems are accessible through their campus networks. As such, they are vulnerable to security breaches that may compromise confidential information and expose the universities to losses and other risks. At Jordanian universities, security is critical to the physical network, computer operating systems, and application programs and each area has its own set of security issues and risks. This paper presents a comparative study on the security systems at the Jordanian universities from the viewpoint of prevention and intrusion detection. Robustness testing techniques are used to assess the security and robustness of the universities' online services. In this paper, the analysis concentrates on the distribution of vulnerability categories and identifies the mistakes that lead to a severe type of vulnerability. The distribution of vulnerabilities can be used to avoid security flaws and mistakes.

Keywords: Information System, Information Security, Information-security Measurement, Security Threats, Vulnerability Measurement and Penetration Test.

1. INTRODUCTION

Now a day, the Internet is used to provide a growing number of services for Jordanian universities like online registration, online libraries systems, online fees payment, and online portals, all these services are transferring confidential information over public networks, and the internet. This development has heightened user sensitivity to security violations. Most users use browsers to access these online services which making web based application a critical part of the internet communication infrastructure. A web based application developed their specific services over hyper text transfer protocol to the data base accesses, such implementation can introduce security holes, if they aren't implemented with care. Such typical security holes of web applications are well-known to hackers; there are even tools on the internet, which automatically look for and use certain security holes. Security for web applications became therefore an urgent problem (Peine & Mandel, 2006). Once the online services using web applications platform so the infrastructure platform must be investigated for discovering and recognizing the malignant patterns for intrusion detection. There is a need for evaluating the security of application systems by attack simulation of indoor and outdoor malicious. A fake attacking process involves an active analysis of the application systems for important and critical vulnerabilities that could results from poor system design and configuration or operational weaknesses. To get vulnerabilities classification, This analysis is carried out from the attack vector and its behavior (Hansman & Hunt, 2004). Web site and whole information domains analysis need a good information security metrics as an important factor in making sound decisions about various aspects of security, ranging from the design of security architectures and controls to the effectiveness and efficiency of security operations. Security metrics strive to offer a quantitative and objective basis for security assurance (Berinato, 2005). The main uses fall into several broad classes such as strategic support, security quality assurance and tactical oversight from point of view of monitoring and reporting of security status. The security requirements of web based applications include confidentiality, authentication, availability, authorization, integrity and non-repudiation, so

how to efficiently evaluate the security of web application services is a challenging research topic. There can be no information security without information security triad or given six basic security concepts to be covered by security testing (Feruza & Kim, 2007). The educational web service security requirements must satisfy addressing in the context of comprehensive application system architecture. This should include institutional portals, central directory service and user trust relationships (Gleason, 2002). According to the characteristics of educational web service application and the classification threats, security decisions must always be made with an understanding of these threats. The top threats facing web services can be classified into the following categories (Singhal, Winograd, & Scarfone, 2007):

1. Message alteration, where the attacker can insert, remove or modify information within a message to deceive the receiver.
2. Loss of confidentiality; where the information within a message is disclosed to an unauthorized individual.
3. Falsified messages, where fictitious messages that an attacker intends the receiver to believe are sent from a valid sender.
4. Principal spoofing: where the attacker constructs and sends a message with credentials such that it appears to be from a different, authorized principal.
5. Forged claims, where the attacker constructs a message with false credentials that appear valid to the receiver.
6. Replay of message, where the attacker resends a previously sent message.
7. Replay of message parts, where the attacker includes portions of one or more previously sent messages in a new message.
8. Denial of service, where the attacker causes the system to expend resources disproportionately such that valid requests cannot be met.
- 9.

Research into security policies, security infrastructure, threats and vulnerabilities of computer information systems continues to grow because it's evolving nature and significant economic impact on organizations. Information security policy means protecting information and information systems from unauthorized access, use, disclosure, disruption, modification, perusal, inspection, recording or destruction (Johnson & Merkow, 2010). As information is an extremely valuable and important corporate asset that requires protection against risks that would threaten its confidentiality, integrity and/or availability (Feruza & Kim, 2007). Suitable information security controls must therefore be selected and implemented. Therefore, the logic of well planned policy is depending on the needs of organizational policy definition that guides personal and technology decision which serve the organizational needs. By definition, security policy refers to clear, comprehensive, and well-defined plans, rules, and practices that regulate access to an organization's information systems. Information system security relates to the adequacy of management controls to prevent, avoid, detect and recover from whole range of threats that could cause damage or disruption to computer systems. Good security policy protects not only information systems, but also individual employees and the organization as a whole. It also serves as a prominent statement to the outside world about the organization's commitment to security. Security measurements have proven to be much more successful when the target of assessment is audited and penetrated carefully to avoid security holes. Vulnerability analysis and penetration test attempt to exploit any one of the vulnerabilities to gain unauthorized access (Arkin, Stender, & McGraw, 2005). The valuable educational information such as student identification number, student mark records, as well as academic and employee identification numbers, and their confidential financial records are subject of attack. Attacker are well aware of pervious valuable information accessible through web applications and their attempts to get at it are judged by several important factors (Stolfo, Bellovin, & Evans, 2011). Gartner reported that 75% of hacks happen at the application layer, not at the network or system layer, (Arkin, Stender, & McGraw, 2005; , "www.gartner.com"). To check application layer there is a need for information gathering where the tester used an automated scanning, web crawlers, and social engineering, to gain information about the target application. Gathered information is used to generate possible attack in which testers use the identified information, together with domain knowledge about possible vulnerabilities to generate attacks (Dahl, 2005). Penetration test and

vulnerabilities analysis based on fake attacks used to find logs information about the attack and to generate a report that details the discovered vulnerabilities and corresponding remedy, a result information can be used by application developers to eliminate the vulnerabilities and improve the security of their produced application software (Petukhov & Kozlov, 2008). The searching and eliminating vulnerabilities in the web application is one of the common ways of securing mechanism, the other ways are included in safe development (Cook & Rai, 2005; Meier, Mackman, & Wastell, 2005), implementing intrusion detection and/or protection systems (Halfond & Orso, 2005; Su & Wassermann, 2006), and web application firewalls (Ristic, 2006). Penetration test provides detailed information on actual, exploitable security threats if it is encompassed into an organization's security doctrine and processes. This will help the organization to identify quickly and accurately real and potential vulnerabilities for the purpose of isolate and prioritize vulnerabilities, and assist the organization fine-tune, test configuration changes or patches to proactively eliminate identified risks (Bacudio, Yuan, Chu, & Jones, 2011). In this paper I will tackle the issue of Information systems safety in Jordanian educational organizations, considering public universities as a case study and propose a circulated model for enhancing the security of information system in educational organizations. Through the special case study on Mutah University, the experimental results provide valuable reference to check out security vulnerabilities of Web service and help to optimize the system's security design. In this paper, Section 2 presents an elaborate discussion of the experimental platforms as well analysis of their results; while Section 3 presents the remedies for detected vulnerabilities; and Section 4 concludes the paper and points out the next work.

2. CURRENT SITUATION ANALYSIS

In this paper, penetration test and web application scanners were used to discover the importance of each security parameter and to evaluate the whole web site response. This test is designed to evaluate an information system's defense and discover weaknesses in the whole domain website design and its resources from ethical hacking point of view and how the site reacts to an attack, whether or not a whole system's defenses can be breached, and what information can be acquired from the whole system. A comprehensive security health check performed using Netsparker Professional Edition version 2.3.0.9 ("www.mavitunasecurity.com/netsparker") to evaluate the current security status of Jordanian public universities from point of view of vulnerability types and severity groups. Test was done on the universities as given Table1; it covered all security scanning tests on the whole domain scope with 25 concurrent connections to the target back end database following the crawling and attacking principles. All universities sites were checked using Netsparker as whole domains; much iteration of crawling tests was performed to find the vulnerability holes in given sites. Results is used to take the next steps to reinforce these universities to defense their sites from injections such as SQL, Boolean SQL, Blind SQL, Command, Blind command, Expression language and HTTP header, as well Open Redirection, Local, Remote file inclusion and Remote code evaluation Table2.

University	DNS Name	IP address
Jordan	ju.edu.jo	87.236.232.79
Yarmouk	yu.edu.jo	87.236.233.10
Mutah	mutah.edu.jo	87.236.232.229
Jordan Scince	just.edu.jo	87.236.232.175
Al al-Bayt	aabu.ed.jo	87.236.233.39
Hashemite	hu.edu.jo	87.236.232.216
Balqa Applied	bau.edu.jo	87.233.233.117
Al Hussein	ahu.edu.jo	87.236.233.71
Tafila Technical	ttu.edu.jo	87.236.233.188
Germany Jordan	gju.edu.jo	87.236.233.228

TABLE 1: Jordanian Universities Domains and IP Addresses.

