行政院國家科學委員會專題研究計畫　成果報告

整合數位浮水印與資訊安全之著作權保護管理系統

計畫類別：個別型計畫
計畫編號：NSC92-2416-H-009-012-
執行期間：92 年 08 月 01 日至 93 年 07 月 31 日
執行單位：國立交通大學資訊管理研究所

計畫主持人：蔡銘箴

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Abstract

The fast development and utilization of the Internet has dramatically transformed the business transaction into the digital format. However, the techniques of the duplication and modification of digital data are comparatively effortless. Therefore, the copyright protection and authentication management system is in great demand to meet the business applications since the buyer and the sale identity must be verified, the ownership of the document must be maintained.

Traditionally, network security issues are handled through the cryptography which involves sophisticated encryption and decryption schemes. However, cryptography can substantially ensures the attributes of the confidentiality, authenticity, and integrity only if the message is transmitted through a public channel, such as an open communication network. It does not protect against unauthorized copying after the message has been successfully transmitted. Therefore, watermarks embedded in the data can uniquely identify the ownership or usability of the document. The watermarking provides sufficient copyright protection. The main problem with using watermark technology is its reversibility, any mechanism which can read or detect the watermark can also remove it by inverting the watermark process. Other approaches like digital signal processing can also significantly affect the integrity of the document.

The goal of this research project is to design a digital copyright protection management system which will elaborate the digital watermarking technique in conjunction with the data security schemes to compensate the reversibility of detectable watermark. Such mechanism will make the authentication and copyright protection more reliable for the open network communication like the Internet. We believe the proposed project can provide a useful ownership identification and protection framework and more robust, reliable than pure readable watermarking design architecture.

Keywords: Internet, electronic commerce, digital watermarking, data security, digital right management

中文摘要

網際網路的蓬勃發展已使得越來越多的商業交易以數位化的格式來進行，然而數位資訊重製及改造的技術相當容易，衍生出對所有權保護及認證技術需求的日益迫切，交易的雙方必須對

資訊來源的真實性及使用者的身份，提供認證。

傳統上，網路安全能夠經由密碼學加以保障，但是密碼學僅在訊息傳輸經過公共管道時才擔保訊息的機密性、鑑別性與真確性，而且密碼學並不能阻止成功傳輸卻未經授權的訊息。而數位浮水印則是一個即使經過傳輸後也能確保多媒體資料版權的有效方式。浮水印嵌入在資料內，能夠有效地鑑別文件的擁有者或經授權的使用者。然而，任何可以閱讀或察覺浮水印的機制，可以藉由浮水印嵌入程序的作法來反向操作去移除嵌入的數位浮水印，或甚至用濾鏡等數位處理的方式來破壞數位浮水印。

本計畫之主要目的，為設計發展一個數位著作權保護管理系統，以浮水印為基礎並結合密碼學技術，以彌補浮水印可逆性結構的不足，達到使數位多媒體物件之著作權管理機制能夠在 Internet 等開放網路環境架構下順暢運行的可靠性，以保護智慧財產權著作人的所有權。並同時使用可測性浮水印結構，用來克服浮水印可逆性的問題；如此的機制，可提供信賴的智財權保護機制，並且比其他可讀性的浮水印結構更為強韌與可靠。

壹、 文獻探討

- 數位著作權管理系統 (Electronic Copyright Management Systems, ECMS)：

ECMS 可自動化管理並在開放網路下發佈經交易的多媒體文件，並且考慮到能夠連結網路環境、協同合作以保護多媒體資料之智慧財產權的整體服務。

目前有許多計畫正在發展 ECMS，例如最新一代的 MPEG 標準 (MPEG-21) 將，在法律允許以及高可靠度的保證下，建立合理範圍內的智慧財產多媒體文件交易的規則或協定。

以下為建立有效 ECMS 系統的兩個方法，這兩個方法皆需要散佈多媒體文件前之所有權認證工具 (authoring tools)：

預防盜版，例如 IBM的Cryptolope (http://www-3.ibm.com/software/security/cryptolope)。

追蹤盜版，例如 the ECfunded Imprimatur (http://www.imprimatur.net)。

- 以密碼學為基礎的 ECMS (Cryptography-based ECMSs)

在以密碼學為基礎的 ECMS 中，著作者在著作權管理系統中將包裹的數位物件譯為密文來整合應用。因為使用者無法存取未經授權應用的文件，故資料擁有者可以很容易的控制其資料的用途，例如使用者可以在電腦螢幕上呈現影像卻無法列印，或者可以播放音樂但無法儲存等。

這個方法的主要缺點是難以建立一個嵌入應用標準，而且當多媒體文件最後傳送到終端使用者手中後（例如顯示在個人電腦螢幕上或是播放出來），它仍然可能未經允許而被擷取或複製。例如 Liquid Audio (http://www.liquidaudio.com) 就是一個應用於商業系統的例子。

- 以浮水印為基礎的 ECMS (Watermark-based ECMS)

以浮水印為基礎的ECMS能夠牢固且強韌地在已被購買的數位物件中嵌入與智慧財產權相關的浮水印資訊，這些隱藏的智財權資料可由著作權所有者命名、或是由系統給定一個獨一無二的識別代碼以辯認文件的真偽。浮水印能夠在文件中隱藏資料傳佈者(distributor) 或經授權購買者(buyer) 之識別資訊(identification) 或指紋(fingerprinting)，它能夠檢驗文件的法律地位，而且追蹤網路上侵犯智財權的物件散佈路徑。

目前浮水印技術的主要限制是它的可逆性，也就是說任何可以閱讀或偵測出浮水印的人都可以移除它。所以雖然目前看來尚有一段很長的路要走，但只有致力發展非對稱性浮水印的方法才能克服浮水印技術本質上的限制。另一方面來說，因為智財權資料已直接嵌入數位內容本身中，故以浮水印為基礎的智財權管理系統不需要使用者採用特定已加入浮水印的多媒體內容。

貳、 研究成果

我們發展了一個以浮水印為基礎並結合密碼學的 ECMS，以補浮水印可逆性結構的不足，來達到高可靠度的著作權保護。在開放網路環境下交易的多媒體文件牽涉到許多參與者 (actors)：文件的著作者(author) 或著作者群、編輯者(editor) 、傳佈媒介 (media distributor) 、購買者 (buyer) 等等；這也牽涉到電子付款的議題，例如資訊安全與顧客隱私等。為了簡化我們的描述，我們限制了參與者的數量，並且不涉及付款與隱私保護的問題。

貳.1 交易模型 Transaction Model

圖 1 為一個簡化的交易模型：

a. 著作者 (Document author or authors)：數位影像作者或智慧版權擁有者，須向 CS/CA 申請專利。
b. 第三方認證、存證單位(CS and CA，Collecting Society)：公正第三方，處理平台上專利認證問題。包括：發給各成員 PIN、著作品 CUN、提供著作者申請 Public Key 等等，並對於所申請之專利留下存證，以供日後發生法律問題使用。
c. 數位影像電子商店 (distributor)：經過平台 CA/CS 所認證過的數位影像商務業者，可接受著作者的作品販賣請求以及對

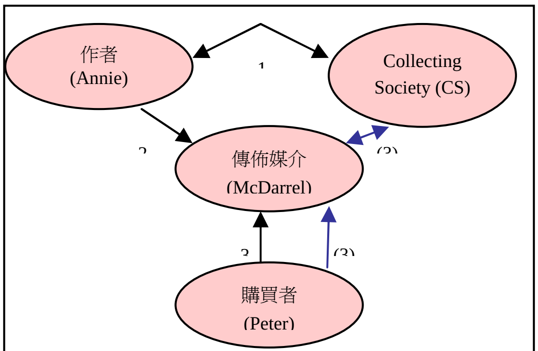

圖 1 交易的精簡模型

購買者提供數位影像販賣的服務。
d. 購買者 (Buyers) ：數位影像最終購買者。
e. 識別資料：
PIN(Personal Identifier Number)：個人識別號碼，對於平台中的各個成員，CA/CS 會發給獨一的 PIN 來識別該成員。
CUN(Creation Unique Number)：著作品識別號碼，對於每一件通過專利申請的產品，CA/CS 會發給獨一的 CUN 予以識別。

貳.2 系統建置 System Implement 系統建置

ECMS 的核心在於浮水印的嵌入與

抽取，我們將整個ECMS系統先縮小至只有 Author、CS、buyer 三方，即將販賣者與CS合併，這樣有助於整個系統的建置（圖2）。

因此在實際系統上，我們將做到

1. 可以讓Author註冊身份以獲得PIN。
2. 讓Author能夠上傳影像，並獲得該影像之CUN。
3. 利用 Web 系統來嵌入浮水印到影像裡，且讓Author可以下載及管理。
4. Buyer可以瀏覽並購買喜歡的影像。
5. 系統可以讓Author驗證認為有問題的影像，並判定是否有侵權問題。

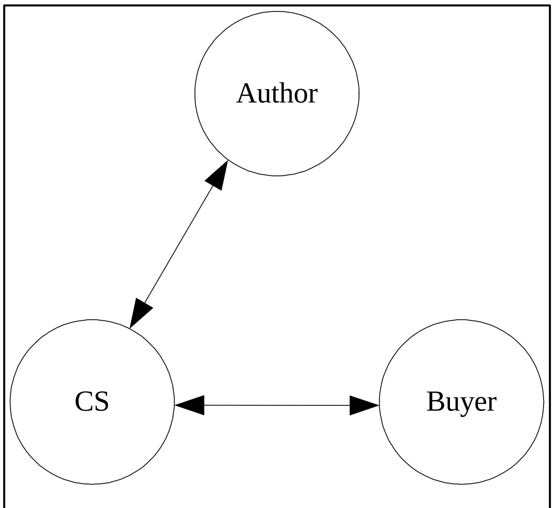

圖2 系統建置模型

這些功能可說是整個ECMS的核心，因此在選擇Middleware上，我們選擇了兩種不同平台，一是由 Microsoft 提出的 Web-Service，另一則是由Sun提出的J2EE Platform，這兩種平台各有優缺點，所使用的技術也不相同，我們將其都實做出來，並比較其差異。

一、J2EE Platform

Java 是由 Sun 所提出的一個軟體平台，其依據平台應用領域分為三個版本，標準版本(J2SE，Java 2 Standard Edition）用於開發個人電腦上的應用軟體，企業版本（J2EE，Java 2 Enterprise Edition）用於開發企業級的商用程式，如資料庫應用軟體、ERP系統等，以及微型版本(J2ME，Java 2 Micro Edition）則是針對消費性裝置的應用開發。

