NECTEC สวทช NSTDA

NECTEC Technical Journal

วารสารวิชาการเนคเทค ปีที่ 1 ฉบับที่ 3 เดือน กรกฎาคม – สิงหาคม 2542 Vol 1, No. 3, July – August 1999 ISSN 1513-2145

PREFACE

My duty as the temporary acting Editor-in-Chief of NECTEC Technical Journal ended with the closing of this issue. I agreed to take on this duty during June-August of 1999 when our EIC had to be away. During this 3 months, I have learnt that running the newly born bi-monthly technical journal is much harder than I thought.

As you may notice, this issue of NTJ is quite late and thin. Coming to technical research, people would like to publish their works in the journal with well-established reputation. It is totally understandable. Thus make it hard for the new journal like NTJ to collect papers and go through all reviewing process in every 2 months. Aiming to make it a hi-quality journal is our first directive and certainly makes the job harder in the beginning. Nonetheless, we believe that in the end we will become one proud recognizable journal, which provides the solid floor to Thai researchers in multidisciplinary fields related to electronics and computers. How fast can we become? That will depend on the contributions from you all, whose works are within the scope of this journal. I would like to encourage you, your colleagues, and friends to continually share the knowledge, submit papers, and get to know us better. We promise to do our part and to work hard to achieve what we would like to see.

For any flaws of NTJ that may have happened during my short term of inexperience, I sincerely apologize.

Piyawut Srichaikul

Acting Editor-in-Chief

June-August 1999

A Current-Tunable Sinusoidal Quadrature Oscillator Using Signal-Differencing All-Pass Filters

Banlue Srisuchinwong
Department of Electrical Engineering, Sirindhorn International Institute of Technology, Thammasat University, P.O.Box 22, Thammasat Rangsit Post Office, Patumthani 12121
email : banlue@siit.tu.ac.th

ABSTRACT – An integrable current-tunable sinusoidal quadrature oscillator is presented. A current-tunable all-pass filter is used as the frequency-selective network. The implementation is fully-balanced so as to enable accurate quadrature signals with symmetry. The oscillation frequency is current-tunable over a wide-freqency sweep range of approximately three orders of magnitude. The quadrature signals possess the amplitude matching and the quadrature phase matching of better than 0.004 dB and 0.15°, respectively. The maximum useful frequency of oscillation is in excess of 8 MHz, and total harmonic distortions can be adjusted easily to be approximately 0.5 percent.

KEY WORDS – Sinusoidal quadrature signals, current-tunable all-pass filters.

บทคัดย่อ – บทความนี้เสนอวงจรกำเนิดสัญญาณรูปซายน์แบบควอดราเจอร์ที่ปรับความถี่ด้วยการปรับค่าของกระแสไฟฟ้า โดยใช้วงจรกรองสัญญาณแบบออลพาสส์ที่ปรับค่ากระแสได้ วงจรมีความสมดุลเพื่อให้สัญญาณรูปซายน์มีความสมมาตร ความถี่ถูกปรับค่าได้ประมาณ 1,000 เท่าด้วยการปรับค่าของกระแส สัญญาณรูปซายน์แบบควอดราเจอร์ มีขนาดใกล้เคียงกันถึง 0.004 เดซิเบล และแตกต่างจากมุม 90 องศาไปน้อยกว่า 0.15 องศา ความถี่สูงสุดที่ใช้งานได้มีค่าสูงกว่า 8 เมกะเฮิรตซ์ ความเพี้ยนทางฮาร์โมนิกส์มีค่าประมาณ 0.5 เปอร์เซ็นต์

คำสำคัญ – สัญญาณรูปซายน์แบบควอดราเจอร์ วงจรกรองสัญญาณแบบออลพาสส์ที่ปรับค่ากระแสได้

1. Introduction

Quadrature oscillators typically provide two sinusoids with 90° phase difference for a variety of applications such as quadrature modulators and carrier recovery circuits. Integrable quadrature oscillators based on relaxation [1] and ring oscillators [2] have been reported. However, both types of oscillators are generally classified as nonlinear oscillators where periodically switching mechanisms are employed and therefore outputs may not be readily low-distortion sinusoidal waveforms [3]. Although two-integrator oscillators have also been suggested for integrable quadrature oscillators, they usually include some forms of relaxation [4, 5] or ring oscillators [6].

In constrast, linear oscillators employ frequency-selective networks such as LC or RC circuits and therefore low-distortion sinusoidal outputs can be readily generated [3,7]. Recently planar inductors [8], underetched coils [9] and bonding wire inductors [10] provide a good basis for integrable inductors, most LC oscillators are however difficult to tune over wide frequency ranges [7]. On the other hand, sinusoidal quadrature oscillators using RC all-pass filters have been the counterpart, but they usually require the use of operational amplifiers [11, 14]. Although current-mode RC all-pass filters and other current-mode approaches have been suggested for such oscillators [12, 15, 16], most of them require switching among different resistors (or capacitors) for a tunable frequency range. Techniques of a current-tunable bandpass filter have been reported for a wide-tunable frequency range and such switching is not necessarily needed [13].

In this paper, a new realisaton of an integrable current-tunable sinusoidal quadrature oscillator is presented using r_e tunable signal-differencing all-pass filters as the frequency-selective network, where r_e is the small-signal dynamic resistance of a forward-biased based-emitter junction of a bipolar transistor. The implementation is fully-balanced so as to enable accurate quadrature signals with symmetry. The oscillation frequency is current-tunable over a wide-freqency sweep range of approximately three orders of magnitude. The quadrature signals possess the amplitude matching and the quadrature phase matching of better than 0.004 dB and 0.15°, respectively, and total harmonic distortions of approximately 0.5 percent. The maximum useful frequency of oscillation is in excess of 8 MHz.

2. Circuit Descriptions

Figure 1 shows the basic circuit configuration of the current-tunable sinusoidal quadrature oscillator consisting of two identical stages in series. Each stage is formed by a fully-balanced current-tunable all-pass filter connected with a differential amplifier. For the first stage, the all-pass filter is formed by ten matched transistors (Q1 to Q10), a capacitor C and two current sinks I and I_F, where the small-signal, differential, input voltage V_{AB} is applied to the bases of Q1 and Q2 between nodes A and B, and the small-signal, differential, output voltage V_{GF} is taken across the emitters of Q9 and Q10 between nodes G and F. The current I /2 biases the (Q3, Q9) and the (Q4, Q10) branches, whilst the frequency setting current I_F /2 biases the (Q1, Q8, Q7) and the (Q2, Q5, Q6) branches. The differential pair (Q21 and Q22), functioning as a voltage-to-current converter, constitutes the required loop gain controllable by the loop-gain setting current I_G to initiate and to sustain steady-stead oscillations.