Severity Type	Hole Vulnerability	University									
		Jordan	Yarmouk	Mutah	Jordan Science	Al al-Bayt	Hashemite	Balqa	Al Hussein	Tafila	Germany Jordan
Critical	SQL Injection						x	x			
	Boolean Based SQL Injection	x									
Important	Database User Has Admin Privileges	x									
	Local File Inclusion	x						x			
	Cross-Site Scripting			x	x	x					x
	Pasword Transmitted Over HTTP			x			x	x	x		x
Medium	MAC is not Enabled in ViewState	x			x				x		
	Password Transmitted Over Query String			x							
	Invalid SSL Certificate Detected				x						
	ColdFusion Source Code Disclosure			x							
	Open Redirection				x						
Low	Internal Server Error	x	x	x	x	x	x	x	x	x	x
	Cookie Not Marked As Http Only	x	x	x	x					x	
	ASP.NET version Disclosure	x	x		x			x	x		x
	Social Security Number Disclosure	x		x		x			x		
	ASP.NET Stack Trace Disclosure					x	x				x
	ViewState is not Encrypted	x			x			x	x		x
	MS Office Information Disclosure	x		x		x	x			x	
	Internal IP Address Leakage	x			x	x		x	x		
	Redirected Response BODY Has Two responses	x									
	PHP Version Disclosure		x	x							x
	Auto Complete Enabled			x	x		x	x	x		x

	Apache Version Disclosure			x						x	
	Backup File Found			x				x			
	Tomcat Version Disclosure					x					
	Tomcat Exception Report Disclosure					x					
	Database Error Message							x			
Informatio	NTLM Authorization Required	x			x						
	Microsoft SQL server Identified	x									
	Forbidden Resource	x	x	x	x	x	x	x	x	x	x
	ASP.NET Identified	x			x						
	E-mail Address Disclosure	x	x	x	x	x	x	x	x	x	x
	IIS Version Disclosure	x	x		x		x	x	x		x
	Internal Path Leakage (Windows)	x		x	x		x	x	x	x	x
	Apache Version Is Out Of Date			x							x
	PHP Version Is Out Of Date			x							x
	Tomcat Version Is Out Of Date					x					
	Redirected Response BODY IS Too Large					x					x
	Sitemap Identified					x					x
	Internal Path Leakage (*nix)					x					
	Directory Listing (IIS)						x				
	File Upload Functionality Identified	x									

Table 2: Jordanian Public Universities Vulnerabilities and Severities Evaluation.

Test was done for each site to get the severity of prioritize vulnerabilities as critical, important, medium, low and informational vulnerability types as defined by payment card industry (PCI) standard, where the critical level is given to flaws that could be easily exploited by a remote unauthenticated attacker and lead to system compromise without requiring user interaction. Important rating is given to flaws that can easily compromise the confidentiality, integrity, or availability of resources. Medium rating is given to flaws that may be more difficult to exploit but could still lead to some compromise of the confidentiality, integrity, or availability of resources, under certain circumstances. Low rating is given to all other issues that have a security impact. Figures 1, 2, 3, 4, 5 shows all individual prioritize vulnerabilities parameters. Figure 1 shows that Hashemite University web application site is the most critical vulnerable problems; Figures 2, 5 shows that Al al-Bayt University is the highest in important and information severity problems, while Figures 3, 4 indicate that Mutah University whole domains website is the most in medium and low severity problems.

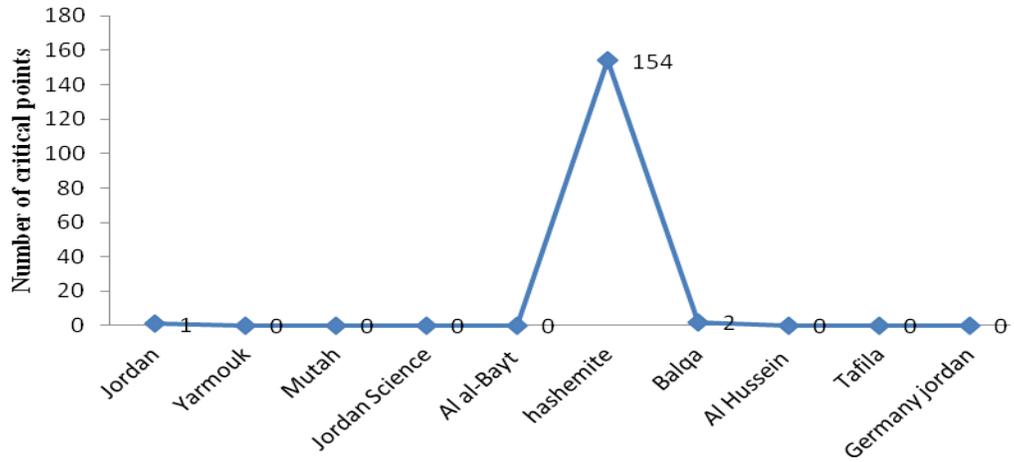


FIGURE 1: Critical Severity Problems Among University Sites.

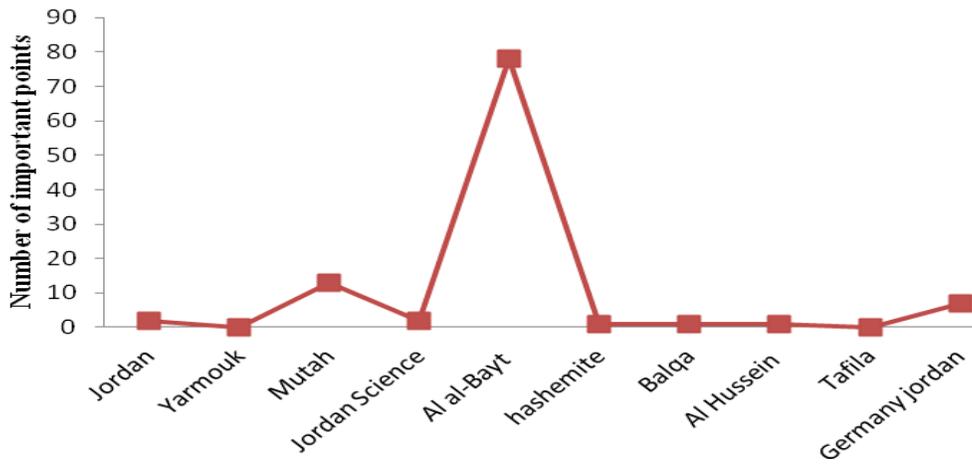


FIGURE 2: Important Severity Problem Among University Sites.

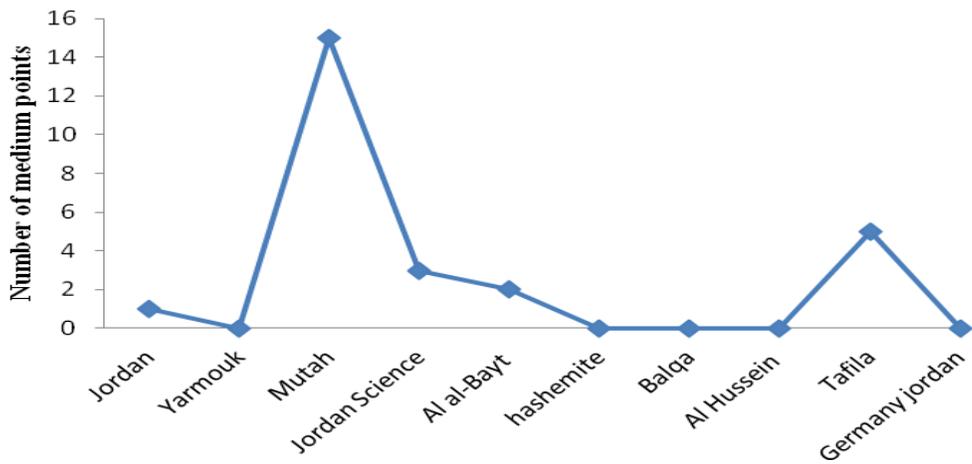


FIGURE 3: Medium Severity Problem Among University Sites.

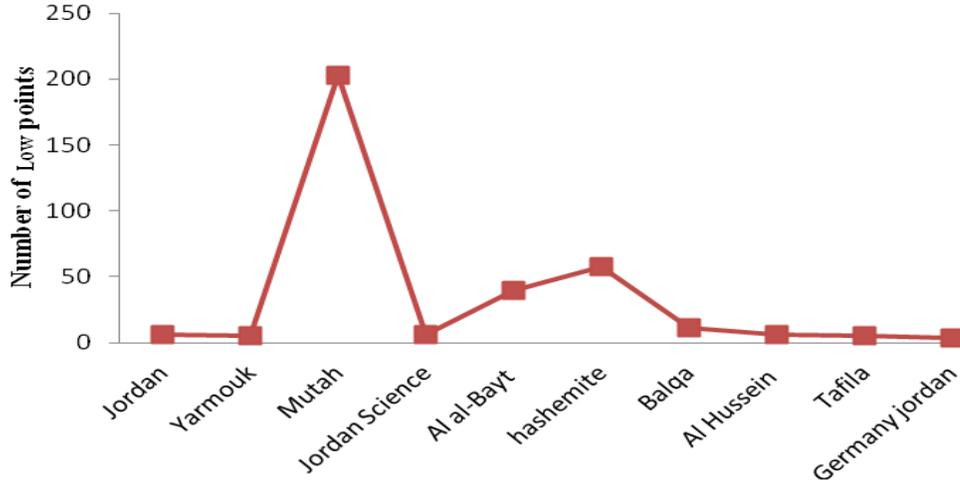


FIGURE 4: Low Severity Problem Among University Sites.