而我們選擇 J2EE，目的是希望提出一個低成本、高可用性、高可靠性以及高可擴展性的網路應用程式平台，透過這個統一的開發平台，J2EE降低了開發多層次網路應用程式時所需的費用及其複雜性，同時也對現有的應用程式提供良好的支援，完全支援EJB(Enterprise JavaBean)，具有良好的封裝與佈署能力，可與現有的加解浮水印程式結合，達到我們的目的。圖3是我們設計的元件圖。

整個架構由幾個原件構成，User端只需要一般的瀏覽器，在伺服器端，又分成兩個部分，在前端的呈現是由JSP與Java Servlet 作為溝通介面，另一則是 EJB（Enterprise JavaBean） Container中的EJB元件，這個EJB元件是負責將現有的浮

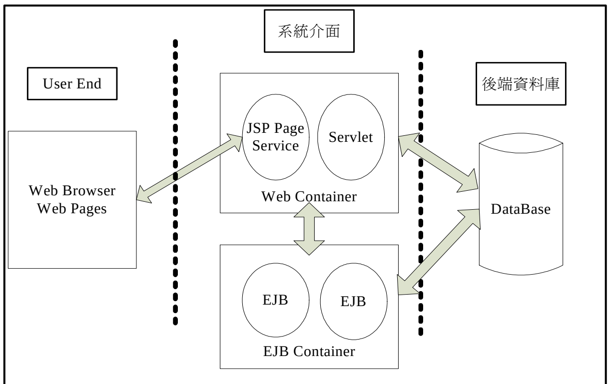

圖3 J2EE Platform 元件圖

水印程式包覆起來，並藉由JSP或Servlet的呼叫來執行，並可以將執行的結果回傳到網頁上或是直接進入 Database，相同地，因為系統會有Author來註冊身份，故同樣需要與Database進行直接溝通，如此一來，有幾項優點：

A. 不論是JSP或是Servlet，其安全性都

較高。

B. EJB 的元件可以不斷地重複使用，例如浮水印程式一旦被包覆起來，就可以藉由傳送參數來重複執行，且若是要修改原程式碼也非常方便。

C. 除錯將非常快速，一旦這些元件都各自獨立後，除錯將非常快速，有錯誤的環節將可以很快被偵測出來，並修改完成。

➢ 建構環境

- Windows 2000 Server
- Tomcat 5.0（Web Server）
- JSP 2.0
- Servlet 1.1
- Enterprise JavaBean
- MySQL 4.0（DataBase）

➢ 系統流程

圖 4 是整個網站地圖，

一旦進入首頁就會看見 Author 與 Buyer 各自專區（圖 5）

我們可以依照網站地圖按圖索驥，不過我們的重點將注重於 author 與 CS 之間註冊

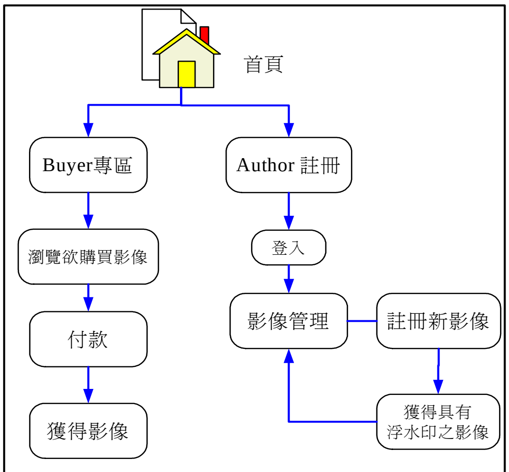

圖4 網站地圖

與加解密浮水印的過程，因此，針對 Author 會有較詳盡的說明。

圖 6 是 Author 登入畫面，已經註冊的 author 必須輸入獲得的 PIN 作為登入帳號，若無 Author PIN，則需註冊並獲得一份 Author PIN，才能進入 Author 專區（圖 7）。

圖 5 系統首頁

圖 6 Author 登入畫面

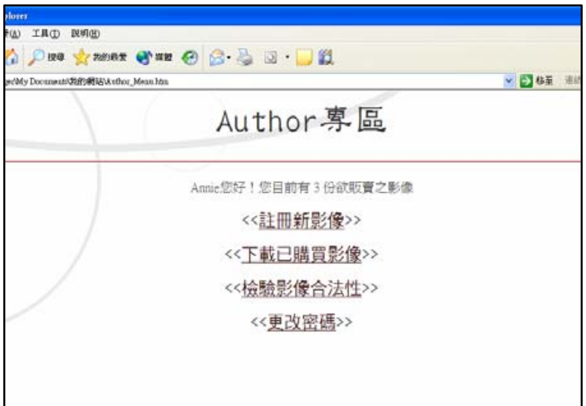

圖 7 Author 功能專區

Author 專區的功能可說是整個 ECMS 的核心功能

a. 註冊新影像：提供 Author 上傳並註冊一份新的影像，這份影像將經過 EJB 所包覆的浮水印程式如圖 8

這份影像將經過負責影像上傳的 Servlet 控制（圖 9-1），一旦 Servlet 接收到影像後，就會針對影像呼叫 EJB 進行嵌入浮水印的動作，並且嵌入之後會給予 Author 屬於該文件的 CUN（圖 9-2）。

b. 第二個部分是影像管理功能（圖 10），如圖所示，在此可以管理 Author 所註冊過的所有文件，並可以瀏覽這些影像或是下載回去，

c. 第三個部分是檢驗影像的合法性，這部分的主要目的是讓 Author 在發現某張影像未經授權時，可以藉由此驗證區進行該影像的浮水印驗證（圖 11-1）；這畫面是要讓使用者輸入他在網路上發現可能未經授權之影像，以及原影像的 CUN，系統可以將這兩張影像經由抽取浮水印的程式，進行影像驗證。

而依照驗證的結果，系統也將給予說明是否有侵權的問題（圖 11-2）。

d. 第四部分則是讓 Author 修改密碼，這只是一般的資料庫存取，在此就不多做贅述。

e. 最後是從 Buyer 區進入，就可以看見 Author 欲販賣的影像，並可以信用卡付帳購買（圖 12）。

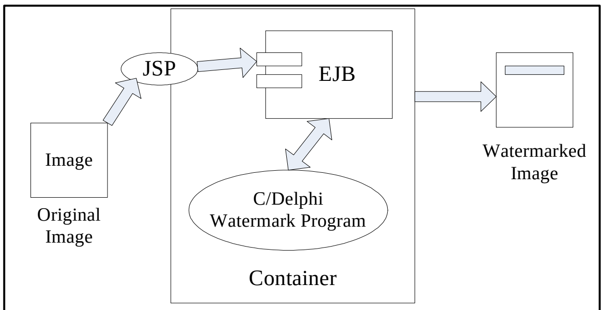

圖8 EJB包覆浮水印程式示意圖

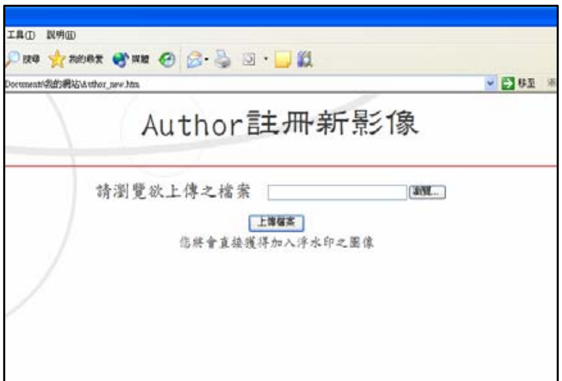

圖 9-1 Author 註冊新影像

圖 9-2 Author 獲得該影像之 CUN

圖 10 Author 影像管理介面

二、Web-Service

➢ Web Service 架構

Web Services 的觀念其實就可以想像 Internet 上充滿了各種型式的服務（www 網頁也可算是其中一種服務），只要是 Internet 使用者，便可以在 Local 端使用世界各地發表的

Web Service。更清楚的來說，Web Service 就像是 Internet 上的元件服務，不論使用何種系統平台、何種程式語言所撰寫出的應用程式，都可以將它們引用到自己的應用程式之中。

網路服務就是存在於網際網路上面的一種應用程式，不同於本機端開發的應用程式，每個功能模組都可以自行定義及開發，透過網路服務的機制，任何人可以在網際網路上面尋找自己想要的應用程式模組，將其納入所要開發的應用程式中，也可以將自行開發完成的應用程式模組，經過註冊後提供給網際網路上使用者使用。

➢ Web-Service 基本架構

所示為網路服務的基本架構概念圖，從此圖中可以更清楚的了解網路服務的運作機制是由三個單元組成

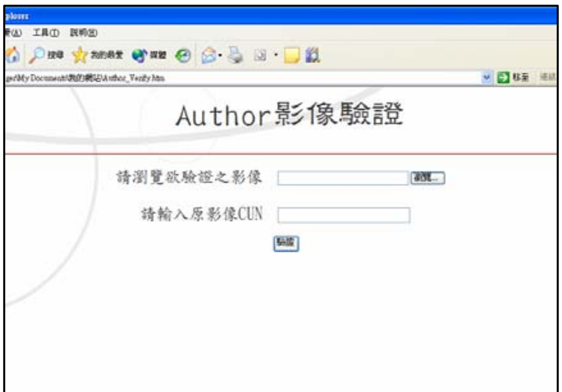

圖 11-1 Author 影像驗證書

圖 11-2 Author 影像驗證結

（圖 13），分別是服務提供者(Service Provider）、服務需求者（Service Requester）及服務註冊機構(Service Registry），而三者之間的關係分別存在有發行（Publish）、尋找（Find）及聯結（Bind）。

分散式的問題藉由整個系統採用 Web service 建置而獲得解決。Web service 的環境，可以依賴.Net Framework 本身對於 Web service 架構的支援輕易達成。電子商務技術及介面問題，則仰賴 ASP.NET 和 Web service 配合資料庫所開發的網頁介面來滿足系統需求。第三點，舊有程式與系統整合，是整個架構在建置上比較迫切的問題，如何讓需求者透過網頁介面來使用這