Similarly, for the second stage, the all-pass filter is formed by ten matched transistors (Q11 to Q20), a capacitor C and two curent sinks I and I_F, where the small-signal, differential, input voltage V_{MN} is applied to the bases of Q11 and Q12 between nodes M and N, and the small-signal, differential, output voltage V_{OP} is taken across the emitters of Q19 and Q20 between nodes O and P. The current I /2 biases the (Q13, Q19) and the (Q14, Q20) branches, whilst the frequency setting current I_F /2 biases the (Q11, Q18, Q17) and the (Q12, Q15, Q16) branches. The differential pair (Q23 and Q24) constitutes the required loop gain controllable by the loop-gain setting current I_G to initiate and to sustain steady-stead oscillations.

It can be seen from Figure 1 that the input of the first stage V_{AB}, at nodes A and B, is connected to the output of the second stage, at nodes A′ and B′, but they possess the opposite polarities. On the other hand, at nodes M and N, the input of the second stage V_{MN} is connected to the output of the first stage, and they possess the same polarities. The circuit is fully-balanced so as to enable accurate quadrature signals with symmetry. The circuit is also relatively simple and integrable as devices can be fabricated on-chip.

3. Ideal Analysis

The analysis of Figure 1 assumes that each transistor acts as an idealised voltage-controlled current source (VCCS), where the collector current is simply equal to the small-signal voltage across the base-emitter nodes divided by r_e, where r_e is the usual ratio of the thermal voltage and the emitter bias current. The common-emitter current gain factors (β's) are also assumed to be infinite. As the two stages of Figure 1 are identical, only the first stage will be described. For clarity, the all-pass filter of the first stage can be isolated such that the inputs of the all-pass filter between nodes A and B are disconnected from the outputs of the second stage between nodes A′ and B′, and the outputs of the all-pass filter between nodes G and F are disconnected from the inputs of the differential amplifier between nodes G′ and F′.

For such isolation, it can be assumed for the moment that the bases of Q9 and Q10 at nodes D′ and E′ are temporarily disconnected from nodes D and E, respectively. As a result the bases of Q9 and Q10 at D′ and E′ are then temporarily connected together with an appropriate bias voltage say V_{bias}. In such temporary cases, let V_{O1} be the small-signal, differential, output voltage at node D with respect to node E, and V_{O2} be the small-signal, differential output voltage at node F with respect to node G. The input voltage V_{AB} results in a small-signal, differential, output current $i_{d1} = V_{AB} / 2r_{e1}$ passing, through nodes D and E, the loading impedance $4r_{e1} / (1+s\tau)$ where $r_{e1} = (2V_T / I_F)$ is the emitter resistance of either Q1, Q2, Q5, Q6, Q7 or Q8, V_T is the usual thermal voltage of approximately 25 mV associated with a pn junction at room temperature, and time constant $\tau = 4C\, r_{e1}$. Therefore the transfer function $V_{O1} / V_{AB} = 2 / (1+s\tau)$ represents a first-order low-pass filter. In addition, V_{AB} also results in another small-signal, differential, output current $i_{d2} = V_{AB} / 2r_{e2}$ passing, through nodes F and G, the loading resistance $2r_{e2}$ where $r_{e2} = (2V_T / I)$ is the emitter resistance of either Q3, Q4, Q9 or Q10. Therefore the transfer function $V_{O2} / V_{AB} = 1$ represents a buffer.