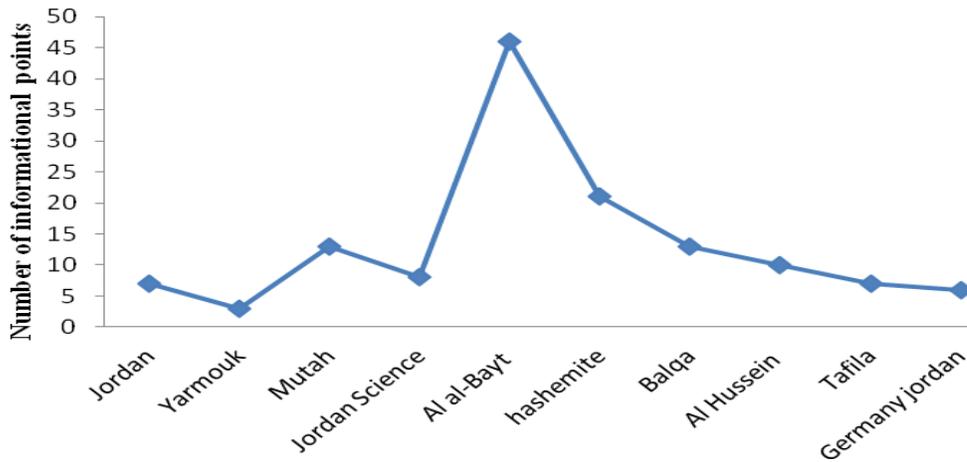


FIGURE 5: Information Severity Problem Among University Sites.

A conclusion of previous figures shown indicates that the Hashemite University with the highest critical vulnerability holes, Balqa applied and Jordan universities were investigated with minimum range of holes from 1 to 2, while the other universities were free from critical holes. Important investigated holes were found in Al al-Bayt, Mutah, Germany-Jordan and Jordan University, respectively. Medium holes were found to be high in Mutah whole domain site as well as low vulnerability holes. Table 2 gives all details of severity vulnerability types, here a concentration will be on the major holes and their remedies. Critical risk severities were found in.

3. DETECTED VULNERABILITIES, ANALYSIS AND REMEDIATION

According to the given results in Table 2, with the investigation of critical and important vulnerabilities there found the following attacks:

SQL and Boolean Based injection: It allows an attacker to alter backend SQL statements by manipulating the user input. An SQL injection occurs when web applications accept user input that is directly placed into a SQL statement and doesn't properly filter out dangerous characters. This is an extremely common vulnerability and its successful exploitation can have critical implications.

SQL injection impact: It depends on the backend database, database connection settings and the operating system; an attacker can compromise the integrity of database and expose sensitive information by mount one or more of the following type of attacks successfully:

- Reading, Updating and Deleting arbitrary data and tables from the database.
- Executing commands on the underlying operating system.

SQL injection remedy: A very robust method for mitigating the SQL injection threat is to use parameterized queries. Wherever possible do not create dynamic SQL queries or SQL queries with string concatenation.

Database User Has Admin Privileges: It is related to SQL Injection vulnerability in the application which identified that the target web site is connecting to the backend database by using a user that has administrative privileges.

Database User Has Admin Privileges impact: An attacker can gain extra privileges via SQL Injection attacks. The attacker might carry out the following type of attacks:

- Gain full access permission to the database server.
- Gain a reverse shell to the database server and execute commands on the underlying operating system to gain administrator access to the target system.

Database User Has Admin Privileges remedy: A database user must be created with the least possible permissions for hosted application and connect to the database with that user.

Local File Inclusion: It is occurred when a file from the target system is injected into the attacked server page.

Local File Inclusion impact: Depends on exploitation and the read permission of the web server user, an attacker might carry out one or more of the following attacks:

- Gather usernames and harvest useful information from the log files
- Remotely execute commands via combining this vulnerability with some of other attack vectors such as file upload vulnerability or log injection.

Local File Inclusion remedy: A file path must not be permitted to be appended directly, it must be hard coded via and index variable. An application programming interface must be limited to allow inclusion only from a directly directories bellow it to avoid traversal attack.

Cross-site Scripting: A dynamic script in the context of the application is allowed and executed by attacker. This allows several different attack opportunities, mostly hijacking the current session of the user or changing the look of the page by changing the HTML on the fly to steal the user's credentials. It targets the users of the application and administrator instead of the server to gain full control over the application and administration panel.

Cross-site Scripting impact: Using cross site scripting, the following attacks can be leveraged:

- Hi-jacking users' active session and intercept data.
- Mounting phishing attacks.

Cross-site Scripting remedy: To avoid this kind of attack, output should be encoded according to the output location and context.

Password Transmitted Over HTTP: The criticality of this vulnerability that password data is sent over HTTP.

Password Transmitted Over HTTP impact: An attacker can intercept network traffic to steal user's credentials.

Password Transmitted Over HTTP remedy: All sensitive data should be transferred and served over HTTPS and rather than HTTP.

The other detected vulnerabilities categorized into medium, low and informational levels as shown in table2, an attacker might carry out one or more of the following attacks: application tampering, performing man in the middle attack and encryption traffic between website and the visitors observation, obtaining server side source code of the web application, which can contain sensitive data such as database connection strings, usernames and passwords along with the technical and business logic of the application. Redirect Users to other malicious web sites which can be used for phishing and similar attacks. Internal server error or server responded with an HTTP status 500. Providing an additional layer of protection against Cross-site Scripting attacks because of cookie was not marked as HTTPOnly. Auto complete was enabled in one or more of the form fields.

Previous attacks remedies: Secure socket layer certificate activation to provide secure communication between your website and its visitors. Ensure that the server has all the current security patches applied and remove all temporary and backup files from the web server. Ensure that you only accept URLs which are located on accepted domains. Analyze and review the application code in order to handle unexpected errors. Mark the cookie as HTTPOnly. Add the attribute auto complete="off" to the form tag or to individual "input" fields. Avoid disclosed information in website platforms.

4. CONCLUSION AND FUTURE WORK

This paper has described a full detailed analysis of real and potential vulnerabilities in public Jordanian universities. It's providing the information required to effectively and efficiently isolate and prioritize vulnerabilities for the purpose of assisting the universities to fine-tune and test configuration changes or patches to proactively eliminate identified risks. Based on given analysis a unified security policy for educational institutes will be proposed in the future work.

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Enhancing Teaching and Learning through Content Management

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Abstract

The last few decades have witnessed development in new Web technologies and tools. The current iteration of the Web: Web 2.0 offers several components that facilitate the learning process. Online teaching and learning tools among others, is one such component. This new technology as manifested in wikis and blogs has gained recognition for their potential use in colleges and academic institutions. Wikis and blogs are Web tools that can facilitate professor-student collaboration as well as student-student interaction and collaboration. They also provide a means of constructing and building knowledge, and facilitate collaborative learning. This article discusses the use of wikis and blogs as tools for teaching and learning. It also reports on the implementation of these technologies in an academic institution.

Keywords: Online Learning Environment, Collaboration, Blog, Wiki, Pedagogy, Knowledge Building, Tools, Constructivism.

1. INTRODUCTION

In recent years colleges and universities have adopted and continue to adopt new and emerging technologies to facilitate the teaching and learning process. It has now become common for a professor to have a course Web site where course resources are provided for students enrolled in a particular course. Materials such as course syllabi, published papers, announcements and reading assignments are often posted for students to access at any time. Studies have shown that in recent years the number of students working full-time and part-time has continued on an upward trend. In a *New York Times* article by David Koepfel on October 26, 2003, students provide numerous reasons as to why they seek employment [1]. Emily Brandon in an article published in the *U.S. News & World Report* magazine reports that "...75 percent of all undergraduates under the age of 22 work [2]." This information was attributed to the analysis of the American Council on Education. Working full-time or part-time is not limited to college and university students only. High school students have after school part-time jobs as well. More often than not this trend continues when the student goes to college, thus it has become the "new normal."

As this trend continues, course Web sites have proven to be a valuable resource for students who have to juggle work and school. In response to the "new normal" colleges and universities have had to find ways of accommodating the current day student. A majority of universities have incorporated online teaching into their academic curriculum to address the needs of those students who are unable to attend brick and mortar classes on a regular basis. It can also very useful for those who are able to attend the traditional class sessions. For instance, those who miss classes are able to visit course Web sites to review the information that was presented during the class period. Also, they are able to access announcements that might have been made

during the class period. Additionally, class assignments can be accessed at the students' convenience.