圖 12 Buyer 瀏覽欲購買之影像

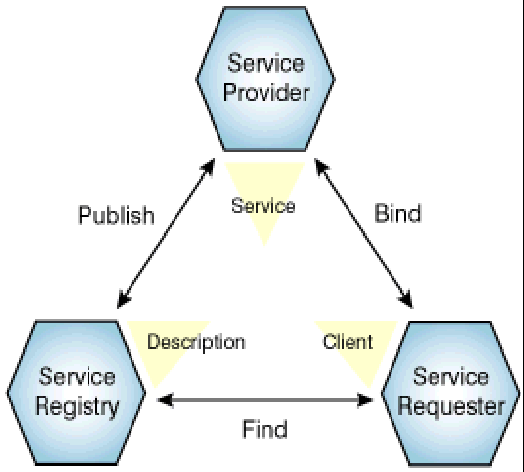

圖 13 Web-Service 基本架構圖

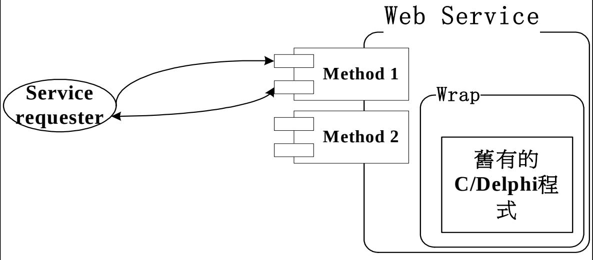

圖14 以Web-Service使用舊有的程式

些舊有的系統或程式，不但是架構是否能快速建置的癥結，也是日後系統能否迅速推展的要素之一。因此，使用 wrap 的方式把舊系統包進 web service 之中（圖 14），如此一來，服務需求者可以藉由網頁上的介面，透過 web service 所提供的 method，來利用這些系統及服務。雖然架構不同，但是畫面和功能都是相同的，因此就不做介面介紹了。

參、研究討論

藉由這個雛形系統的建立，我們看到了數位影像發展的未來，且也體會到整個商務數位影像發展仍有不少難關需要克服：

1. 兩種不同的平台所建立的網站功能大致相同，速度上是 Web Service 佔了優勢，原因為我們使用的作業系統是 Microsoft Windows，已針對這方面進行最佳化，J2EE Platform 終究是多了一層，連包覆浮水印程式都要再多一層 EJB，不若 VB.NET 直接使用。且在開發速度上也是 Web Service 較快。但在安全性上就是 J2EE 佔了優勢，因 Web Service 在安全協定上尚有許多未規範之處，使得系統建立雖快，卻有許多安全上的疑慮，不若 JSP 般穩定且安全。
2. 目前浮水印的技術仍然侷限於 RAW 格式的檔案，並非所有的格式都可以嵌入浮水印，且影像的大小也有所限制，例如不能小於 64×64。
3. 在我們的雛形系統中，我們只先使用了一層浮水印，但是在整個 ECMS 的架構下，加入三層的浮水印，如此是否會影響影像的品質，仍需要進一步研究。

肆、結論

在使用浮水印技術以落實著作權法律規範應用到真實世界之前，還需要再做更深一層的研究，除了使系統更加強韌之外，我們還需要有更深入的協定級分析（protocol-level analysis）才能澄清浮水印技術能達成什麼目標、或不能夠達成什麼目標。

雖然目前浮水印技術上的彈性尚不足以應付其實務需求，但是以數位浮水印落實著作權的保護仍是一件非常可行的辦法，且此技術可以用在不同的多媒體視訊、音訊等媒體上，並達成資訊隱藏的效果，具有不影響到原有的訊號、強固性高等優點，由本文的 ECMS 雛形系統就能清楚的展示浮水印技術的潛力。

此外，我們所研究的中介軟體上，Web-Service、J2EE 都已具備了相當優異的平台架構，可以結合現有的應用軟體，大大地節省了開發軟體的時間，以及有更加的整合性，整合多個不同的單位，加上跨平台概念的實行，未來 PDA、行動裝置等都可以使用，可想見數位影像的電子商務將是明日之星。

伍、結果與討論

本研究計劃已獲得相當豐富的研究成果，由於前一年相關計畫的前導，再加上這一年孜孜不倦的努力，在本年內，已有數篇英文會議論文的發表。

第一篇英文會議論文是發表在 ICE B2003，於民國 92 年 12 月 9 日至 12 月 13 日在日本東京市舉行，論文題目是“The Analysis of Critical Factors of E-Learning System for E-Business”，內容請見附件一。

第二篇英文會議論文是發表在 ICDCS 的 MNSA workshop，於民國 93 年 3 月

23 日至 3 月 26 日在日本東京市舉行，論文題目是"DCT and DWT-based Image Watermarking by Using Subsampling"，內容請見附件二。

陸、計劃成果自評

本研究計劃研究成果，已獲得相當具體及深入的學術成果，並提供電子商務的實際應用與數位浮水印，資訊安全之著作權保護管理系統智財權之可延續性的研究；在此同時，將繼續做更深入的探討外，也努力參與相關學術研討及論文發表，以達更專精的學術研究為目的。

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網路資源

- Authena Open Source Digital Rights Management <http://authena.org/>
- Content Wire: Digital Rights Management <http://www.content-wire.com/drm/drm.cfm>
- Cover Pages: XML and Digital Rights Management <http://xml.coverpages.org/drm.html>
- Digital Object Identifier <http://www.doi.org>
- Digital Rights Management Workshop <http://www.w3.org/2000/12/drm-ws/>
- EContent Management: Digital Rights Management <http://www.econtentmag.com/r8/>
- Internet Digital Rights Management (IDRM) <http://www.idrm.org/>
- Interoperability of data in e-commerce systems <http://www.indecs.org>
- Open Digital Rights Language <http://odrl.net/>

附件一

The Analysis of Critical Factors of E-Learning System for E-Business†

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Abstract

Many factors such as barriers, reasons, vendor consideration, success factors and challenges play important roles in implementing electronic-learning systems for e-business. In this paper, a questionnaire is used to collect respondents' attitudes toward those factors, and the result is analyzed.

The result of chi-square test indicates that the respondents who have e-learning systems in their organizations are mostly from industries, and for those who have not tend to emphasize more on "cost and unawareness" which scored under 0.4 (i.e. low internal consistency) in reliability. However, the variance of the respondents' attitudes toward the remaining six factors is not large.

Keywords: e-Learning, e-Business, barriers, reasons for implementation, vendor consideration, success factors, challenge factors.

1. Introduction†

Problems may be encountered when implementing e-Learning systems for e-business; however if barriers are known in advance, problems are easier to be solved. In addition, reasons for implementation from different stakeholders setup directions to be followed for e-Learning systems. If the expectation of an e-Learning system is known, corporations can be more confident setting up corresponding strategies (see Figure 1) and implementation can be started. Furthermore, suitable vendors can supply satisfactory e-Learning solutions to corporations. Suitable vendors which provide contents, technologies and services help shorten the implementation time, and guarantee a successful e-Learning system for e-business. Success and challenge factors are collected from related articles which suggest actions to be taken for a better implementation.

In sum, it is recommended to analyze the situation of the corporation as well as plan the expectations for e-Learning systems for e-business. Suitable vendors shall be chosen, and lastly success and challenge factors serve as references for their e-Learning systems.

2. Purpose

B2B e-Learning systems facilitate enterprises' (i.e. business-to-business) learning mechanisms via the Internet. Some research reports the factors of their implementations. However, the relationships among the responses toward these factors and whether respondents have e-Learning systems in their organizations are seldom observed. Why do corporations need to understand all these critical factors clearly? Because by doing so, corporations save time and avoid spending money on unnecessary places. If corporations know exactly what different stakeholders feel toward these items, the results will be valuable.

This research investigates implementation factors, and provides practical advices. It analyzes the collected data which is from the survey of "critical factors of an e-Learning

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system for e-business”, and tests such as chi-square test, factor analysis and t-test are used to verify whether there are significant differences in respondents who have e-Learning systems in their organizations, and those who have not. Lastly, the differences and new findings are emphasized.

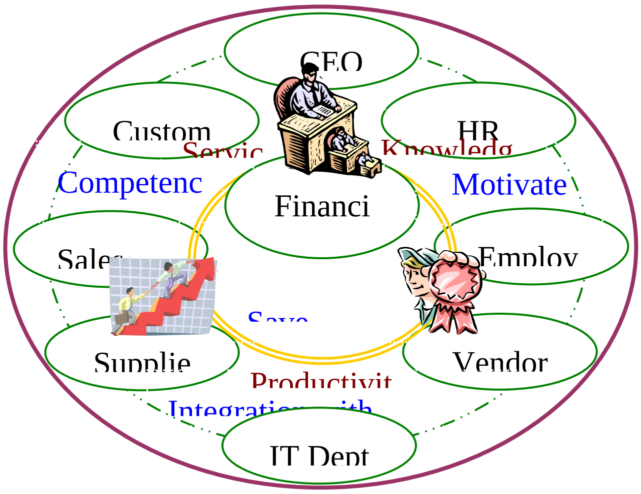

Figure 1 Strategy and Stakeholders

3. Methodology

The research methodology consists of “select critical factors”, “questionnaire design”, “chi-square test”, “factor analysis”, “t-test” and “conclusions” (see Figure 2). The critical factors which collected from the related literatures (see Table 1) are categorized into barriers for e-Learning, reasons for implementation, vendor consideration, success and challenge. A questionnaire which includes nine demographic questions and thirty-eight questions of critical factors is thus designed.

Chi-square test, factor analysis and t-test are conducted to examine if there are significant differences among the responses toward these factors and whether the respondents have e-Learning systems in their organizations. Lastly, the results will be well examined and feedback to the survey for advanced research.

3.1 Designing Questionnaire

Three different types of questionnaires that are web-based, e-mail and hardcopy are provided. The majority of the respondents prefer the web-based questionnaire. The questionnaire consists of six sections. Section 1 identifies the demographic information of the respondents. Questions include gender, age, career, department, position and education. Section 2 focuses on the attitudes of respondents toward the identified “four barriers”. Section 3 emphasizes their attitudes toward “reasons for implementation”.

Section 4 focuses on “vendor consideration”. Section 5 weights their viewpoints toward “success factors”, and lastly section 6 examines the attitudes toward “challenge factors”. These factors are measured using Likert-type scale which ranges from 5 to 1 with the following equivalence, “5”: “strongly agree”; “4”: “agree”; “3”: “neutral”; “2”: “disagree”; “1”: “strongly disagree”.