By reconnecting the bases of Q9 and Q10 at nodes

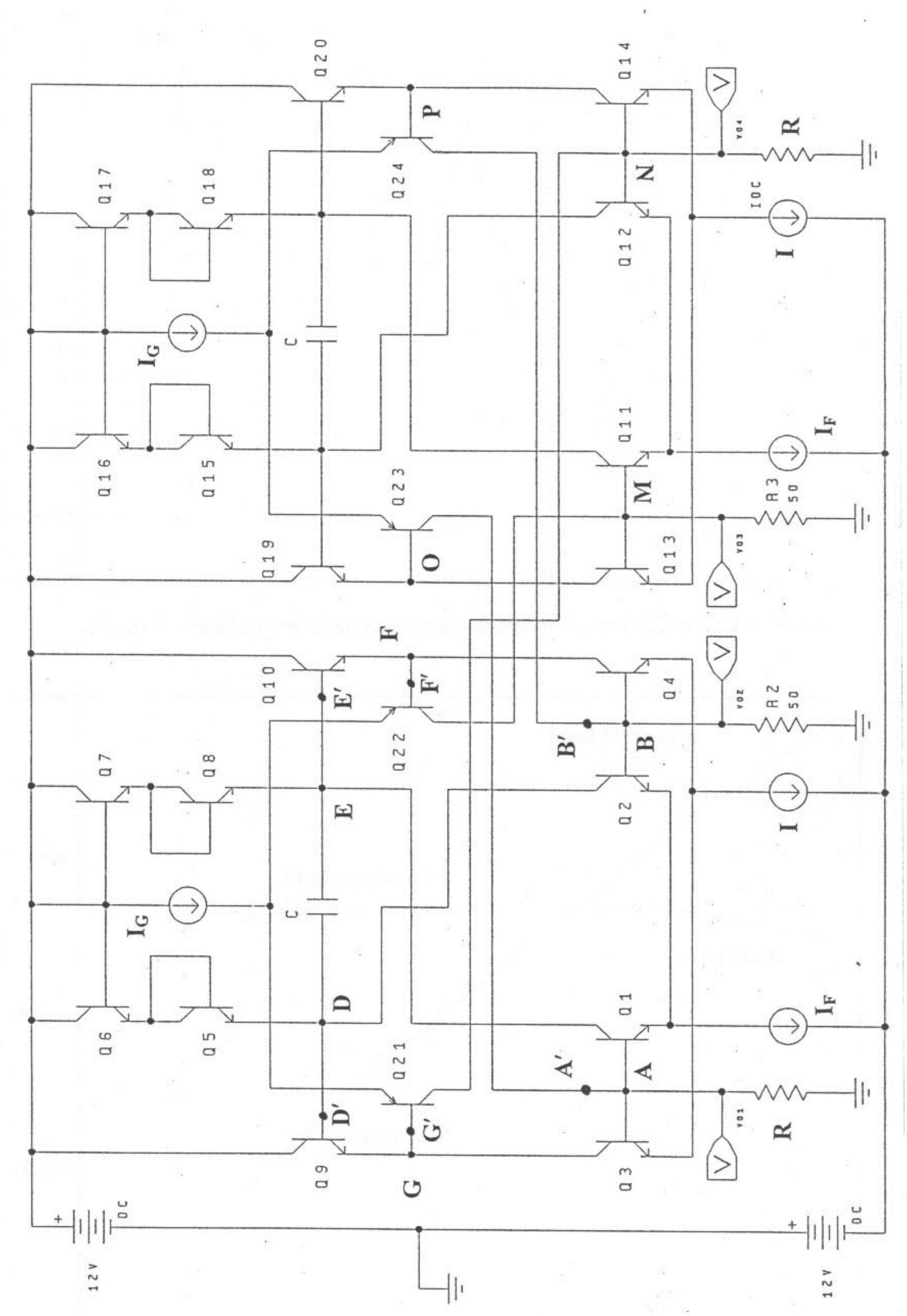


Figure 1 : Circuit diagram of the fully-balanced current-tunable sinusoidal quadrature oscillator.

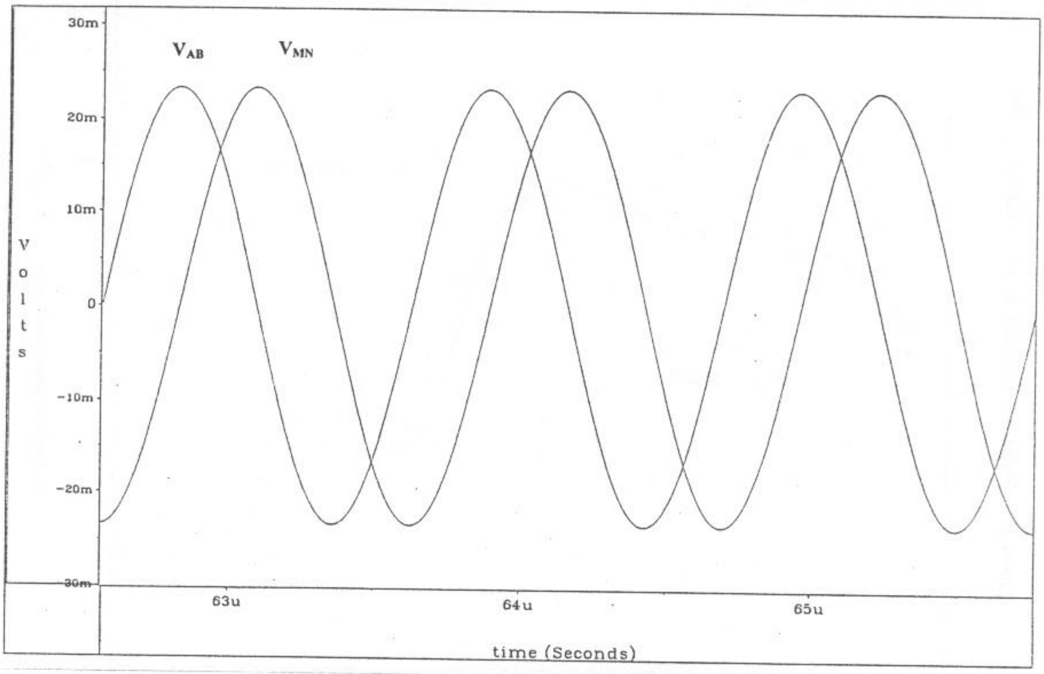


Figure 2 : Oscillograms of the quadratrue waveforms V_{AB} and V_{MN} at $I_F/2$ = 700 uA.

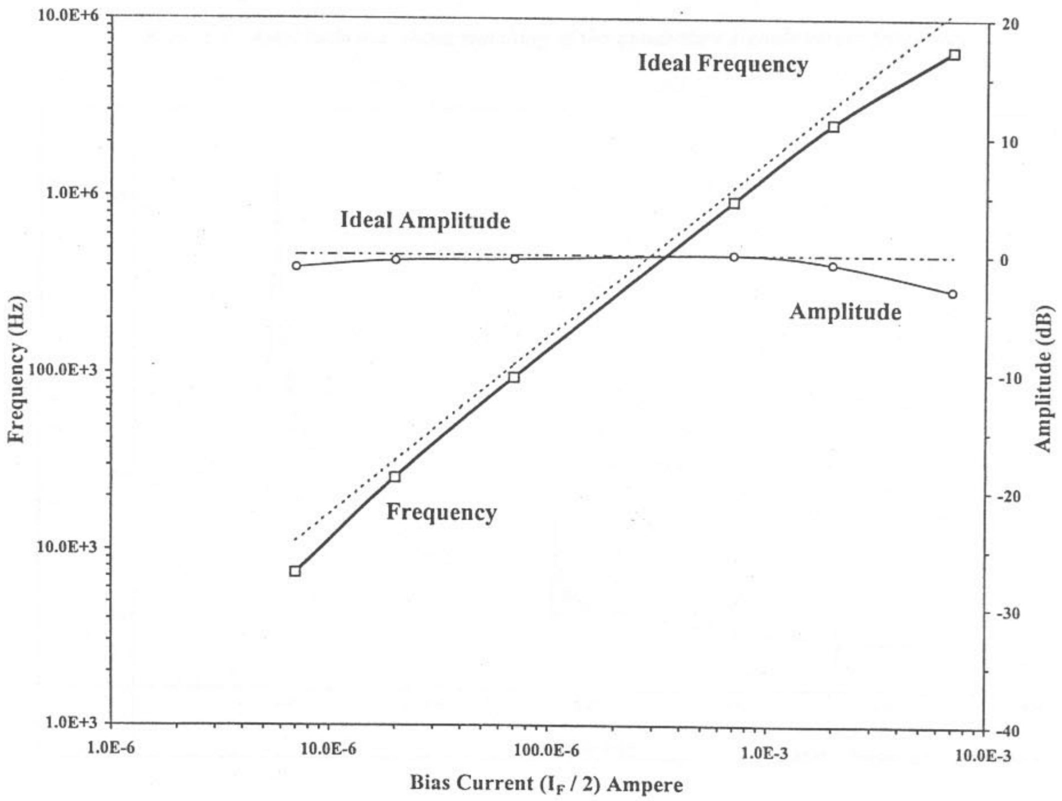


Figure 3 : Plots of oscillation frequencies and amplitude versus bias currents $I_F/2$.