The potential use of internet technologies as pedagogical tools was envisioned more than two decades ago. In his book *Understanding Technology*, Susskind [3] argues that the ability to provide certain information and learning materials through technology meant teachers would be less occupied. As a result, teachers and instructors have more time to provide one on one interaction with students. In essence each student has his/her own private professor [3]. McMullin [4] concurs with this view when he states "... to the extent that it streamlines or reduces the administrative burden on teachers, it correspondingly increases their ability to invest more time in teaching."

The interaction between professors and students in an academic setting cannot be over emphasized [5]. Recent studies have shown this interaction to be quite beneficial to both students and professors. A 2006 report which surveyed 2400 law school students in 64 law schools revealed that frequent interactions between professors and students was related to very beneficial outcomes [6].

2. BACKGROUND & MOTIVATION

Online Learning Environment (OLE) continues to be used as a tool for providing instruction to students. There are many published articles on the usefulness and importance of online teaching methods [7, 8, 9, 10, 11, 12, 13]. WebCT is one such learning environment providing various modules to enhance teaching and learning. Currently, it is used by millions of faculty and students in universities and colleges all over the world [9]. In recent years, other online technologies have emerged to increase the number that is already in use. One such technology is a Wiki. Web logs or blogs have also become quite a popular online tool which has found its way into academia.

2.1 Current System in Use & Limitations

WebCT/Blackboard is currently the OLE of choice for many colleges and universities. These non-traditional teaching tools or courseware provide facilities that enable faculty without any Web development training and knowledge of Web programming languages to easily use these tools. Consequently, its popularity has soared [14]. The ability to customize online courseware is a cogent reason for their widespread usage in universities. Institutions that use this non-traditional teaching tool can configure it using strategies that best fit with their academic needs and vision.

WebCT/Blackboard is the current system in use in most universities. The current customization grants privileges to only faculty to upload and post course materials. In any given semester, a professor can post announcements and comments about courses he/she is teaching. Provision is also made for the instructor to post scores and grades for students in a class. Students have the ability to only view grades and access other course materials such as presentation slides and information posted by the professor.

Quite often students lose their log in credentials such as passwords, and the system does not provide a mechanism for students who have lost or forgotten their login credentials to reset them. Consequently, students have to go through a cumbersome process to reset their password, which may further delay their work.

3. WIKIS & BLOGS AS PEDAGOGICAL TOOLS

Most online learning takes place in an asynchronous environment where 24 hour access may be guaranteed. Wiki and blog technologies fall under this type of communication and cooperation. For instance, a professor may post course materials and students are able to access and download these materials at their own convenience. Parker and Chao [15] assert this form of communication is conducive for cooperation and collaboration, that is, the professor and the student do not have to be logged into the online environment for learning to occur. Wiki usage can also be found in the corporate world. Such organizations as Wall Street Journal, Gartner and Business Week acknowledge its usefulness in collaboration. A survey conducted by Majchrzak et

al. [16] on the corporate use of wikis revealed great potential in the areas of collaboration, work flow process and knowledge accumulation for future use.

Since this technology became available, it remains fairly new in academia. However, in recent times, it has begun to emerge as a relatively new teaching tool to complement or possibly replace other non-traditional course management systems like WebCT, Blackboard, etc., as a tool for information sharing and dissemination. As a practical example, for any given course a professor or student can create a page in the wiki about a topic that is relevant to the course for further research and input. The professor can then provide students with a general research direction for the topic. Content can then be provided and edited by 'adders' and 'synthesizers' as categorized by Majchrzak et al. [16]. As the iterations of providing and editing content occurs, students would have the ability to process the information that is already in the wiki; in so-doing they add to their knowledge base [17]. Cress and Kimmerle [17] and Aharony [18] further argue that knowledge can also be developed from prior internalized knowledge. They contend that the interaction of prior knowledge with those acquired from using wikis creates new knowledge. Thus, a wiki is viewed as a tool that facilitates the sharing and shaping of knowledge [19]. Parker and Chao [15] list possible uses of educational wikis as presented by Duffy and Burns as follows:

- Students can use a wiki to develop research projects, with the wiki serving as ongoing documentation of their work.
- Students can add summaries of thought from the prescribed readings, building a collaborative annotated bibliography on a wiki.
- A wiki can be used for publishing resources like syllabi and handouts, and students can edit and comment on it for all to see.
- Teachers can use wikis as a knowledge base, enabling them to share reflections and thought regarding teaching practices, and allowing for versioning and documentation.
- Wikis can be used to map concepts. They are useful for brainstorming, and editing a given wiki can produce a linked network of resources.
- A wiki can be used as a presentation tool in place of conventional software, and students are able to directly comment and revise the presentation content.
- Wikis are tools for group authoring. Often group members collaborate on a document by emailing to each member a file that each member edits on their computer, and some attempt is then made to coordinate the edits so that everyone's work is equally represented; using a wiki pulls the group members together and enables them to build and edit the document on a single, central wiki page.

Blogs, like wikis have also witnessed a significant increase in its usage. Today, blogs have become part and parcel of social life. In politics for example, it has become an effective tool for organizing people at the grass root level and also enhance contributions. Scholarly papers on blogs do acknowledge its potential use in pedagogy [20]. Richardson [20] in *Blog, Wikis, Podcasts, and Other Powerful Web Tools for Classrooms* cites learning specialists Fernette and Brooks on the potential benefits of this technology:

- Can promote critical and analytical thinking
- Can promote creative, intuitive and associational thinking
- Can promote analogical thinking
- Potential for increased access and exposure to quality information
- Combination of solitary and social interaction

In institutions where it is already being used, it allows the teacher and students to begin conversations that spur deeper thinking [21]. Any student seeking to make a contribution or post a comment to a blog implicitly ought to have read the posting before making comments accordingly. Two independent surveys on the use of blogs in pedagogy conducted at two different institutions produced similar results.

The first survey conducted by the Brisbane Graduate School of Business on using blogs for particular courses in the Master of Business program yielded some promising results [21]. The responses as presented in Table 1, shows that support did exist for using the blog. This is also made evident in the comments that were posted:

'I spent time prior to each blog constructing an entry. To do that I did need to have a good understanding of what I wanted to blog about. I also spent time reading and considering the blogs of other students and found their comments and perspectives thought provoking.'

'Even though at first people were afraid to take the risk and blog, I found it a good way to discuss concepts and participate in further discussion. It also allowed the sharing of up-to-date information that would not have been possible in lecture time.'

'I particularly enjoyed seeing the almost daily observations of students of the applications of the 414 theory and [the] "thinking about things" technique.'

'I felt that it offered a method to give comment on a wide range of macroeconomic issues that started debate and interesting conversation.'

A total of 102 students were enrolled in the classes, out of which 51 responded to the survey. Sixty-six percent of the respondents agreed that the blog did assist them in their learning with only 12 percent disagreeing (see Table 1).

Question 2: If you did not participate in the MBA Blog you do not need to answer any further questions. Thank you for your input. If you did participate, please answer this question and questions 3-5. Do you think the MBA Blog assisted you with learning in GSN414/GSN451?	Score	%
A. Strongly agree	6	17
B. Agree	17	49
C. Neither agree nor disagree	8	23
D. Disagree	2	6
E. Strongly disagree	2	6
F. No answer	16	

TABLE 1: Survey Results of Blog as Medium for Facilitating Learning.

As earlier stated interaction is very much a part of the learning process. Professor-student interactivity as well as student-student interaction cannot be over emphasized. The survey also found that 77 percent of students either agreed or agreed strongly that intellectual exchange took place at an appreciable level as shown in Table 2. Similarly, another survey by Cobanoglu [22] of students in a hospitality technology class showed almost identical results on the use of blogs.

Question 3: Do you believe the MBA Blog increased the level of meaningful intellectual exchange between student more broadly?	Score	%
A. Strongly agree	6	17
B. Agree	21	60
C. Neither agree nor disagree	7	20
D. Disagree	1	3
E. Strongly disagree	0	0
F. No answer	16	

TABLE 2: Survey Results of Blogs a Medium for Interactivity.

It is important to state that as teaching and learning trends towards the constructivist paradigm, where pedagogy tends to focus on instructional scaffolding as oppose to information transmission, these tools can play a significant role moving forward [24].

4. PROJECT DESCRIPTION & IMPLEMENTATION

4.1 Understanding Wikis & Blogs

A wiki is defined by the Merriam-Webster's online dictionary as a Web site that allows visitors to make changes, contributions, or corrections. Wikipedia defines it as a collection of Web pages that is designed to enable anyone who accesses it to modify and contribute content. In essence any Web site that allows for modification and contribution of content by users, either registered or anonymous can be referred to as a wiki. The two common types currently in widespread use are categorized as restricted access and open-access wikis, where access is granted to authenticated and unauthenticated users respectively [23]. It is a Web site whose content can be created, edited and modified by a group of users collaboratively [25]. The technology emerged in the mid-1990s and gained prominence in the year 2000. Currently, Wikipedia is the most popular wiki with close to 3 million articles [26].