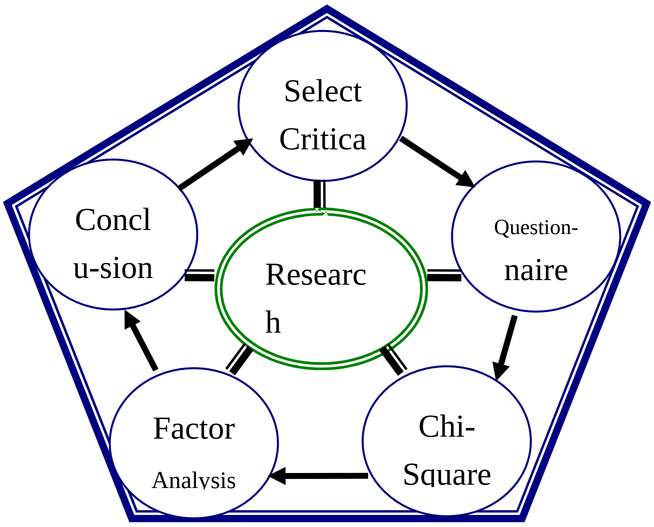

Figure 2 Research Methodology

Table 1 Factors Selected from Related Literatures

Factors / Findings	Source
① Barriers	
◆ Budgetary considerations. ◆ Immaturity of learning object technologies. ◆ Lack of awareness.	SRI [18] Consulting Business Intelligenc e

◆ Cost versus value. ◆ Quality of learning content. ◆ Internal resistance to using technology instead of face-to-face learning.	Forum Corp. [9]
② Reasons	
◆ Stay nimble and innovative. ◆ Increase customer satisfaction. ◆ Stomp the competition. ◆ Cut costs. ◆ Satisfy the IT department. ◆ Improve my skills. ◆ Earn more money.	Lance Dublin and Jay Cross [14]
③ Vendor Consideration	
◆ Content, Technology and Service.	Digital Think [4]
◆ Experience. ◆ Cost.	Rosenberg [15]
④ Success	
◆ Executive stakeholders. ◆ Be the learner. ◆ Marketing is your friend. ◆ Virtual project teams. ◆ Measure everything.	Cisco [2]
◆ Include peer interaction. ◆ Provide mentoring. ◆ Offer performance feedback.	David Price & Patrick von Schlag [3]
⑤ Challenge	
◆ The first seven items as described in Section 3.2 – Challenge Factors.	Digital Think [4]
◆ Perceived difficulty of using such a system.	Forum Corp. [9]

3.2 List of Factors under Investigation

In this survey, five main items are observed, and each of them contains sub-items The are listed below:

<u>Factors of Four Barriers [9] [18]</u>

B1 Cost too high
B2 Technology Immaturity
B3 Solution Immaturity
B4 Unawareness

<u>Factors of Reasons for Implementation [14]</u>

R1 Increase Competence
R2 Stay Innovative
R3 Support 24 x 7 Training
R4 Reduce Training Time
R5 New Training Technology
R6 Reduce Training Cost
R7 Increase Revenue
R8 Decrease Time Spending on Selling
R9 Flexible Learning
R10 Win-Win Situation
R11 Customer On-Line Learning
R12 Enhance Customer Satisfaction

<u>Factors of Vendor Consideration [4] [15]</u>

V1 Content
V2 Technology Integration
V3 Service Quality
V4 Implementation Experience
V5 Implementation Cost
V6 Reputation

<u>Success Factors [2] [3]</u>

S1 Organizational Support

S2 Virtual Project Teams

S3 Measure everything

S4 Include Independent Learners

S5 Include Peer Interaction

S6 Provide Mentoring

S7 Offer Performance Feedback

S8 Marketing

<u>Challenge Factors [4] [9]</u>

C1 Correct Target Setup

C2 LMS Configuration

C3 Tutors and SMEs Integration

C4 Content Creation

C5 Multiple Modes of Learning

C6 Back-End Systems Integration

C7 Web Infrastructure

C8 Online Access Capability Training

3.3 Conceptual Model

A qualitative phase of this research is conducted to identify possible factors leading to the implementation of an e-Learning system for e-Business [1]. Related literatures on e-Learning systems for e-Business are also reviewed in order to select the factors of interest. Figure 3 depicts the conceptual model of the six factors naming, “Barriers”, “reasons”, “vendor consideration”, “success” and “challenge” and “implementation”.

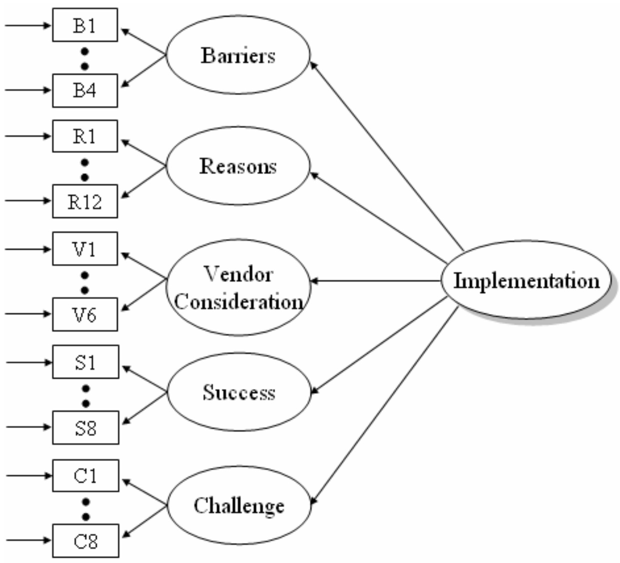

Figure 3 Proposed Models of Factors of Implementing E-Learning Systems for e-Business

4. Analysis Methods

Information on the attitudes toward critical factors of e-Learning systems for e-business is gathered through survey. Four types of analysis algorithms are used for different factors. Percentage analysis is used for demographic information, and chi-square test examines the relationships among different demographic data as well as whether the respondents have e-Learning systems in their organizations. Factor analysis extracts new factors from those five critical items. New factors are verified using Cronbach’s alpha test to measure the reliabilities. T-test examines the differences among the extracted factors and whether the respondents have e-Learning systems in their organizations.

Excel 2002 and SPSS10.0 are used to compute those results. Detailed explanation and diagrams are provided and discussed in the following sections. Chi-square test contains the row and column variables of the test. Factor analysis and Cronbach’s alpha test are explained in Section 4.2 and 4.3. T-test contains one diagram of the test and grouping variables.

4.1 Chi-Square Test

Figure 4 depicts the variables of chi-square test. The relationships among gender, working field, department, role, experience and whether the respondents have e-Learning systems in their organizations are carefully examined.

Gender consists of female and male. Field contains students and the respondents from industries. Department is divided into two groups: Non-IT and IT departments. Role consists of the respondents’ experiences on implementation of e-Learning systems. Lastly, experience includes those who have or have not experiences of using e-Learning systems.

4.2 Factor Analysis

According to Foster [12], factor analysis is a technique or a family of techniques which aim to simplify complex sets of data by analyzing the correlations between them. A component or a factor explains the variance in the inter-correlation matrix, and the amount of variance explained is called the eigenvalue.

A factor loading is the correlation of a variable with a factor. If a loading is higher or equal to 0.3, it is frequently taken as meaningful when interpreting a factor. In this paper, principal components analysis is recommended as the method for reducing the number of variables. In order to obtain an orthogonal simple structure rotation, varimax method is used.

4.3 Cronbach’s Alpha Test

According to Foster [12], reliability refers to the consistency of the results on different items in a test.

Cronbach's alpha is one of the standard ways to express the reliability of a test. The value can be obtained by using SPSS10.0. A reliability coefficient of 0.8 or higher is considered as "acceptable" in most social science applications. The value should not be lower than 0.7. However, tests of personality often have much lower values, partly because personality is a broader construct.

4.4 T-Test

Figure 5 depicts the test and grouping variables of t-test. The differences among "Cost and Unawareness" and "Immaturity" in barriers factor, "Training Effectiveness" and "New Revenues" under reasons for implementation, "Vendor Consideration", "Success", "Challenge" and whether the respondents have e-Learning systems in their organizations are carefully examined.

5. Demographic Information

The survey was conducted from May 13th to May 27th, 2003. There is a total number of 142 respondents, including 56 females (39.44%) and 86 males (60.56%) respectively (Figure 6), agreed to participate in this research. Most of them were from Hsin-Chu Industrial Science Park and National Chiao Tung University.

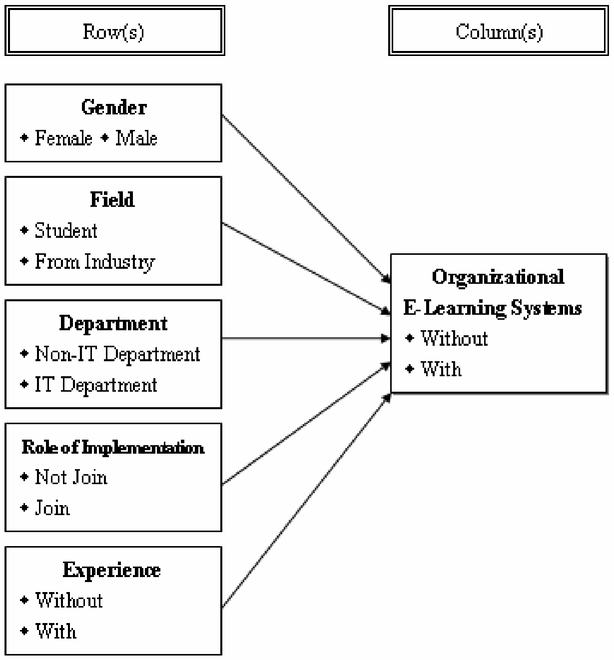

Figure 4 Variables of Chi-Square Test

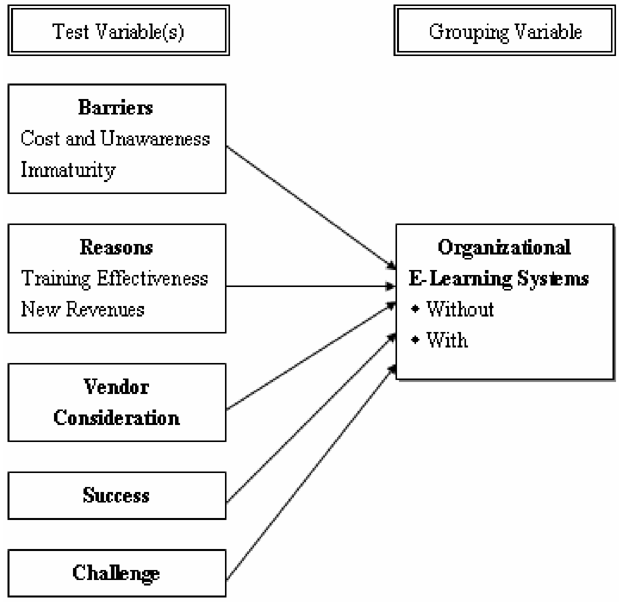

Figure 5 Test and Grouping Variables of T-Test

From figure 7, it clearly illustrates that 29.58% of the respondents were students, and 23.24% of the respondents came from the information technology industries, 16.20% were from electrical and electronics, and 15.4% were from military, government and academic. After the analysis of the departments' bar chart as shown in Figure 8, it is found that 21.13% of the respondents were from the departments of information technology, 11.27% were from management, 10.56% were from technical support, 8.45% were from research & design. 53.52% of the respondents have no e-Learning systems in their organizations (Figure 9). The respondents who have no experiences of implementing e-Learning systems accumulate 72.54% whereas the ones who have account for 27.46% (Figure 10). Lastly, Figure 11 illustrates their experiences of using e-Learning systems.