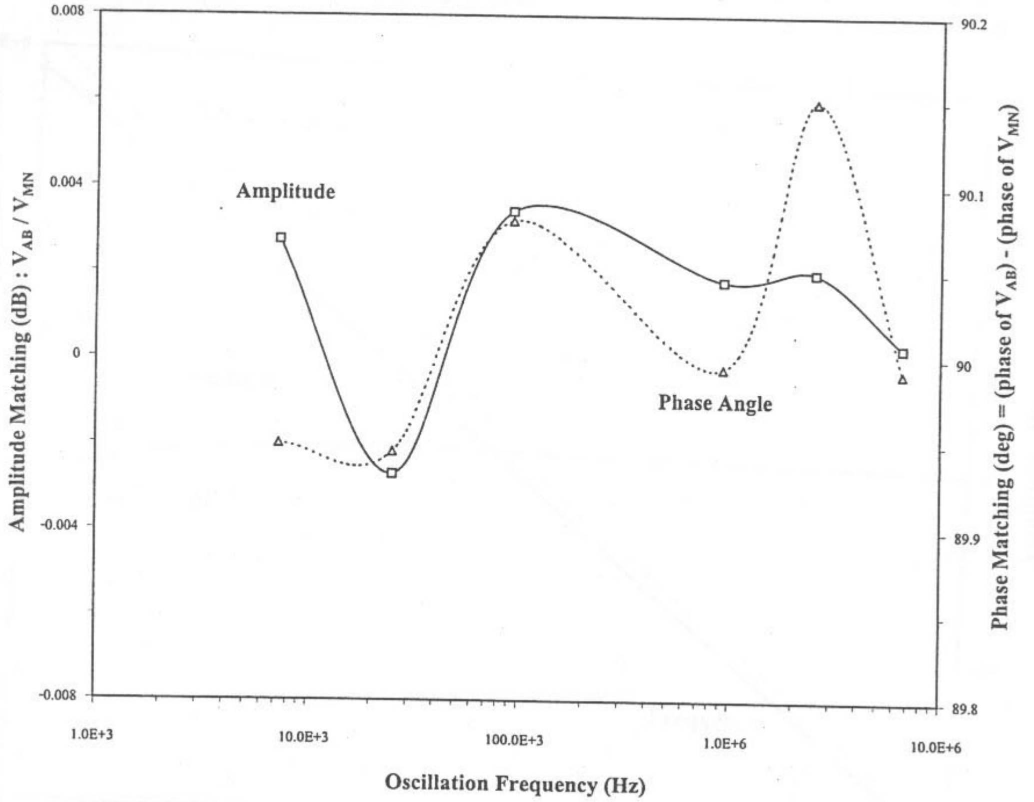


Figure 4 : Amplitude and phase matching of the quadrature signals versus frequency.

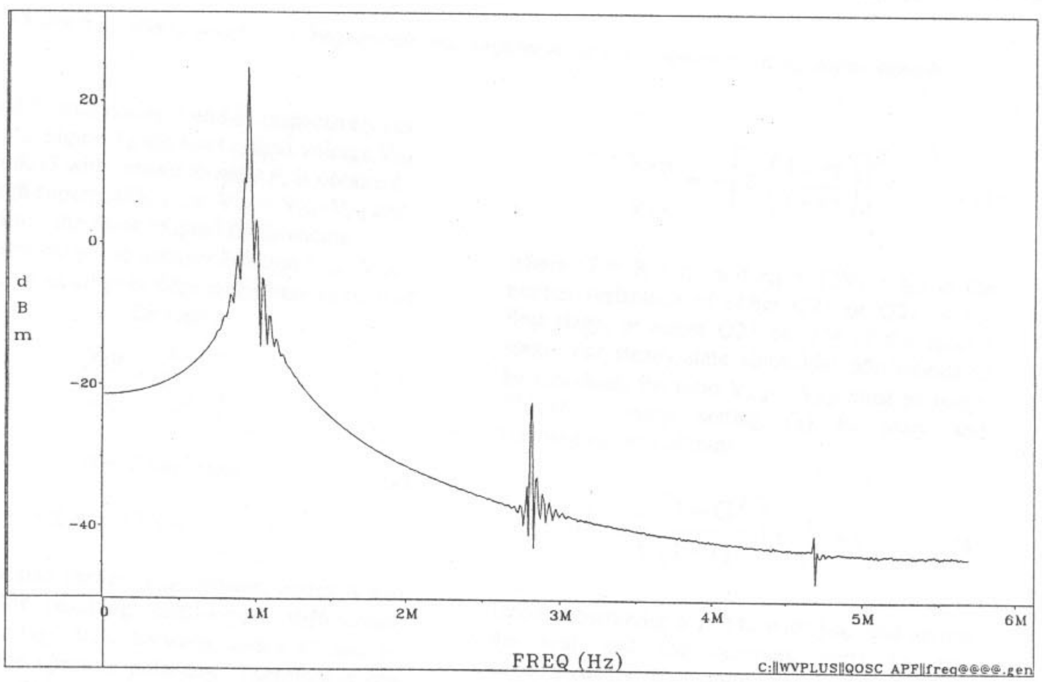


Figure 5 : Harmonic spectrums of the output waveform V_{AB} at $I_F/2$ = 700 uA.