Prior knowledge of Web development tools are not required in order to use a wiki. Only a Web browser is needed to access a wiki. Any editing or additions to an existing page is recorded and reverting to a previous state can be easily accomplished [27]. Related wiki topics can be linked with hyperlinks, expanding it to create a body of knowledge. Research in any given area of interest can be done by searching for the topic [23].

Formally known as Weblog, a blog is a Web tool which is usually maintained by an individual or groups of individuals with regular writings or posts of comments. Hyperlinks, hypermedia and other resources can be embedded in blogs to enrich the content. It is a Web page with posts listed in reverse chronological order [25]. Its popularity has increased since its inception in the late 1990s and there has been a consistent growth in its usage since. As of the year 2007 there was an estimated number of over 75 million existing blogs [28, 29].

Like wikis, blog users do not require the knowledge of Web development or development tools. Access to a blog is easily accomplished through the use of a Web browser. Blog technology facilitates the instant publication of posts to the Web from computer systems with an internet portal [30]. A blog can have several links to other blogs and other resources, hence providing additional learning resources.

4.2 Project Description

The goal of this project is to implement a system that enhances teaching and learning. The aim is to build a CompSciWiki application that enhances interaction and collaboration between

professors, instructors and students. It affords students in a particular course the ability to access a central location for all information and resources regarding the course. The professor has the ability to readily post assignments and related course materials which students are able to access at all times. Additionally, a blog application is built to allow students and teachers to initiate conversations through posting blogs, comments and other resources. Published information will serve as an important source of knowledge. File upload and download capabilities are provided so that students and professors can upload materials that may be useful for the course.

4.3 System Functionality & Use

The CompSciWiki module developed has the following characteristics:

- Authenticate users
- Disallow anonymous content submissions and/or modifications
- Authenticated users have the privilege of creating new pages and modifying or editing existing pages
- Keep track of user modifications
- Hyperlink to other pages
- Text formatting

CompSciWiki Use Case

Only authenticated users have the ability to edit pages. Preventing unauthenticated users from editing the pages removes the threat of visitors to the site deleting otherwise useful content. Anonymous users are only able to view the published pages, but, do not have the privilege of editing/modifying. Once a student logs into the wiki module of the system, he/she has the ability to modify the content on any page, or submit new page content. They can also create new pages and proceed to add content. After adding content the page can then be published. Tracking submission and modification is relatively easy, as students are authenticated.

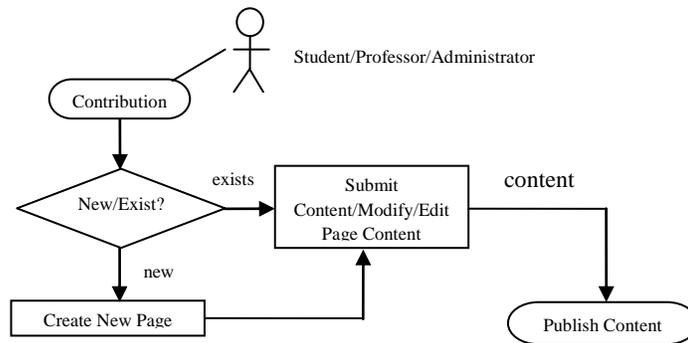


FIGURE 1: CompSciWiki Use Case diagram.

The CompSciBlog module implemented allows for the professor/administrator to publish blog entries. Similar to the wiki module, this module has features such as:

- Disallow unauthenticated users from posting comments or publishing blog entries
- Authenticate users
- Upload blogs to be published
- Post class materials and resources

CompSciBlog Use Case

The professor is solely responsible for publishing a blog. However, a blog file upload mechanism is provided for students to submit blog files for publishing. A mechanism is implemented that display the comments submitted, the date, and time it was submitted. This in turn, would provide an avenue to determine those who have participated for them to be credited accordingly.

Submitted blogs for publishing have to be Web publishable. Files with the following extensions are accepted: .htm, html, .doc, and .pdf. Consequently, a hard validation is performed on all blog files uploaded to ensure that this requirement is met. It is important to recognize that these files types can be displayed quite easily in a Web browser. At any given time an upper limit is placed on published blogs. The professor/administrator has the sole right as to which blogs are published after consultations with the students. For instance, the professor might ask the students to blog about a topic that was taught in class, and from the submitted entries decide on those that best capture the essence of the topic.

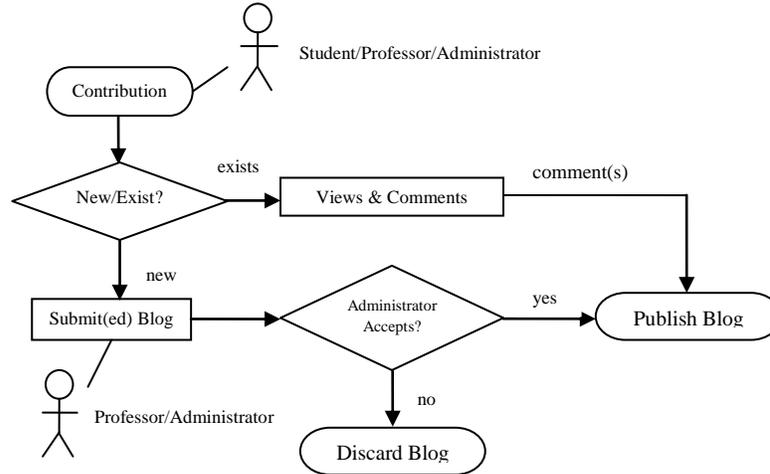


FIGURE 2: CompSciBlog Use Case diagram.

Provision is made for uploading documents and files to the system. Materials and resources that students have researched and found to be potentially helpful for other students can be uploaded to the application. The materials are kept in a directory where it can be accessed by all.

The instructor/administrator has the ability to execute certain tasks and perform certain functions that students are barred from doing. These are listed as follows:

- Provision is made to post course materials such as syllabi, slides, announcements, etc.
- Ability to remove posted items in any module
- Mechanism to assign privileged status to some users
- Monitor student participation

4.4 Development Tools

For this project the .NET development framework is used as the platform of choice for implementation with ADO.NET components, Visual Basic and JavaScript as the backend programming languages. The decision to use the above mentioned software and language stems from the fact that Visual Studio 2005 edition is widely used for Rapid Application Development (RAD). The package also comes with Microsoft SQL Server which as stated earlier is adequate for the purpose of this project. Visual Studio 2005 provides developers with three options in developing a Web application. File system, http, and ftp are the options available. The file system option is used for this implementation. This option organizes files that make up the entire Web site project in a file system structure. It also provides other administration tools for managing users, granting privileges to groups of users to perform certain actions, and maintaining user profiles in a relational database.

5. INTEGRATE WIKIS & BLOGS INTO DISTANCE EDUCATION

Significant changes have taken place in distance education from the days when instruction materials were sent through the mail. The mode of teaching and learning has equally evolved

over time. It has also gone through several name changes, from independent study to correspondence study, etc., during which period learning materials were next to impossible to obtain. Fast forward to present day, technology has made it possible for this method of instruction and learning to evolve and grow at a fairly rapid pace. However, an evaluation by Schwartz et al. [31] conducted in 24 universities around the world showed that there was only minimal use of these new technologies in distance learning. Hence, the impetus exists for designers to integrate wiki and blog technologies among others into this mode on education [32]. Jonassen et al. [33] proffer context, construction, collaboration and conversation as functional principles in the development of this emerging learning environment. Over the years, distance learning has adopted some technological innovation such as the use of recorded videos and audio, and more recently electronic mails and video conferencing. Wikis and blogs can be used to augment these adopted technologies in ways, such as:

- Generally, distance education takes several forms and involves the use of printed texts, published literature, study guides, video and audio, compact disc, etc. Electronic mails and video conferencing is the medium of communication. However, in recent times, other technologies have been incorporated, making it possible for interactions and active participation in distance education to occur through webinars, blogs and wikis [34].
- Collaborative authoring is part of the wiki design, where everyone can submit input on a given topic either in a synchronous or asynchronous environment. Wiki collaborative authoring can take many different forms, such as student-student collaboration as well as professor-student collaboration [35]. This comparatively provides a better means of collaboration in a distance learning setting. In two case studies by Exter et al. [36], they concluded that “the flexibility and relative ease of use, of many Web 2.0 tools, especially when used in an integrated way presents almost unlimited opportunities to facilitate collaboration with distance education students.”
- Information dissemination in a traditional distance education setting involves the sending of electronic mail blasts to all students. Blogs on the other hand, provide a communication tool for disseminating information to people (students), and for enabling feedback. They facilitate a shared space for information sharing and initiating dialog [37].

It is our belief that the adoption of computer-mediated communication tools, like blogs and wikis can be effective in this mode of education. Therefore, going forward, the integration of these social Web technologies will be imperative, as in recent times there has been a pivot towards constructivism at various levels of educations, especially, in higher education [38].