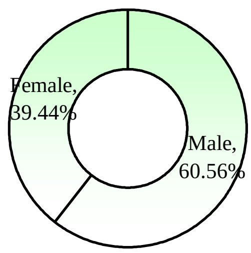

Figure 6 Gender

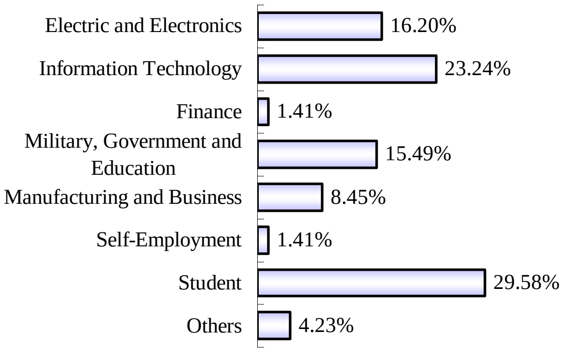

Figure 7 Industry

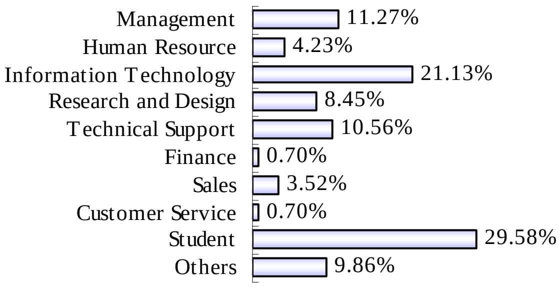

Figure 8 Department

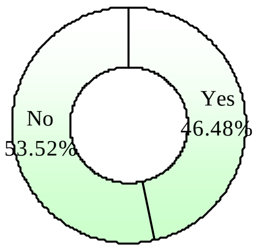

Figure 9 E-Learning Systems Implemented in Organizations

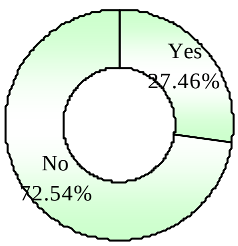

Figure 10 Joining the Implementations of E-Learning Systems

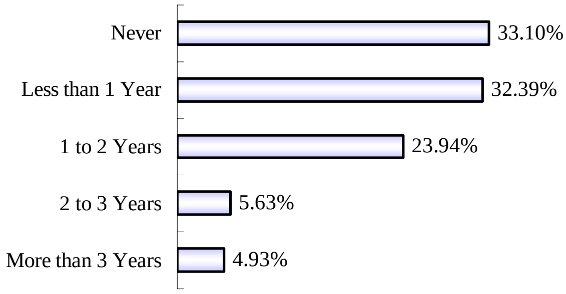

Figure 11 Experiences of Using E-Learning Systems

6. Chi-Square Test on Demographic Items

The chi-square test was conducted to test whether there were significant differences among different demographic data as well as whether the respondents have e-Learning systems in their organizations.

① Gender

The chi-square value is 1.087 (df=1, n=142) and the p-value is .297 ($p>0.05$) which means that there is no significant difference. Thus we concluded that whether the respondents have e-Learning systems in their organizations do not have significant difference in gender.

② Working Field

The relationship between the respondents' fields and whether they have e-Learning systems in their organizations is shown in Table 2 (Note: ① WO/EL = Without Organizational E-Learning Systems; ② W / EL = with Organizational E-Learning Systems). The chi-square value is 5.78 (df=1, n=142) and the p-value is .016 ($p<0.05$) which means that there is a significant difference. When comparing the percentages of the two working field groups in Table 2, the percentage of the respondents who are students and have e-Learning systems in their organizations (19.7%) are smaller than those who are from industries (80.3%). It is obvious that the majority of the respondents who have e-Learning systems in their organizations are from industries rather than students. Figure 11 depicts the line chart of field * organizational e-Learning systems.

Table 2 Field * Organizational E-Learning Systems Cross Tabulation

Field	WO/ EL	W/ EL	Total
Students	29 (38.2%)	13 (19.7%)	42 (29.6%)
From Industries	47 (61.8%)	53 (80.3%)	100 (70.4%)
Total	76 (100.0%)	66 (100.0%)	142 (100.0%)
Chi-Square Value	X^2=5.78	df=1	n=142

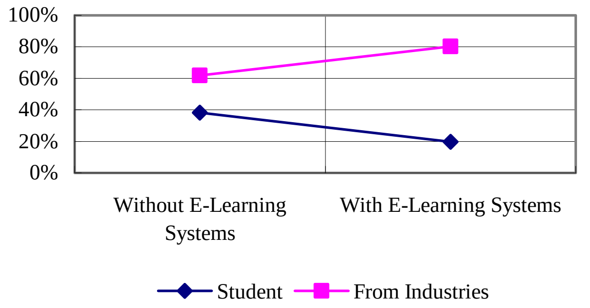

Figure 12 Field * Organizational E-Learning Systems

③ Department

The chi-square value is 2.642 (df=1, n=142) and the p-value is .104 (p>0.05) which means that there is no significant difference. Thus we conclude that whether the respondents have e-Learning systems in their organizations do not have significant difference in non-IT or IT departments.

④ Role in Implementation of E-Learning System

The relationship between the respondents' roles in implementations of e-Learning systems and whether they have e-Learning systems in their organizations is shown in Table 3. The chi-square value is 20.033 (df=1, n=142) and the p-value is .000 (p<0.001) which means that there is a significant difference. In order to find out which role group has more respondents, the percentages of the two role groups in Table 3 are compared. When comparing the respondents who have no e-Learning systems in their organizations, it is clear that the respondents who have no experiences of implementing e-Learning systems accumulate greater percentage (88.2%) than those who have (11.8%). However, if comparing the respondents who have e-Learning systems in their organizations, the percentages of respondents who have no experiences of implementing e-Learning systems (54.5%) and who have (45.5%) are very close. Therefore, we conclude that most of the respondents who have no e-Learning systems in their organizations also have no experiences of implementing e-Learning systems. Figure 13 depicts the line chart of role * organizational e-Learning systems.

⑤ Experiences on Using e-Learning Systems

The relationship among the respondents' experiences on using e-Learning systems and whether they have e-Learning systems in their organizations is shown in Table 4. The chi-square value is 24.506 (df=1, n=142) and the p-value is .000 (p<0.001) which means that there is a significant difference. In order to figure out which experience group has more respondents among those who have e-Learning systems in their organizations, the percentages of the two experience groups are compared. It is obvious that the respondents with experiences show greater percentage (87.9%) than those who do not (12.1%). Thus we conclude that the majority of the respondents who have e-Learning systems in their organizations also have experiences of using e-Learning systems. Figure 14 depicts the line chart of experience * organizational e-Learning systems.

After the analysis of the chi-square test, we conclude that only working field, role and experience have significant differences between the respondents who have no e-Learning systems in their organizations and those who have. The respondents who have e-Learning systems in their organizations are mostly from industries and have experiences of using e-Learning systems. However, the majority of the respondents who have no e-Learning systems in their organizations also have no experiences of implementing e-Learning systems.

Table 3 Role * Organizational E-Learning Systems Cross Tabulation

Role	WO/ EL	W/ EL	Total
Not Join	67 (88.2%)	36 (54.5%)	103 (72.5%)
Join	9 (11.8%)	30 (45.5%)	39 (27.5%)
Total	76 (100.0%)	66 (100.0%)	142 (100.0%)
Chi-Square Value	X^2=20.033	df=1	n=142

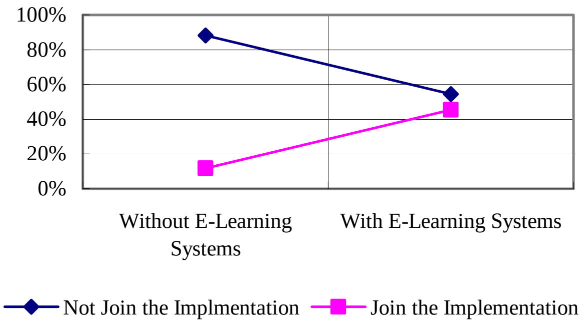

Figure 13 Role * Organizational E-Learning Systems

Table 4 Experiences * Organizational E-Learning Systems Cross Tabulation

Experience	WO/ EL	W/ EL	Total
Have no Experience	39 (51.3%)	8 (12.1%)	47 (33.1%)
Have Experience	37 (48.7%)	58 (87.9%)	95 (66.9%)
Total	76 (100.0%)	66 (100.0%)	142 (100.0%)
Chi-Square Value	X^2=24.506	df=1	n=142

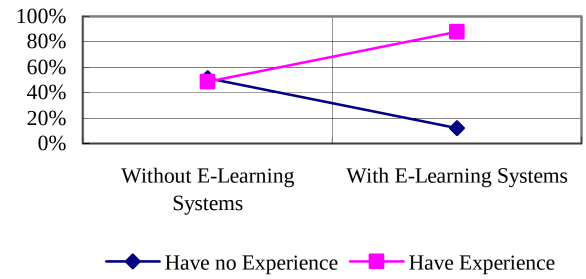

Figure 14 Experiences * Organizational E-Learning Systems

7. Factor Analysis & Cronbach's Alpha Test

The following sections explain the results of factor analysis and Cronbach's alpha test, which are carefully calculated using SPSS version 10.0. It uses the extraction method of principal components and varimax rotation. Additional information regarding the results is also described, such as factor loadings, eigenvalues, percentages of variance and Cronbach's alpha values.