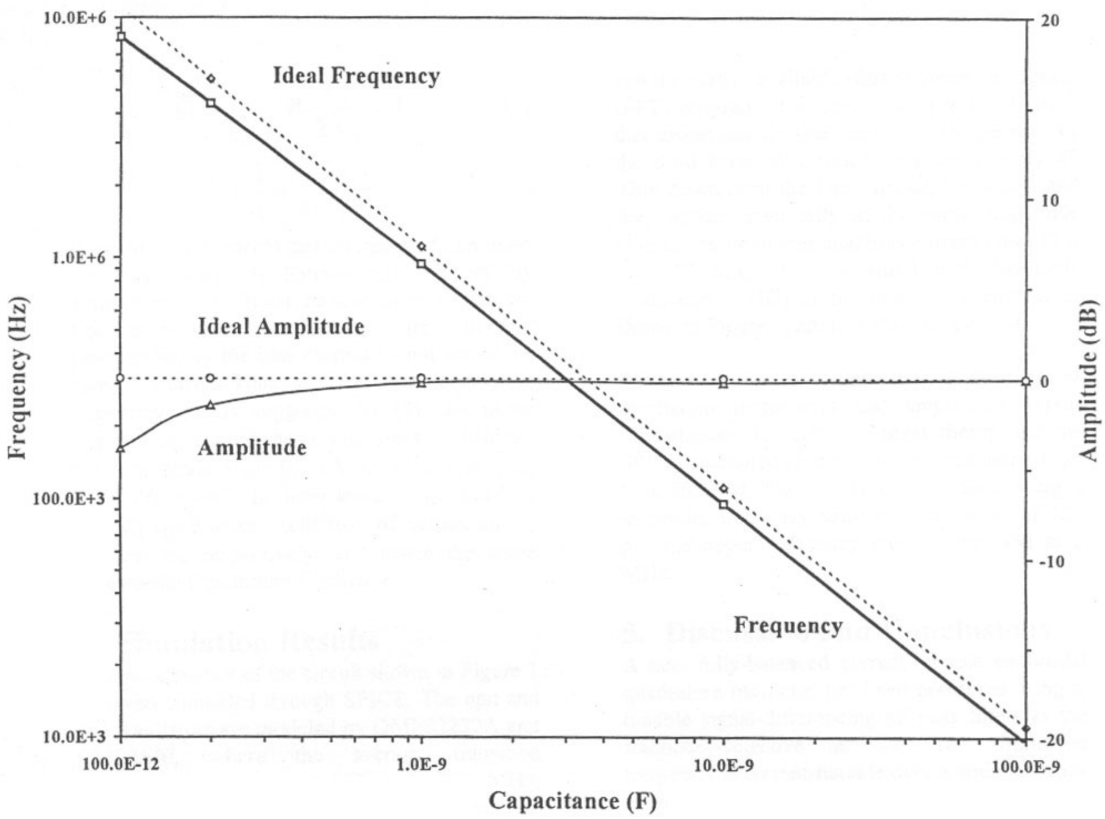


Figure 6 : Plots of oscillation frequencies and amplitude versus frequency setting capacitances.

D′ and E′ with nodes D and E, respectively (as shown in Figure 1), the total output voltage V_{GF}, at node G with respect to node F, is obtained through superposition, i.e. $V_{GF} = V_{O1} - V_{O2}$ and hence the name "Signal Differencing". Consequently, the transfer function V_{GF} / V_{AB} represents an all-pass filter with phase angle θ of the forms

$$\frac{V_{GF}}{V_{AB}} = \frac{1 - s\tau}{1 + s\tau} \qquad (1)$$

$$\theta = -2 \tan^{-1} (\omega\tau) \qquad (2)$$

where $\theta = -\pi/2$ at $\omega = 1/\tau = I_F / (8CV_T)$.

As mentioned earlier, V_{AB} between nodes A and B and the resulting small-signal, differential, output voltage $V_{A'B'}$ between nodes A′ and B′ possess the opposite polarities. Therefore it can be shown that the relationship between V_{AB} and $V_{A'B'}$ can be written as

$$\frac{V_{A'B'}}{V_{AB}} = -\left[G \left(\frac{1 - s\tau}{1 + s\tau} \right) \right]^2 \qquad (3)$$

where $G = R / r_{e3}$ and $r_{e3} = (2V_T / I_G)$ is the emitter resistance of either Q21 or Q22 of the first stage, or either Q23 or Q24 of the second stage. For steady-state sinusoidal oscillations to be sustained, the ratio $V_{A'B'} / V_{AB}$ must be unity. Therefore, upon setting (3) to unity and rearranging, one obtains

$$s^2 + s\frac{2}{\tau}\left(\frac{1 - G^2}{1 + G^2} \right) + \frac{1}{\tau^2} = 0 \qquad (4)$$

Upon substituting s in (4) with $j\omega_0$, and setting the real and the complex parts to zero simultaneously, the required value of G to sustain steady-state sinusoidal oscillations and the angular frequency of oscillations ω_0 can be written as

$$G = \frac{R}{r_{e3}} = R\frac{I_G}{2V_T} = 1 \qquad (5)$$

$$\omega_0 = \frac{1}{\tau} = \frac{I_F}{8CV_T} \qquad (6)$$

It can be seen from (5) that the required condition for steady-state oscillations can be set by adjustments of I_G. It can be seen from (6) that the frequencies of oscillations are linearly proportional to the bias current I_F and hence the name "Current-Tunable". At the oscillation frequency ω_0, as suggested by (2), the phase angle θ_0 of V_{MN} of the second stage is different from the phase angle θ_1 of V_{AB} of the first stage by $\theta_0 - \theta_1 = -\pi/2$. In order words, V_{MN} and V_{AB} provide quadrature oscillation of values sin θ_0 and cos θ_0, respectively, and hence the name "Sinusoidal Quadrature Oscillator".

4. Simulation Results

The performance of the circuit shown in Figure 1 has been simulated through SPICE. The npn and pnp transistors are modeled by QMPS2222A and QMP3640, where the average transition frequencies (f_T) are at 300 and 500 MHz, repectively. As an example, the values of capacitor C is equal to 1000 pF, bias current I and I_G are approximately 200 uA and 1.2 mA, respectively, and R = 50 Ω. Figure 2 shows the resulting oscillograms of the quadrature waveforms V_{AB} and V_{MN} at, for example, I_F / 2 = 700 µA where the oscillation frequency is measured to be 936 kHz. It can be seen from Figure 2 that V_{AB} and V_{MN} are, as suggested previously, cosine and sine signals, respectively, with 90° phase difference. Figure 3 illustrates comparisons of the plots of oscillation frequencies and amplitudes versus bias current I_F / 2 for cases of ideal analysis and SPICE analysis. It can be seen from Figure 3 that the oscillation frequencies are, as suggested by (6), tunable by the bias current I_F over approximately three orders of magnitude.

Figure 4 depicts the amplitude matching (dB) in terms of the ratio V_{AB}/V_{MN}, as well as the phase matching (deg) in terms of [(phase of V_{AB}) – (phase of V_{MN})] of the quadrature signals versus frequency. It is evident from Figure 4 that the amplitude matchin is 0.004 dB, whilst the phase matching for 90° is better than 0.15°. Figure 5 shows the power levels (dBm) of the fundamental frequency and the next harmonics of the oscillogram V_{AB} depicted in Figure 2 using commercially available fast Fourier transform (FFT) program. It is clearly seen from Figure 5 that distortions are due mainly to the presence of the third harmonics which is approximately 47 dBm down from the fundamental frequency, and they remain essentially at the same magnitude over the entire operational bias-current range (7 µA to 7 mA). The measured total harmonic distortions (THD) of the output waveforms, as shown in Figure 5, are less than 0.5 percent.