6. DISCUSSION

Online teaching methods and tools can be considered as a resource that facilitates the learning process, and assist students to acquire the required knowledge to help in their academic activities. Boulos et al. [39] argue that the use of these technologies spur on learners' elevated engagement and focus with learning materials. They further argue that the shared working spaces provided by using these technologies, improve collaboration between learners and yield desirable outcomes [39].

Wikis are a useful tool for facilitating online learning groups [40, 41]. For group learning to occur, the exchange of ideas, information dissemination and group interaction must occur. Wikis can be used to support these activities. Also, they can be used as a repository of the shared knowledge representative of the learning group [40].

Creating new pages is perhaps what makes a wiki a powerful learning tool. For instance, a student can create a page about a topic, and other students can then provide their reflections and researched information on that topic, thereby negotiating meaning. As content is provided, and continuous editing occurs, the topic can develop into a complete article authored by several users. A professor may also initiate a discussion page on the wiki requiring all students in the

course to research information on the topic in question. Participation can then be monitored as each user entry is logged by the system. Therefore, those students that do not partake can be easily and appropriately identified. In essence students that do not take part would be graded accordingly [42].

In the case of a blog, submitting a post on any published piece would require the student to read and reflect on the posts. This is made evident by submitted comments by students in a survey [21]. It is anticipated that a knowledge resource will develop over time as entries and comments are made. Students are not created equal. Therefore, the pace of learning can vary from student to student. Being able to accommodate such students is a key part of teaching. Blogs can facilitate an environment where students can learn at their own pace [43].

As these technologies gain widespread use especially in academia, it will be in order for faculty in colleges and universities to acquaint themselves with the technology. Most importantly, training faculty to be conversant with these new technologies is of utmost importance. This will provide them a basis and the skills required to enable them incorporate wikis and blogs into their instruction. It will also create a situation where professors and instructors will not only be 'content consumers', but rather 'content creators' as characterized by Campio et al. [44]. It is envisaged that students would be both the former and the latter as they become more familiar and functionally adept in its usage.

7. SUMMARY & CONCLUSION

This paper discussed the emergence of wikis and blogs as tools for teaching and learning. It highlighted the overarching importance of these technologies as the education paradigm shifts toward the constructivist approach. Technological tools that make this trend a reality are bound to be widely embraced and adopted. For this reason, teachers' roles would need a re-alignment. Shieh et al. [45] cite Kochtanek and Hein who contend that professors/instructors must move away from being agents of knowledge transmission and become knowledge facilitators. Furthermore, to encourage and facilitate content consumption and more importantly, content creation by students, it is imperative for faculty to become more proficient in using these technologies. Hence, universities need to provide them with the requisite knowledge and expertise through training and workshops.

Currently, a good number universities and colleges have a mix of both the traditional face-to-face teaching and online learning methods. Faculties on college campuses continue to incorporate social Web components into teaching and instruction. Offering these technologies to students can be of great value to them in future as they would have become familiar with the collaborative practice. It is important today for students to learn the skills that will propel and drive the future. Also, for universities and colleges to remain competitive, they will have to embrace the changing dynamics of educating today's students.

The development of these technologies as applied in academia is still in its nascent stages. Therefore, further research is needed in ascertaining ways to leverage these emerging tools to enhance teaching and learning. It is envisaged that thinking critically about these tools, coupled with research by users and potential users will help to promote a more holistic form of learning.

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Automated Protocol for Counting Malaria Parasites (*P. falciparum*) from Digital Microscopic Image Based on L*a*b* Colour Model and K-Means Clustering

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Abstract

Basis for malaria parasites diagnosis in most hospitals and clinics, especially in developing countries, which is manually done, is strenuous and time-consuming. In this paper, we present an automated protocol for counting malaria parasites (*P. falciparum*) from digital microscopic red blood cells (RBCs) images based on L*a*b* colour model and K-Means clustering algorithm using Matlab. This method is device-independent, perceptually uniform and approximates human vision. An image slide of size 300 x 300 x 3 pixels of RBCs with malaria parasites has been counted in less than 10 seconds using a computer with 64-bit Intel (R) Celeron (R) Central Processing Unit and processing speed of 2.20 GHz. The digital counts have a good correlation

with the manual counts. This automated protocol has the potential of providing fast, accurate and objective detection information for proper clinical management of patients.

Keywords: Malaria Parasites, Image processing, Segmentation, K-means, cluster, L*a*b* colour model.

1. INTRODUCTION

Malaria is a worldwide health problem, causing more than 1 million deaths annually. Its annual economic burden is estimated to be around several hundreds of millions United State dollars.[1-4] In spite of available techniques such as fluorescent microscopy, rapid antigen detection methods and polymerase chain reaction (PCR),[1, 5, 6] manual counting of parasites from blood smears is commonly used for malaria diagnosis,[7-9] in most hospitals and clinics especially in developing countries. This manual counting is strenuous, arduous, and requires an expert microscopist [10-14]. Moreover, the accuracy of the final count depends largely on the expertise of the microscopist [8]. It has been observed that the agreement rates among microscopists for the counts are low [13] and is attributed to biasness. For prompt diagnosis, treatment and control of the malaria, fast, accurate and objective detection of malaria parasites is required to facilitate the process [1].

In this paper we present a new automated protocol for counting malaria (*Plasmodium falciparum*) parasites based on L*a*b* colour model and K-means clustering algorithm trained with digital RGB images captured from Giemsa stained thin blood films.

2. RELATED WORK

Advances in digital imaging have made it possible for red blood cells (RBCs) infected with malaria *Plasmodium falciparum* parasites to be imaged and studied. As a result, automatic counting of these parasites has been made possible [15-23]. However, in most of these works, image segmentation was based on red, green and blue (RGB) colour model, which is device-dependent [24] and the colour information is affected by intensity manipulation [25]. Also, the model is not perceptually uniform and does not approximate the human vision. Therefore, features for image segmentation do not appear in a more definite colour scheme in the RGB colour space [26].

S.S. Savkare and S.P. Narote have used Support Vector Machines (SVM) which relies on recognition and classification of cells [23].

3. THE L*A*B* COLOUR MODEL

In contrast to the RGB colour model, the L*a*b* colour model is designed to approximate the human vision using image from RGB colour space via XYZ system. The transformation between RGB colour model and L*a*b* colour model is linear.[26, 27] The aim of the L*a*b* colour model is to eliminate device dependency and bring about perceptual uniformity. The L*a*b* colour model is made up of a luminance, L* and chroma coordinates a* and b*, and are defined as:[28]

$$L^* = \begin{cases} 116.0 \left(\frac{Y}{Y_{wp}} \right)^{\frac{1}{3}} - 16 & \frac{Y}{Y_{wp}} > 0.008856 \\ 903.3 \left(\frac{Y}{Y_{wp}} \right) & \frac{Y}{Y_{wp}} \leq 0.008856 \end{cases}$$

$$a^* = \begin{cases} 500 \left[\left(\frac{X}{X_{wp}} \right)^{1/3} - \left(\frac{Y}{Y_{wp}} \right)^{1/3} \right] & \frac{X}{X_{wp}}, \frac{Y}{Y_{wp}} > 0.008856 \\ 7.787 \left(\frac{X}{X_{wp}} \right) + \frac{16}{116} & \frac{X}{X_{wp}} \leq 0.008856 \end{cases}$$

$$b^* = \begin{cases} 200 \left[\left(\frac{Y}{Y_{wp}} \right)^{1/3} - \left(\frac{Z}{Z_{wp}} \right)^{1/3} \right] & \frac{Y}{Y_{wp}}, \frac{Z}{Z_{wp}} > 0.008856 \\ 7.787 \left(\frac{Y}{Y_{wp}} \right) + \frac{16}{116} & \frac{Y}{Y_{wp}} \leq 0.008856 \end{cases}$$

where X, Y and Z are defined as

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{pmatrix} X_R & X_G & X_B \\ Y_R & Y_G & Y_B \\ Z_R & Z_G & Z_B \end{pmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

The columns of the matrix give the tristimulus values of the RGB values in the XYZ coordinate system. The tristimulus values of white point (wp), $R = G = B = 1$, is given as [24];

$$X_{wp} = \frac{x_{wp}}{y_{wp}},$$

$$Y_{wp} = 1$$

$$Z_{wp} = \frac{z_{wp}}{y_{wp}}$$

and

$$\text{where } x = \frac{X}{X+Y+Z}, y = \frac{Y}{X+Y+Z} \text{ and } z = \frac{Z}{X+Y+Z}$$

3.1 The K-Means Clustering Algorithm

K-means clustering algorithm is commonly used to segment multi-dimensional data sets [29, 30]. Its aim is to minimize the sum of squared distances between all points and cluster centers [30]. This process involves initially selecting known K cluster centres

$$m_1(1), m_2(1), \dots, m_k(1)$$

since the final clusters depend on this initial selected cluster centres K . Having prior knowledge of the number of clusters expected enables one to select the cluster centres K .