Every factor is labeled a new name which reflects the characteristics of the items it contains. Items are ordered according to their factor loadings (from highest to lowest) and grouped according to factors. However, if the difference between the item's highest and second highest factor loadings is less than 0.15, the item is eliminated.

7.1 Analysis of Four Barriers

The factors analysis result of barriers indicates that there are two factors with eigenvalues greater than 1.0. A two-factor solution is suggested after examining the results (see Table 5).

Component one is labeled "Cost and Unawareness" and accounted for 33.372% of the variance. It includes "cost too high" and "unawareness". The reliability (internal consistency) is 0.3702. Component two is labeled "Immaturity" and accounted for 30.031% of the variance. It includes "technology immaturity" and "solution immaturity". The reliability is 0.3848.

Table 5 Factor Analysis of Barriers

Item		Component & Factor Loading	
		1: Cost and Unawareness	2: Immaturity
B1	Cost too High	**.811**	-5.373E-02
B4	Unawareness	**.682**	.141
B2	Technology Immaturity	-9.541E-02	**.900**
B3	Solution Immaturity	.451	**.606**
Eigenvalue		1.335	1.201
% of Variance		33.372%	30.031%
Cronbach's Alpha		0.3702	0.3848

Note. Boldface indicates highest factor loadings.

Table 6 Factor Analysis of Reasons

Item		Component & Factor Loading	
		1: Training Effectiveness	2: New Revenue
R3	Provide 24 x 7 Full time Training	**.834**	6.830E-02
R5	New Training Technology	**.830**	.164
R9	Flexible Learning	**.793**	.289
R11	Customer On-Line Learning	**.782**	.132
R4	Reduce Training Time	**.757**	.228
R1	Increase Competence	**.738**	.385
R6	Reduce Training Cost	**.547**	.378
R10✱	Win-Win Situation	.538	.431
R8	Decrease Time Spending on Selling	-7.382E-02	**.886**
R7	Increase Revenue	.248	**.672**
R2✱	Stay Innovative	.464	.550
R12✱	Enhance Customer Satisfaction	.428	.507

Eigenvalue	4.796	2.457
% of Variance	39.964%	20.477%
Cronbach's Alpha	0.9033	0.5678

Note. Boldface indicates highest factor loadings.

✱ indicates the difference between two factor loadings is less than 0.15.

7.2 Analysis of Reasons for Implementation

The factor analysis result of reasons indicates that there are two factors with eigenvalues greater than 1.0. A two-factor solution is suggested after examining the results (see Table 6).

Component one is labeled "Training Effectiveness" and accounted for 39.964% of the variance. It includes all the sub-items about training. The reliability is 0.9033. Component two is labeled "New Revenues" and accounted for 20.477% of the variance. It includes "decrease time spending on selling" and "increase revenue". The reliability is 0.5678.

7.3 Analysis of Vendor Consideration

The factor analysis result of vendor consideration indicates that there is one factor with eigenvalue greater than 1.0. A one-factor solution is suggested after examining the results (see Table 7).

Component one is labeled "Vendor Consideration" and accounted for 62.289% of the variance. It contains all the items in vendor consideration. The reliability is 0.8658.

7.4 Analysis of Success Factors

The factor analysis result of success indicates that there is one factor with eigenvalue greater than 1.0. A one-factor solution is suggested after examining the results (see Table 8).

Component one is labeled "Success" and accounted for 65.314% of the variance. It contains all the items in success. The reliability is 0.9227.

7.5 Analysis of Challenge Factors

The factor analysis result of challenge indicates that there is one factor with eigenvalue greater than 1.0. A one-factor solution is suggested after examining the results (see Table 9).

Component one is labeled "Challenge" and accounted for 66.420% of the variance. It contains all the items in challenge. The reliability is 0.9274.

Table 7 Factor Analysis of Vendor Consideration

Component 1: Vendor Consideration		Factor Loading
V3	Service Quality	**.911**
V2	Technology Integration	**.892**
V4	Implementation Experience	**.875**
V1	Content	**.840**
V5	Implementation Cost	**.723**
V6	Reputation	**.344**
Eigenvalue		3.737
% of Variance		62.289%
Cronbach's Alpha		0.8658

Note. Boldface indicates highest factor loadings.

Table 8 Factor Analysis of Success Factors

Component 1: Success Factors		Factor Loading
S6	Provide Mentoring	**.863**
S5	Include Peer Interaction	**.837**
S1	Organizational Support	**.829**
S7	Offer Performance Feedback	**.820**
S3	Measure Everything	**.816**
S4	Include Independent Learners	**.810**
S2	Virtual Project Teams	**.793**
S8	Marketing	**.685**
Eigenvalue		5.225
% of Variance		65.314%
Cronbach's Alpha		0.9227

Note. Boldface indicates highest factor loadings.

Table 9 Factor Analysis of Challenge Factors

Component 1: Challenge	Factor

Factors		Loading
C3	Tutors and SMEs Integration	**.849**
C2	LMS Configuration	**.837**
C6	Back-End Systems Integration	**.821**
C4	Content Creation	**.816**
C7	Web Infrastructure	**.814**
C8	Online Access Capability Training	**.812**
C1	Correct Target Setup	**.774**
C5	Multiple Modes of Learning	**.796**
Eigenvalue		5.314
% of Variance		66.420%
Cronbach's Alpha		0.9274

Note. Boldface indicates highest factor loadings.

8. T-Test of Seven Extracted Factors

T-test is conducted to examine whether there are significant differences between the above seven factors and whether the respondents have e-Learning systems in their organizations. The seven factors are "Cost and Unawareness" and "Immaturity" under barriers, "Training Effectiveness" and "New Revenues" under reasons for implementation, "Vendor Consideration", "Success" and "Challenge".

8.1 Barriers

The t-test result of "Cost and Unawareness" (t=-2.147; p<0.05) from t-test shows significant differences between the respondents who have no e-Learning systems in their organizations and those who have. However, the result of "Immaturity" (t=-.773; p>0.05) from t-test does not have significant difference. The mean value of "Cost and Unawareness" from the respondents who have no e-Learning systems in their organizations is 6.8158; while from those who have is 6.2879. It is obvious that the respondents who have no e-Learning systems in their organizations emphasize more on "Cost and Unawareness" than those who have (see Table 10).

Table 10 Group Statistics of Cost and Unawareness

Group	Mean	t-value	p-value
① Without Organizational E-Learning Systems	6.8158	-2.147	0.034
② With Organizational E-Learning Systems	6.2879		

8.2 Reasons for Implementation

The t-test results of both "Training Effectiveness" (t=-.162; p>0.05) and "New Revenues" (t=.987; p>0.05) do not show significant differences between the respondents who have no e-Learning systems in their organizations and those who have.

8.3 Vendor Consideration

The t-test result of "Vendor Consideration" (t=-1.009; p>0.05) does not have significant differences between the respondents who have no e-Learning systems in their organizations and those who have.

8.4 Success

The t-test result of "Success" (t=-.683; p>0.05) does not have significant differences between the respondents who have no e-Learning systems in their organizations and those who have.

8.5 Challenges

The t-test result of "Challenge" (t=-.964; p>0.05) from t-test does not have significant differences between the respondents who have no e-Learning systems in their organizations and those who have.

At the end, we conclude that only "Cost and Unawareness" have significant differences between the respondents who have no e-Learning systems in their organizations and those who have. Furthermore, the respondents who have no e-Learning systems in their organizations obviously consider it more important than those who have. On the contrast, regardless the respondents who have e-Learning systems in their organizations or not, they do not significantly differ in the attitudes toward other remaining factors.

9. Conclusion

9.1 New Findings

The following represents the new findings of this investigation. They are gathered from the results of chi-square test, factor analysis and t-test.

① Results of Chi-Square Test

The results of chi-square test indicate that the majority of the respondents who have e-Learning systems in their organizations are mainly from industries. Most of the respondents who have not e-Learning systems in their organizations also have not experiences of implementing e-Learning systems.

② Results of Factor Analysis

From the results of factor analysis, only the two factors in barriers have reliabilities lower than 0.4 which indicates low internal consistencies. However, the other five factors have reliabilities higher than 0.7 which represents high internal consistencies.

③ Results of T-Test

When examining the results of t-test, the respondents who have not e-Learning systems in their organizations emphasize more on "Cost and Unawareness" than those who have. However, whether the respondents have e-Learning systems in their organizations, they do not have significant different attitudes toward the other six factors which are "Immaturity", "Training Effectiveness", "New Revenues", "Vendor Consideration", "Success" and "Challenge".

9.2 Contributions

The following represents the seven contributions of this investigation. They are approaches and considerations, advantages and disadvantages of e-Learning systems for e-Business, elementary concepts and understanding, useful information, examples of benefits, where corporations stand and references from other e-Learning stakeholders

① Basic Approaches and Considerations

There are some basic approaches and considerations proposed to help the corporations who are just getting started with the implementations of e-Learning systems for e-Business.

② Advantages and Disadvantages of E-Learning Systems for E-Business

It advises the decision makers what the advantages and disadvantages are. They shall balance from the situations they choose, and avoid the failures from other people's experiences. Different stakeholders shall know their own responsibilities and jobs.

③ Elementary Concepts and Understanding

The elementary concepts and understanding about the implementations of e-Learning systems are introduced. It also gives a good e-Learning guide and roadmap. No matter the reader is a beginner or an expert, this paper can enrich his / her e-Learning knowledge.

④ Useful Information

All the analytical results in the study provide useful information on how the respondents rate on all the critical factors proposed. The information leads corporations to have a successful e-Learning system for e-Business.

⑤ Benefits

If corporations know respondents' attitudes toward the barriers, barriers are easier to be solved. By knowing the reasons for implementation, corporations can propose a sound e-Learning project. The results of vendor consideration can aid to choose an appropriate one. The rates of success and challenge factors undoubtedly give strong evidences for a better e-Learning system.