Figure 6 illustrates comparisons of the plots of oscillation frequencies and amplitudes versus capacitances, for cases of ideal theory and the SPICE simulated results, and the bias current I_F / 2 is fixed at 700 µA. It is seen that, using a minimum frequency setting capacitances of 100 pF, the upper frequency can be expected at 8 MHz.

5. Discussion and Conclusions

A new fully-balanced current-tunable sinusoidal quadrature oscillator has been presented using r_e tunable signal-differencing all-pass filters as the frequency-selective network. The oscillation frequency is current-tunable over a wide-freqency sweep range of approximately three orders of magnitude. The amplitude matching and the quadrature phase matching are better than 0.004 dB and 0.15°, respectively. The total harmonic distortions are approximately 0.5 percent. The maximum useful frequency of oscillation is approximately 8 MHz. By using better transistors of much higher f_T (e.g. in the region of several GHz) and much smaller value of C (e.g. using stray capacitance), much higher, more useful, values of the oscillation frequency, as suggested by (6), may be expected.

Acknowledgements

The author is grateful to M. Watchakittikorn for his useful suggestion.

References

[1] C.J.M. Verhoeven, "A high-frequency electronically tunable quadrature oscillator", *IEEE Journal of Solid-State Circuits*, Vol.27, 1992, pp. 1097-1100.

[2] A.W. Buchwald, and K.W. Martin, "High-speed voltage-controlled oscillator with quadrature outputs, *Electronics Letters*, 27, 1991, pp. 309-310.

[3] D. A. Johns and K. Martin, *Analog Integrated Circuit Design*, John Wiley & Sons, 1997.

[4] J. Davidse, *Analog Electronic Circuit Design*, Prentice Hall, 1991.

[5] B. Linares-Barranco, A. Rodrigez-Vazquez, E. Sanchez-Sinencio, J.L. Huertas, "10 Mhz CMOS OTA-C voltage-controlled quadrature oscillator", *Electronics Letters*, vol. 25, 1989, pp. 765-767.

[6] J.van der Tang, D. Kasperkovitz, "A 0.9-2.2 Ghz monolithic quadrature mixer oscillator for direct-conversion satellite receivers", *Proceedings of the 1997 IEEE International Solid-State Circuits Conference*, February, 1997, 40, pp. 88-89.

[7] A. Sedra and K.C. Smith, *Microelectronic Circuits*, 4th Ed., Oxford University Press, 1998.

[8] R. Duncan, K. Martin, A. Sedra, "1 Ghz quadrature sinusoidal oscillator", *Proceedings of the 1995 17th Annual Custom Integrated Circuits Conference*, May, 1995, pp. 91-94.

[9] A. Rofougaran, J. Rael, M. Rofougaran, and A. Abidi, "A 900 Mhz CMOS LC-oscillator with quadrature outputs", *Proceedings of the 1996 IEEE International Solid-State Circuits Conference*, Vol. 39, 1996, pp. 392-393.

[10] J. Craninckx, and M. Steyaert, "A CMOS 1.8 Ghz low-phase-noise voltage-controlled oscillator with prescaler", *Proceedings of the 1995 IEEE International Solid-State Circuits Conference*, Vol. 38, 1995, 266-267.

[11] S. Pookaiyaudom and K. Saivichit, "RC phase-shifter variable sinusoidal oscillators using initial conditions-restoration amplitude control", *IEEE Transactions on Instrumentation and Measurement*, Vol. 39, 1990, pp. 1038-1044.

[12] S. Pookaiyaudom and K. Samootrut, " Current-mirror phase-shifter oscillator", *Electronics Letters*, Vol. 23, 1987, pp. 21-23.

[13] S. Pookaiyaudom, B. Srisuchinwong, and W. Kurutach, "A current-tunable sinusoidal oscillator", *IEEE Transactions on Instrumentation and Measurement*, Vol. IM-36, No. 3, 1987, pp. 725-729.

[14] R. Holzel, "A simple wide-band sine wave quadrature oscillator", *IEEE Transactions on Instrumentation and Measurement*, Vol. 42, 1993, pp. 758-760.

[15] J.J. Chen, C.C Chen, H.W. Tsao and S.I. Liu, "Current-mode oscillators using single current follower", *Electronics Letters*, Vol. 27, 1991, pp. 2056-2058.

[16] S.I. Liu and Y.H. Liao, "Current-mode quadrature sinusoidal oscillator using FTFN", *International Journal of Electronics*, Vol. 81, 1996, pp.171-175.

An Investigation of IT Effects on Various Aspects of Organizational Effectiveness

Pituma Panthawi
pituma@nectec.or.th

Summarized from a Dissertation submitted to the Faculty of the Claremont Graduate University in Partial Fulfillment of the Requirements for a Ph.D. Degree in the Management of Information Systems

ABSTRACT – By incorporating level of information technology (IT) investment, availability of hardware and software, computer efficacy of employees, and competency of IT staff in providing services in the examination of organizational IT, and by assessing organizational adaptability, productivity, integration, as well as employee cohesion and development, this study found evidence which indicates positive effects of IT on organizational performance. However, the findings suggest that the relation between IT and performance is by no means simple and straight-forward. That is, the study discovered that contextual conditions of particular organizations (e.g., working culture, competing strategy) appeared to act upon their success in gaining positive IT effects and type of effects they received.