Using the relation

$$n \in Q_j(k) \text{ if } \|n - m_j(k)\| < \|n - m_i(k)\|$$

for all $i = 1, 2, \dots, K$; $i \neq j$; where $Q_j(k)$ denotes the set of samples whose cluster centre is $m_j(k)$ the sample $\{n\}$ is distribute among the K clusters. New cluster centres, given as

$$m_j(k+1) = \frac{1}{N_j} \sum_{n \in Q_j(k)} n, \quad j = 1, 2, \dots, K$$

where N_j is the number of samples in $Q_j(k)$, are computed such that the sum of the squared distances from all points $Q_j(k)$ to the new cluster centre is minimized. If $m_j(k+1) = m_j(k)$ for all $j = 1, 2, \dots, K$ then the algorithm has converged and the process is terminated.

4. MATERIALS AND METHODS

Five digital images of Giemsa stained thin film slides showing *Plasmodium falciparum* (*P. falciparum*) were retrieved from the Public Health Library of the Center for Disease Control and Prevention website [31]. They were retrieved in *portable document format* (PDF) and re-saved as joint *photographic expert group* (JPEG) format. These images were used as training set. Another set of digital images, twenty in number, with similar preparation were acquired from Giemsa stain thin film slides consisting of *P. falciparum* as test samples. These slides were obtained from the Department of Biomedical and Forensic Science, University of Cape Coast (UCC) on May 29, 2012. Images of the slides were captured using Olympus CX41 Microscope, with Olympus Imaging Camera (GMBH) model LC20 and Olympus LCMicro Software for the developed protocol counting using Matlab. The test sample slides were later sent to the Central Regional Hospital, Cape Coast, Ghana for experts counts of malaria parasites.

4.1 Image Transformation From RGB To L*A*B* Colour Space

The RGB image was transformed via XYZ image space to the L*a*b* image space to produce L*, a* and b* components. The pixels belonging to the RBCs and the parasites were identified based on *K-means* clustering using the chromaticity information. The intensities of the colour bands were clustered into different groups using the *K-means* clustering algorithm. The clustering was done by first separating the a* and b* components of the image since all the colour information was contained in these components. The a* and b* components images were combined to an index image, from which objects contained were then separated by colour. The result was a set of three distinct gray level regions in the image, where each region is relatively homogeneous in terms of pixel intensity. These were parasites intensities (cluster 1), RBCs intensities (cluster 2) and background intensities (cluster 3) referring to the colours existing in the original image. Therefore, it was assumed that there were three distinct gray level images referring to the colours existing in the original image to be separated with the *K-means* clustering algorithm. The output variables were cluster indices and the cluster centres. The mean cluster centre was then calculated for all the cluster centres in order to identify the one with the smallest cluster centre value in the image. It has been determined experimentally that the dark blue or purple colour has the smallest cluster centre value [32]. Histogram-based thresholding algorithm,[33] was then applied to cluster 1 to separate the parasites pixels from the background. Binary mask was generated where the value 1 represents the area where parasites were present and 0 corresponded to the background. All pixels outside the given range were not included in the parasites segmentation. Binary morphological operators were then used to ensure that the enclosed regions with distinctly different sizes and shapes from those of RBCs were removed. Smoothing algorithm was used to eliminate irregularities along the contours of RBCs.

4.2 Identification of Parasites Features and Counting

Connected-component labeling was performed to identify the parasites, labeling each of them with the same label. In order to use morphological methods for parasites identification, the shape

and size of the parasites in the image were considered. A disk- shape structural element of radius 2 pixels was chosen and applied onto the filled regions in the image in order to obtain regions where the parasites were located [21]. Morphological opening by the structuring element, followed by dilation of the result, was then applied on the image. The resultant image was then converted to gray scale and a structuring element of ball-shape with radius 6 pixels and height 2 pixels were then applied on the resulted gray scale image. The extent of thickening was controlled by structuring the element shape. The parasites were equated to the dilated image and labeled using a binary labeling system. These labeled pixels representing the malaria parasites were then counted. Figure 1 shows the resulted program for transforming images from RGB colour space to $L^*a^*b^*$ colour space, segmentation in a^*b^* components, and counting of the parasites.

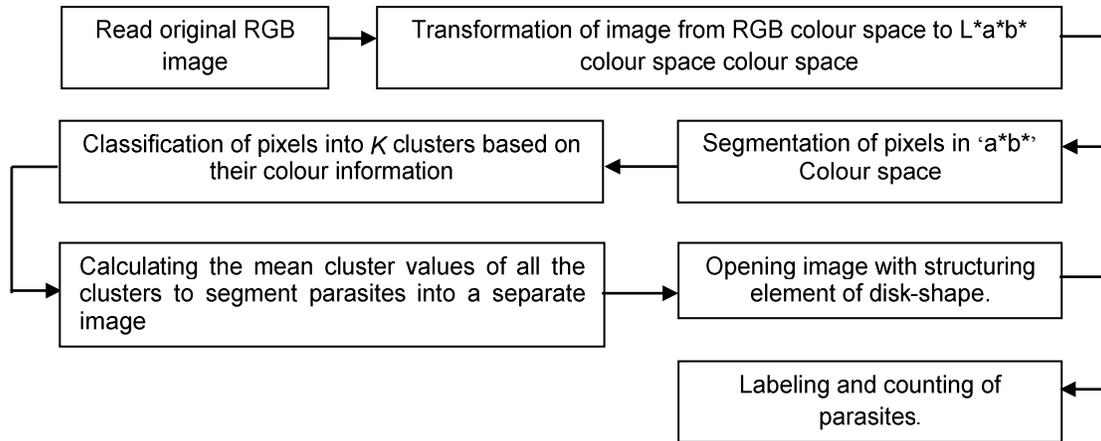


FIGURE 1: Structured program for transformation of images from RGB colour space to $L^*a^*b^*$ colour space, segmentation and clustering of chroma components, a^*b^* , and counting of malaria *Plasmodium falciparum* parasites.

5. RESULTS AND DISCUSSIONS

Figures 2 and 3 show the results of the image transformation from the RGB via XYZ image space to the $L^*a^*b^*$ image space of the images retrieved from the Website and the captured images respectively. In the $L^*a^*b^*$ colour space, colours of pixels which appear similar are located close to each other and produce a range of colours whose form depend on the primaries and the white point.

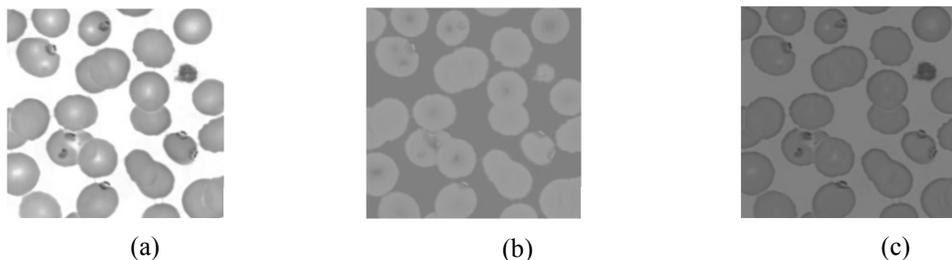


FIGURE 2: Processed images: (a) L^* component (b) a^* component and (c) b^* component of images retrieved from the Website.

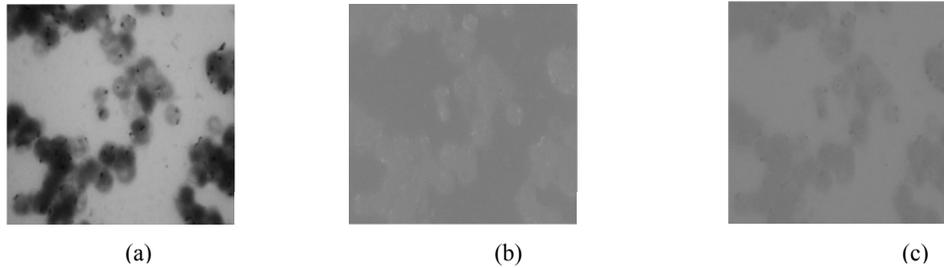


FIGURE 3: Processed images: (a) L* component (b) a* component and (c) b* component of image captured.

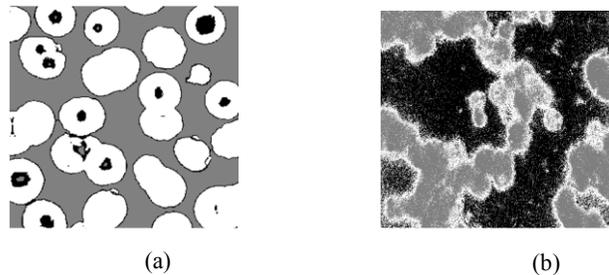


FIGURE 4: Combined a*b* colour component images: (a) images retrieved from the Website and (b) images captured

The combined a*b* components image shows that colour distributions are smooth, with pixel intensities close to zero. The chrominance distribution shows that there are very few pixels which are on the luminance axis, and this is presented in Figure 4. Figures 5a and 6a show one of the original images retrieved from the Website and a captured image respectively. The light shade of pink colour shows the colour of the RBCs and the dark shade of purple colour shows the parasites existing in the RBCs. The K cluster images depict the colours of the RBCs and the parasites existing in the original images but different background, as shown in Figures 5b-d and 6b-d. In Figure 5b-d, cluster 1 show light shade of purple colour for the parasites, cluster 2 show light shade of pink for the RBCs and cluster 3 show black colour for the background.