⑥ Where Corporations Stand

With a clear understanding of these results, corporations know where they stand. Furthermore, they can setup corresponding strategies and objectives which lead them to a smooth implementation of e-Learning system for e-Business.

⑦ References from other Stakeholders

The vendors of e-Learning solutions can figure out what end-users emphasize the most when choosing suitable vendors. Different stakeholders shall consider all the perspectives. By doing so, they can understand what others feel toward a better implementation of e-Learning systems for e-Business.

9.3 Limitations

There are five points of limitations must be acknowledged. All of them are listed and explained in the following. They are time, manpower, demographic, response rate, validity, flexibility and reliability limitations.

① Time and Manpower Limitation

Due to the limited time and manpower, there are still spaces for further investigation.

② Demographic Limitation

Most of the respondents came from Hsin Chu Science Park and National Chiao Tung University, so the results are limited to these areas.

③ Response Rate and Validity

As people tend to dislike questionnaires, thus a low sample size is gathered. Furthermore, the conditions under which the questionnaires are finished cannot be controlled.

④ Flexibility

Questionnaires are less flexible and therefore required more preliminary thought and preparation for their structures and contents.

⑤ Reliabilities of “Cost and Unawareness” & Immaturity”

They are both under 0.4 which mean that their internal consistencies are low. Therefore, in the future study, new test items shall be developed.

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DCT and DWT-based Image Watermarking by Using Subsampling

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Abstract

A subsampling based watermarking scheme has been investigated for digital images in this study. The algorithm utilizes the wavelet multi-resolutional structure and subsamples the individual subband coefficients in order to embed the watermark information respectively. The extracting procedure reverses the embedding operations without the reference of the original image and provides a better copyright protection scheme. Compared with the similar approach by discrete cosine transform based approach, the wavelet based algorithm apparently preserves superior image quality and robustness under various attacks.

1. Introduction

The usage of the Internet has become ubiquitous and everyone feels it is the indispensable part of the future business communication. Since the digital data could be easily transmitted, duplicated and modified, the copyright protection of the intellectual property of the sensitive or critical digital information is an important legal issue globally. Recently, we have seen the trend of the studies in digital watermark for audio, image or video data since the techniques provide the essential mechanism for the ownership authentication [1-2].

Image watermarking is the process of inserting hidden information in an image by introducing modifications to its pixels with the expectation of minimum perceptual disturbance. According to Cox et al [3]'s analysis, watermark should have the following characteristics: unobtrusiveness, robustness, universality and unambiguousness. Cox's approach is to select a fixed number of highest magnitude DCT coefficients and randomly perturbed. Therefore the watermark is placed to the perceptually significant components of the image. Even though the method is quite robust against several known manipulations, the main weakness is the original image must be present for watermark recovery.

Recently, the pursuit of a scheme that doesn't need the original image during watermark recovery has become a topic of intense research [4-5]. This is partly due to the practical issues, like the fact that the watermark recovery process can be simplified without the comparison with the original image which is generally not available. Chu [6] developed a DCT-based scheme and took the advantage of the random perturbation of the DCT coefficients from the subimages obtained by sub-sampling the original image. It has been shown that by employing different modifications to the DCT coefficients pertaining to different subimages, it is possible to recover the watermark without comparison with the original image.

However, the image perceptual quality tends to be considerably corrupted by the block noises as the slight changes of the DCT coefficients. The subsampling operation can also produce the meshed noise which is usually apparent to the observers. For this reason, the watermark strength should be appropriately controlled while inserting the watermark into the image. Hence, we modify Chu's [6] method by using DWT instead of DCT to reduce the influence of block noises upon inserting watermark and adjust the watermark strength for better robustness.

In this paper, we focus on the comparison of DCT and DWT-based image watermarking algorithms by using subsamplimg. Section 2 begins with the discussion of DCT and DWT-based image watermarking algorithms using subsampling; section 3 provides the experimental results and analysis based on various attacks. Finally, section 4 discusses the possible weaknesses and enhancements of the image watermarking algorithms mentioned in this study.

(a) (b) (c)

Figure 1. (a) Subsample "Lena" image into four sub-images. **(b)** The watermarks are inserted at HL3, LH3, and HH3 band respectively with pair of subimages. **(c)** The test image is subsamples into four subimages, and the subimages are transformed via DWT. The watermarks are then inserted at HL3, LH3, and HH3 band respectively with pair of subimages.

2. Algorithms

The algorithms we introduced are modified from Chu's [6] method. Instead of using DCT, we are using DWT for the transformation. At the embedding stage, the following steps are performed to achieve the subsampling-based watermarking scheme:

The first step is to decompose the original image into four subimages through subsampling. As shown in Figure 1(a), given the image $v[n_1, n_2]$, $n_1 = 0, \cdots,$ $N_1 - 1$, $n_2 = 0, \cdots, N_2 - 1$, then

$$
\begin{aligned}
v_1[n_1, n_2] &= v[2n_1, 2n_2], \\
v_2[n_1, n_2] &= v[2n_1 + 1, 2n_2], \\
v_3[n_1, n_2] &= v[2n_1, 2n_2 + 1], \\
v_4[n_1, n_2] &= v[2n_1 + 1, 2n_2 + 1]
\end{aligned} \tag{1}
$$

for $n_1 = 0, \cdots, N_1/2 - 1$, $n_2 = 0, \cdots, N_2/2 - 1$ are the subimages obtained by subsampling the image *v*. Since the sub-images v_i 's are highly correlated, it is expected that $v_i \approx v_j$, for $i \neq j$. This is indeed the case in practice for many images of interest.

After the subsempling, the subimages are transformed via DWT to obtain the sets of coefficients $V_i[n_1, n_2]$. Wavelet transform can be constructed under various decompositions. Generally, pyramidal decomposition is widely used in many signal processing applications and Figure 1.(b) has shown the decomposition structure.

The watermark embedding sequence $W[n]$, $n = 0,$ $\cdots$, $N - 1$ consists of *N* samples drawn from a random source with standard normal distribution (zero mean and unit variance) and with *N* the watermark length.

In our scheme, one pair of coefficients from two different subimages situated in the same DWT domain location is used to insert one watermark sample. Figure 1(c) shows that after 3-level wavelet decomposition, the watermarks are inserted into HL3, LH3, and HH3 band respectively. For the sake of determining a watermark insertion order sequence, we have to decide where each pair of numbers is associated with one watermark sample. An example sequence is (1, 2, HL3), (3, 4, LH3), (3, 1, HH3), (4, 2, HL3), (3, 2, LH3), (4, 1, HH3), $\cdots$, and so on, which indicating the two subimages (1, 2, 3, or 4) to be used to code the particular sample of the watermark and following the subband order HL3, LH3 and HH3 consecutively.

The watermark insertion order sequence can be fixed, or generated as a random sequence. Four consecutive numbers in the sequence must be different, so as to ensure that the watermark is inserted to pairs of different subimages. Since the number of possible order sequences is huge, a person with no knowledge of the exact order sequence can not recover the watermark in a reasonable amount of time.

When the pair of coefficients as V_i and V_j are selected, the following operations are performed:

$$V = \frac{(V_i + V_j)}{2} \tag{2}$$

if
$$\left| \frac{V_i - V_j}{V} \right| \geq 6\alpha \tag{3}$$

Figure 2. The original test image "Lena."

Figure 3. Watermarked version of "Lena" with n=3000, α =1.0 via DWT using subsampling.

then we don't modify V_i and V_j; otherwise, watermark is inserted with:

$$V_i' = V(1+\alpha W),$$
$$V_j' = V(1-\alpha W) \quad (4)$$

In (4), DWT coefficients of the watermarked subimages are denoted by V_i' and V_j'. The positive constant α is known as watermark strength control variable, the choice of α is a tradeoff between image distortion and detection accuracy. Finally, the four watermarked subimages are transformed via inverse DWT and used to compose the image. Figure 2 and 3 shows the original test image "Lena" with 512*512 image size and the watermarked image via DWT with watermark length *n*=3000 and watermark strength control variable α =1.0.

At the decoder stage, the input image is decomposed and transformed via DWT in the same way as the approach at the encoder. The decoding steps are decomposing the image into four subimages through subsampling, transformed via DWT, and recovering the watermark.

In order to recover the watermark, the same watermark insertion order sequence is required to determine which pairs of DWT coefficients are selected. Representing the recovered watermark as $W'[n]$ and each selected pair of coefficients as U_i and U_j, the following operations are performed:

$$U = \frac{(U_i + U_j)}{2} \quad (5)$$

if
$$\left|\frac{U_i - U_j}{U}\right| > 6\alpha \quad (6)$$

then we set $W' = 0$; otherwise, the recovered watermark can be calculated as

$$W' = \frac{1}{\alpha}\left(\frac{U_i - U_j}{U_i + U_j}\right) \quad (7)$$

To verify the threshold accuracy of (3) and (6), a reasonable assumption is that $|W| < 3$ since W has a standard normal distribution. To guarantee this condition, the recovered watermark magnitude can be truncated to ± 3. From (2), (3) and (4) can calculate:

$$V = \frac{V_i + V_j}{2} = \frac{V_i' + V_j'}{2} \quad (8)$$

and
$$\left|\frac{V_i' - V_j'}{V}\right| = |2\alpha W| = 2\alpha|W| < 6\alpha \quad (9)$$

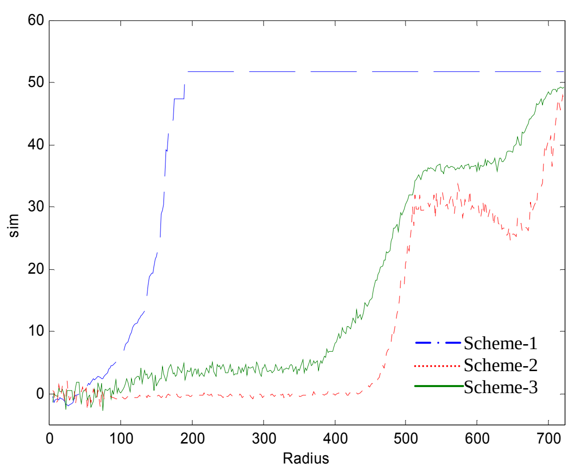
therefore, assuming that the input is the watermarked image, the decoder can replicate the exact threshold verification procedure as the encoder, since $U = V'$. Under noiseless condition, the inserted watermark samples can be recovered exactly, where $W' \approx W$.