KEY WORDS – Organizational Effects of IT, IT and Organization, IT Productivity Paradox

บทคัดย่อ – ในงานวิจัยนี้ ผู้วิจัยได้พิจารณาทั้งระดับของการลงทุนด้านเทคโนโลยีสารสนเทศ (ไอที) อุปกรณ์ฮาร์ดแวร์และซอฟต์แวร์ที่มีใช้ ความสามารถในการใช้คอมพิวเตอร์ของบุคลากร และความสามารถในการให้บริการของบุคลากรไอที เพื่อประกอบการสำรวจถึงระดับและสภาพของทรัพยากรไอทีขององค์กรนั้นๆ และในการพิจารณาประสิทธิภาพขององค์กร ผู้วิจัยได้วัดทั้งความสามารถในการปรับสภาพเพื่อตอบสนองต่อการเปลี่ยนแปลง ประสิทธิภาพในการผลิตงาน ความสามารถในการควบคุมการปฏิบัติงานให้เป็นไปตามกฎเกณฑ์ รวมไปถึงความเป็นน้ำหนึ่งใจเดียวกันและการพัฒนาของบุคลากร เมื่อรวมปัจจัยต่างๆ ที่กล่าวมานี้เข้ามาในการพิจารณา ผู้วิจัยได้พบหลักฐานซึ่งชี้นำว่าไอทีสามารถก่อให้เกิดผลในทางบวกต่อประสิทธิภาพขององค์กร แต่ที่น่าสนใจไปกว่านั้นคือ ในการศึกษานี้พบว่าความสัมพันธ์ระหว่างไอทีและประสิทธิภาพขององค์กรนั้นมีความซับซ้อนอยู่มาก กล่าวคือผลของการวิจัยได้ชี้ให้เห็นว่าลักษณะเฉพาะขององค์กร ตัวอย่างเช่น วัฒนธรรมในที่ทำงาน หรือนโยบายแข่งขันทางการตลาด มีอิทธิพลต่อความสำเร็จขององค์กรนั้นๆ ในอันที่จะได้รับผลดีจากการใช้ไอที และลักษณะเฉพาะขององค์กรนั้นยังก่อให้เกิดความแตกต่างในประเภทของผลที่แต่ละองค์กรได้รับอีกด้วย

1. Research Purpose and Importance

Apparently, IT has become an important component of organizations. However, researchers have not found an all-agreed conclusion of whether or not the IT-organizational performance relation really exists. For example, Brown et al. (1995) found that firms which were leaders in the employment of strategic information systems experienced greater profitability compared to their industrial indexes. By contrast, Kivijarvi and Saarinen (1995) did not detect significant differences in profitability between firms with varying intensities of information system investment.

This research investigates the impact of information technology (IT) on organizational performance. However, the fundamental purpose of the study is not to provide a statistically derived conclusion in regard to the relation between IT and organizational performance. Rather, its mission is to gain further understanding to explain the inconsistency of the previous findings.

For this study, IT refers to the availability of IT resources within organizations. These resources are comprised of not only the IT tangibles (e.g., hardware, software, and telecommunication devices) but also the knowledge to effectively utilize these tangibles. In addition, unlike many previous studies within the IT-firm performance research domain, the term organizational performance will not restrictively refer to financial accomplishment of organizations. Instead, the study utilizes several effectiveness criteria to assess performance.

Previous studies defined and measured IT and firm performance constructs, and determined whether the relation was positive, negative, or non-existent based on the observed variation (or lack of variation) in the value of the performance variable due to the change in the value of the IT variable. These studies typically involved a large number of organizations since the principal focus was on the statistical validity of the relation. As a result, these studies generally sacrificed the 'depth' (i.e., in-depth investigations within each organization) for the 'width' (i.e., number of organizations included) of their investigations.

These previous studies employed various measures and/or surrogates for IT and organizational performance constructs. However, the one most commonly used surrogate for IT was IT investment; whereas measures of performance included, almost solely, those reflecting profitability of organizations for example, return on investment (ROI) and return on asset (ROA). Collectively, previous empirical findings indicated inconsistent results. Restrictive IT and organizational performance measures may indeed contribute to the observed contradiction in the findings. That is, IT investment does not represent the complete construct of IT within organizations. For example, user IT competency and IT staff competency, which may or may not be induced by the investment, are also parts of organizational IT. Therefore, they too are likely to have substantial effects on the IT-performance relationship. Similarly, profitability cannot invariably and thoroughly reflect the performance of firms. Profitability is affected by numerous external factors (e.g., economic condition, governmental regulations), therefore it is possible that an operationally effective organization may not do well financially.

Due to these deficiencies, the study looks at IT investment, IT capacity, user computer efficacy, as well as IT staff competence to measure organizational IT. Similarly, for performance measurement, instead of using profitability indicators, this study employs four sets of criteria which reflect organizational effectiveness. These sets of criteria are adaptability, productivity, integration, and employee cohesion and development. Adaptability refers to the ability of organizations to adapt to changes. Productivity refers to organizational efficiency in work output planing and producing. Integration refers to the ability to integrate and stabilize various internal components into a collective whole. Lastly, employee cohesion and development refers to the ability of organizations to maintain morale and cohesion among the employees and to help them develop knowledge and skills.

Furthermore, the impact of IT on performance of organizations should not be studied out-of-context as many of the previous studies typically did. IT effects may vary from one organization to another since any particular organization operates within its own environmental context which differs from that of any other organization's. Hence, this research does not restrict its investigation solely to IT and performance. The study examines the environments of the organizations as well. Environmental differences may also explain the discrepancy in the previous findings.

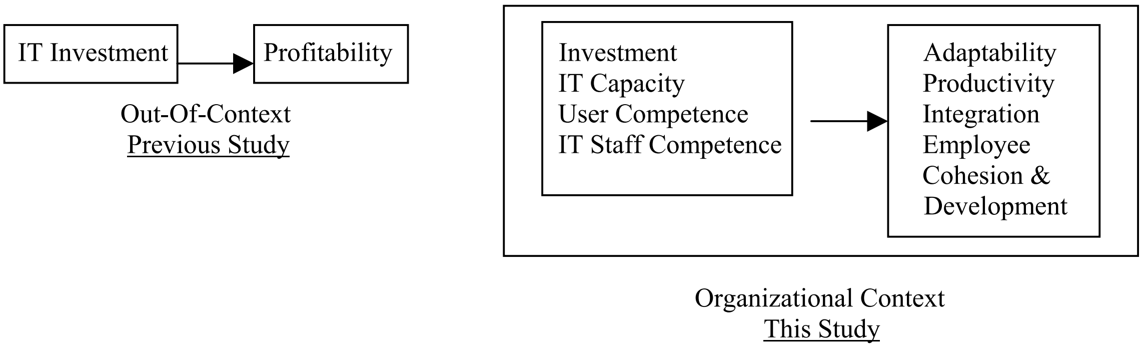


Figure 1. Research Model

In a nutshell, the propositions of this research are the following:
Proposition 1 The restrictive definitions of IT and organizational performance adopted in the previous studies contributed to the inconsistency of their findings.
Proposition 2 The previous studies' omission of organizational context examination contributed to the inconsistency of their findings.