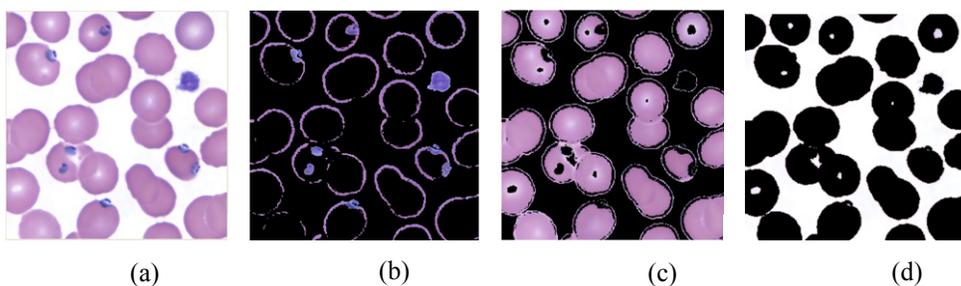


FIGURE 5: Original image and the $K (=3)$ clustered images of the a*b* colour space showing the colours existing in the original image: (a) the original image from the website (b) parasites colour (shade of purple) image, (c) red blood cells colour (shade of pink) image and (d) background colour (white) image.

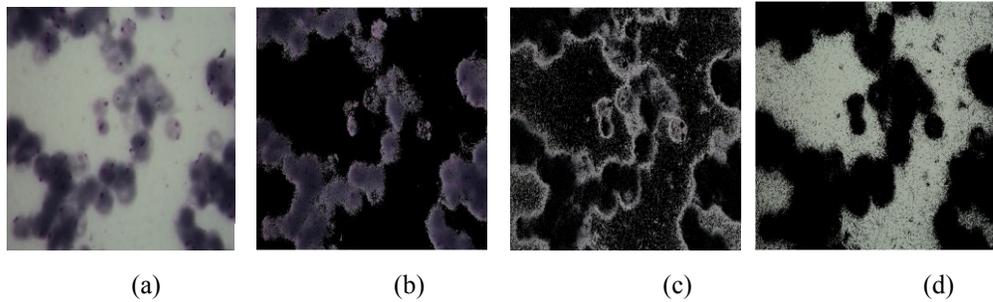


FIGURE 6: Original image and the $K (=3)$ clustered images of the a^*b^* colour space showing the colours existing in the original image: (a) the original image captured (b) parasites colour (light shade of purple) image, (c) red blood cells colour (light shade of pink) image and (d) background colour (light shade of gray) image.

as dark blue or purple colour [16, 23]. The histogram-based thresholding process is based on the fact that pixel values belonging to the parasites differ from the values of the RBCs and the background. The morphological opening followed by dilation was done to remove completely regions of parasite that were not contained in the structuring element. This smoothed parasite contours, broke thin connections and removed thin protrusions. Image dilation grows and thickens the parasites identified and count them in the images. Sample of the images are presented in Figure 7.

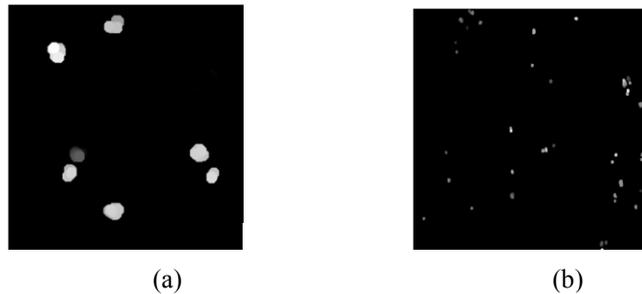


FIGURE 7: Protocol count images of: (a) image retrieved from Website and (b) captured image.

The score plot of the parasites counted from the twenty images, using the Manual counts and the new Protocol counts, are presented in Figure 8. The plot reveals 98.87 % positive correlation between the Manual counts and the new Protocol counts in the images. This indicates the potential of using the Protocol counting as a fast, accurate and objective way of counting malaria parasites. Comparing with literature image processing in $L^*a^*b^*$ colour space is unique since any RGB image can be used. Figure 9 shows a Graphical User Interface (GUI) for the segmentation and counting of the malaria parasites from the RGB images after transforming into $L^*a^*b^*$ colour space. The GUI developed can be easily used by an expert microscopist.

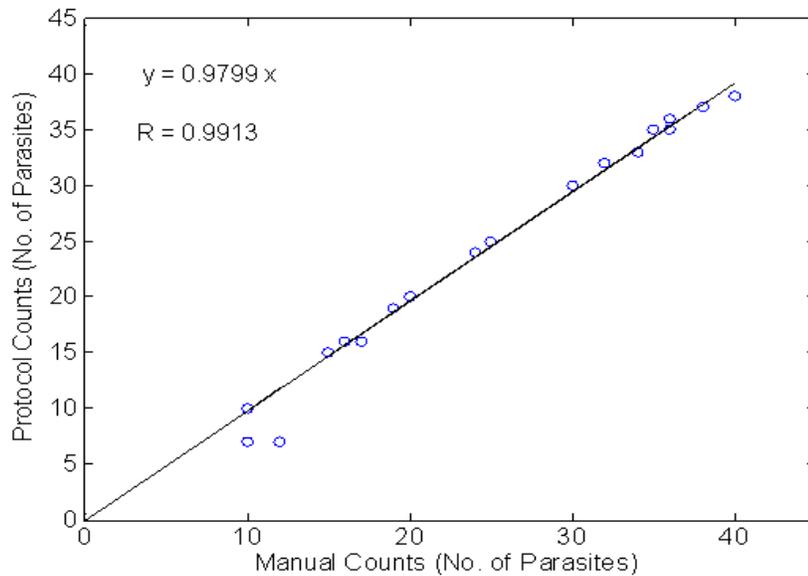


FIGURE 8: Scatter plot of the number of parasites counted using manual counts, by a specialist at the Central Regional Hospital, Cape Coast, Ghana, and the Protocol counts using the developed Matlab codes.

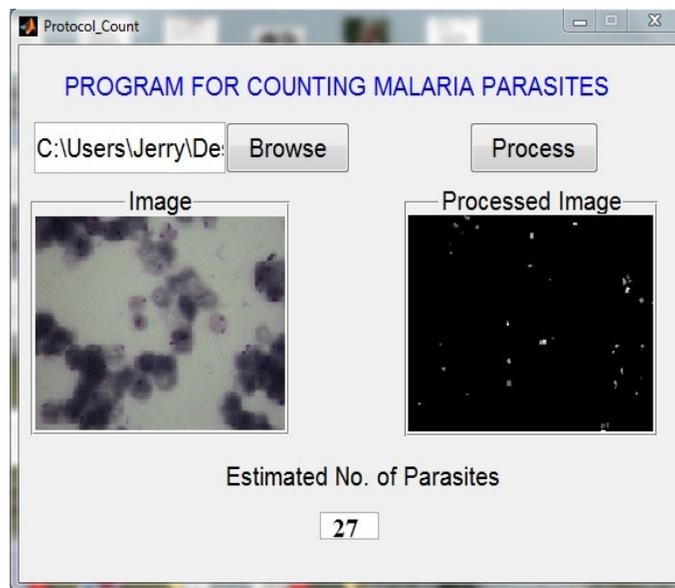


FIGURE 9: Graphical User Interface (GUI) for transformation of images from RGB colour space to $L^*a^*b^*$ colour space, segmentation and clustering of chroma coordinates, a^*b^* , and counting of malaria *Plasmodium falciparum* parasites.

6. CONCLUSION

Using K-means clustering algorithm based on chromaticity, a^*b^* space, we have develop Matlab codes to count *P. falciparum* parasites from RGB digital images obtained from thin film blood smear stained with Giemsa. The algorithm was found to be dependent on the stain colour. The Protocol counts provided approximately 99 % correlation with the manual count from a manual count specialist. The computer processing time for executing the developed codes on an image of size 300 x 300 x 3 pixels was found to be less than 10.0 s using a 64-bit Intel (R) Celeron (R) CPU with processing speed of 2.20 GHz.

Acknowledgments

The authors are grateful to the Office of External Activities (OEA) and the Associate Scheme of Abdus Salam ICTP Trieste, Italy for their financial support during their stay at the centre and the use of the library and computing facilities to write this paper. We are also grateful to International Programme for Physical Sciences (IPPS), International Sciences Programme (ISP), Uppsala University, Sweden and Japan International Cooperation Agency (JICA) for funding and provision of microscopes. We are also grateful to the Central Regional Hospital at Cape Coast for allowing us to use their personnel and laboratory facility. Also to Justice Kwabena Sarfo (PhD), of the Biochemistry Department University of Cape Coast for reading through the manuscript text.

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