3. Experimental Results

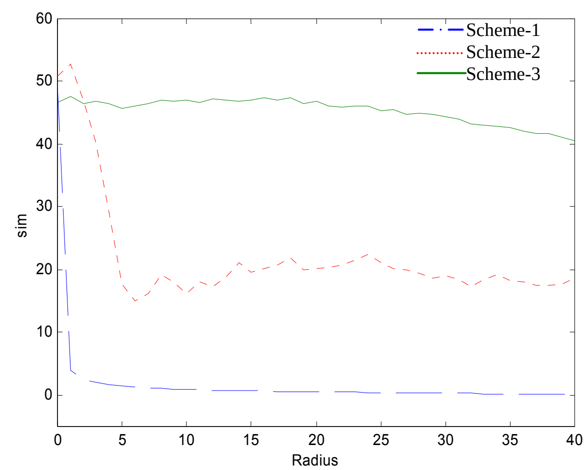
Given the original watermark order sequence W and the recovered sequence W', a distance measure can be established to access the closeness between them. The similarity between two watermarks can be evaluated by a number of ways. Here we use the same similarity measure as proposed in [3], denoted by $sim(W, W')$ that if W and W' are statistically independent, $sim(W, W')$ has a standard normal distribution. Then, if W' is created independently from W then it is extremely unlikely that $sim(W, W')$ >6. Therefore, we can identify whether W' was the original W by a valid detection that $sim(W, W')$ ≤ 6. Note that slightly higher values of $sim(W, W')$ may be required when a

Table 1. SNR of watermarked images with watermark length *n*=3000 and strength α =1.0 under various attacks. Scheme-1 is Cox's [3] DCT-based watermarking into the perceptually most significant spectral components of the image; Scheme-2 is Chu's [6] method of DCT-based watermarking using subimaging; Scheme-3 is DWT-based watermarking using subimaging we proposed.

Methods	Test image (512*512)	watermarked image	Spatial Attacks			
			Smoothing filter (3*3 averaging mask)	Sharpening filter (3*3 Laplacian mask)	Gaussian noise	Histogram equalization
Scheme-1 (Cox, DCT-based)	pepper	45.734	25.921	15.699	14.277	15.833
	Lena	45.736	31.800	19.745	14.376	18.961
	baboon	44.929	14.563	6.083	13.474	14.837
Scheme-2 (Chu, DCT-based, using subsampling)	pepper	5.885	10.534	0.985	5.499	5.809
	Lena	6.149	11.471	1.151	5.718	6.040
	baboon	6.568	10.876	0.992	5.992	6.436
Scheme-3 (DWT-based, using subsampling)	pepper	25.329	25.500	10.719	13.980	15.516
	Lena	30.142	31.503	14.416	14.350	19.556
	baboon	23.213	14.541	5.398	13.044	14.381



(a) Low-pass filtering



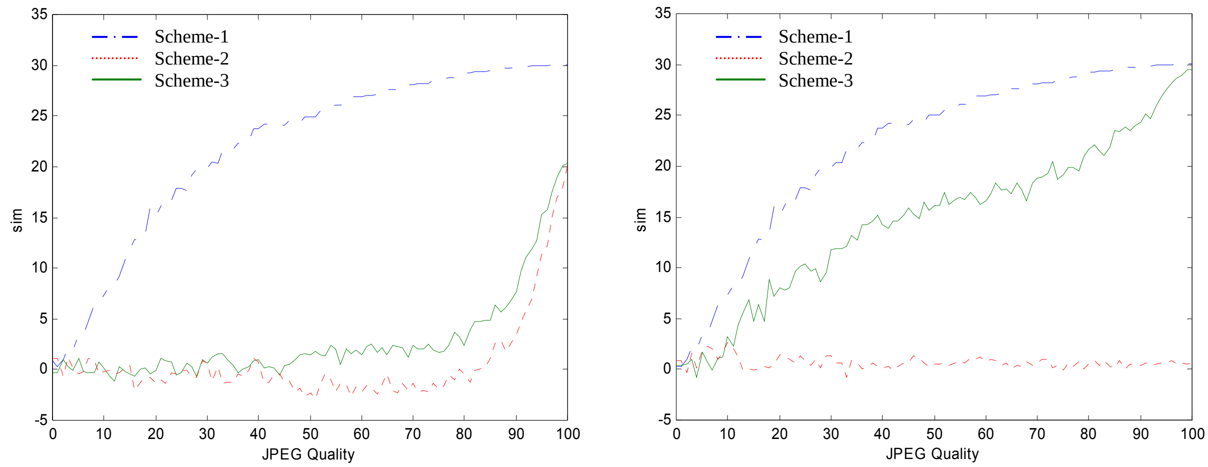
(b) High-pass filtering

Figure 4. Similarity against low-pass and high-pass filter radius. Where α =1.0 was used in Scheme 1 and 3; α =0.1 was used in Scheme 2, and the $sim = 6$ threshold is measured. For blind watermarking method, DWT-based watermarking using subsampling performs better effects than DCT-based subsampling method.

large number of watermarks are embedded in the image.

According to formula (9), the difference image reveals that DCT-based watermarked image's significant amount of energy is located in the mid to high frequency regions. However, DWT-based watermarks are generally located at the highest magnitude DWT coefficients at HL3, LH3, and HH3 from the experiments.

In order to prove the performance of the method we proposed, we used three watermarking inserting schemes to test several well know images like Lean, pepper and baboon with 512*512 image size and the same watermark length and watermark strength. Scheme-1 is Cox's method that needs original image to detect the watermark that is simulated and plotted for comparison; Scheme-2 and Scheme-3 are both using subsampling method without comparison with the original image. As shown in table 1, the signal-to-noise ratio (SNR) of watermarked images under



(a) n=1000, α =0.1 (b) n=1000, α =2.0

Figure 5. JPEG quality comparison with different approach. The $sim = 6$ threshold is measured. When using weak watermark strength in (a), the DWT-based watermarking using subsampling is not as robust against JPEG, and hence using strong watermark strength in (b), it performs quite well under JPEG attack.

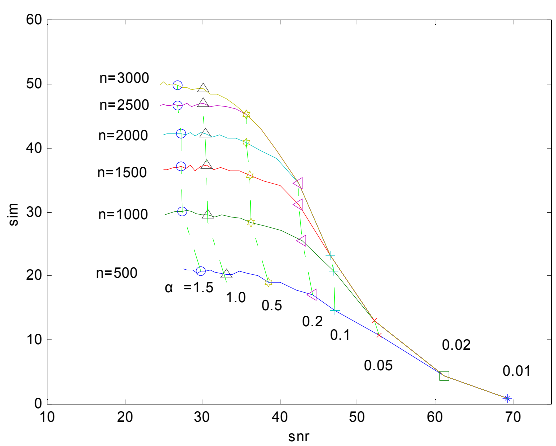


Figure 6. Similarity measures as a function of SNR via DWT using subsampling (Scheme-3). The similarity and watermark length show the direct proportion. When the watermark strength increases, the similarity remains keeping on a high plane.

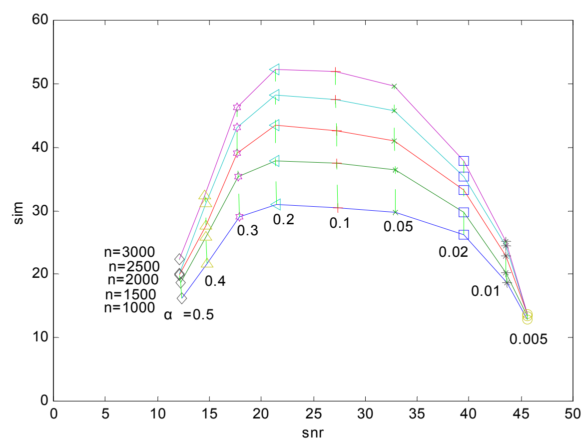


Figure 7. Similarity measures as a function of SNR via DCT using subsampling (Scheme-2). It has a tendency that the similarity will drop off, when the watermark strength increases getting beyond the limit.

various spatial attacks is present. As similarity threshold is 6, the Scheme-3 we introduced has quite well robust against of smoothing filter, Gaussian noise and Histogram equalization than Scheme-2 that via DCT.

For frequency attack filtering, we see how the average similarity measure is affected under low-pass filtering and high-pass filtering in Figure 4. Scheme-3 gets better robust than Scheme-2 in low-pass and high-pass filtering attack, and has excellent robust against high-pass filtering. As threshold $sim = 6$ is measured, Scheme-3 can resist low-pass and high-pass filtering attacks and satisfy human perceptually acceptable quality.

Figure 5 shows how the similarity measure is affected under JPEG attacks with different watermark strength. We found that at the low watermark strength (i.e. Figure 5(a), α =0.1), Scheme-3 we introduced is not as robust against JPEG coding, but the similarity measure remains better than DCT-based Scheme-2 using subsampling. Nevertheless, it performs quite well under high watermark strength (i.e. Figure 5(b), α =4.0) condition. From the plot, Cox's method is better which generally is the case for private watermarking. In many of the applications, original image are not unavailable for comparison. The observation of the image quality for Scheme-3 and Scheme-2 approach under JPEG attack is generally coincided with the testing values. But the Scheme-3 approach almost results better similarity measures than Scheme-2 approach.

By increasing the watermark length and the watermark strength, it is possible to increase the similarity. Figure 6 shows experimental results where six values of watermark length *N* are used to insert a watermark via DWT to the "Lena" image. It is observed that in general, small or no additional image degradation is introduced by lengthening the watermark. Thus, the length of the watermark can be extended if improvement in similarity measure is desired. Also, by lengthening the watermark while lowering the watermark strength, it is possible to maintain the same level of similarity measure while bettering image quality. Then, to compare with inserting a watermark via DCT (See Figure 7), it has a tendency that the similarity will drop off, when the watermark strength increases getting beyond the limit. So using DWT instead of DCT can reduce the influence of black noises upon inserting image watermarking with high watermark strength.

4. Discussion and Conclusion

In this study, we have shown the subsampling based watermarking scheme for digital images. The watermarking detection is performed without the comparison with the original image. The algorithm utilizes the wavelet multi-resolutional structure and subsamples the individual subband coefficients in order to embed the watermark information. Compared with the similar approach for discrete cosine transformed coefficients, the wavelet based approach apparently preserves superior image quality and robustness under attack. Further investigation for different attacks and image quality evaluation is on the way and apparently shows very positive results.

5. References

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