2. The Eight Case Studies

2.1 Research Approach

This research encompasses in-depth case studies of IT effects within eight organizations. These organizations are located in Bangkok, Thailand. The organizations being investigated are in the consumer products[1] and advertising industries. All of these companies are well-known and large in size. Among these companies, the use of computers is primarily for information processing and administration. Furthermore, IT present in these companies is typically mainstream rather than high-tech. Table 1 summarizes the characteristics of the eight companies. Due to the confidentiality agreement between the companies and the researcher, the companies' names are disguised.

Table 1 Participating Companies

Firm	Nationality	Primary Business in Thailand
A	Multinational	Consumer Products
B	Multinational	Consumer Products
C	Multinational	Consumer Products
D	Multinational	Consumer Products
E	Thai	Power Drinks, Pharmaceutical, Consumer Products, Confectionery
F	Multinational	Confectionery, Pharmaceutical
G	Multinational	Pharmaceutical, Consumer Products, Nutrition
H	Multinational	Advertising

[1] soap, detergent, shampoo, toothpaste, etc.

The study possesses both qualitative and quantitative characteristics. As a whole, the research is qualitative in the sense that it involves in-depth examinations of only a small number of units of analysis (i.e., organizations) and it is not aimed at statistical hypothesis testing. However, the quantitative characteristics of the study are shown in its operationalization of the IT and performance variables. That is, the study employs concrete instruments to measure these variables. Furthermore, the study utilizes some statistical analyses on the collected data. Nevertheless, as mentioned earlier, the main purpose of the study is not to draw a statistical conclusion for any particular relation. The results obtained from these statistical analyses will be coupled with the insights obtained from the in-depth exploration of the organizational conditions to produce further understanding regarding the impact of IT on organizational performance.

2.2 Research Instruments

The instruments used in this study are presented in Table 2. These instruments are packaged in two questionnaires: IT questionnaire and employee questionnaire. The IT questionnaire encompasses questions concerning IT investment and IT capacity. For each participating company, the chief information officer (CIO) was typically the respondent of the IT questionnaire. The employee questionnaire incorporates the questions regarding user computer ability, IT staff competency in providing services, and organizational effectiveness in terms of adaptability, productivity, integration, and employee cohesion and development. Within each firm, approximately 30-50 copies of this questionnaire were randomly distributed among office employees. In this study, office employees came from various hierarchical levels. However, the group did not include manufacturing labor.

Table 2 Research Instruments

Variable	Instrument
Investment	[1] IT Investment per Employee [2] IT Expense per Employee [3] Total IT Budget per Employee (Invest.+Exp.)
IT Capacity	[1] Computer per Employee Ratio [2] Variety and Novelty of Application Software
User Competence	Measured by Computer Self Efficacy Instrument (Compeau and Higgins, 1995)
IT Staff Competence	Measured by the Performance Compartment of SERVQUAL Instrument (Pitt et al., 1995)
Adaptability Productivity Integration Employee Cohesion & Development	Measured by Modified Organizational Effectiveness Instrument (Rohrbaugh, 1981) Note: The instrument includes adaptability, productivity, integration, and employee cohesion and development compartments.

Nevertheless, it is not the intention of the study to only rely on the quantitative data collected via the questionnaires to determine IT and organizational performance. The study attempts to accommodate these data with more profound qualitative exploration as appropriate. Please note that the data collection period of this study began in September 1997 and ended in June 1998. During the course of the data collection, Thailand as well as many other countries in the region were facing a serious economic crisis.

2.3 Examination of Organizational Context

As mentioned earlier, this research does not study the IT-performance relation out-of-context. That is, the investigation of the relation also involves an exploration of the organizational environment in which the relation takes place. The primary purpose of the exploration is for the researcher to be aware of organizational conditions which may affect the relation. These conditions include stage of the life-cycle[2], current competitiveness, managerial emphases, working culture, domain of business, and so on. Though these conditions are seemingly non-IT, they too are parts of the collective organizational environment, and are likely to have influences on everything that happens within that environment.

This qualitative exploration is also intended to capture additional insights regarding IT conditions of organizations. As mentioned earlier, this additional qualitative information will be used to augment the quantitative data obtained from the questionnaires. Moreover, this qualitative exploration also enables the researcher to extend the study investigation to include other IT elements which may not be as easily quantifiable as those identified in the research model. (shown in Figure 1) Examples of these elements are tension (if any) between IT staff and users, characteristics of IT use, organization of IT department, overall configuration of IT systems, and recognized significance of IT within organizations. Semi-structured, in-depth interviews with IT and user staff, examination of documents (e.g., newsclippings, corporate documents), and direct observations are data collection techniques used in obtaining this qualitative information.

2.4 Brief Guidelines for Data Analyses

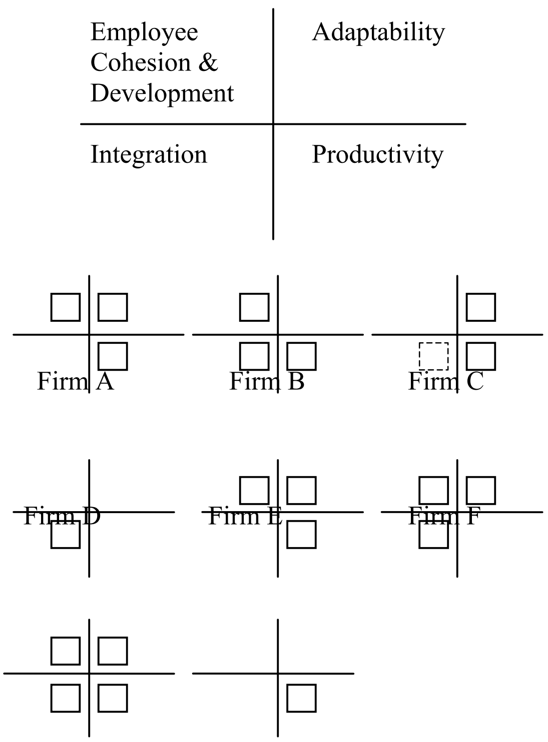
Within each company, linear regressions are conducted between the multi-valued IT variables (i.e., user competence and IT staff competence) and each of the four aspects of organizational effectiveness (i.e., adaptability, productivity, integration, and employee cohesion and development). A simple rule of thumb is

[2] Based on the life-cycle model of Quinn and Cameron, 1983

that if the regression significance is less than 0.05, the regression is statistically significant. Therefore, one can conclude that the independent variables have statistical significance to predict the dependent variable. Simply put, the regression significance of less that 0.05 suggests that the independent variables (i.e., the two multi-valued IT variables) have an effect on the dependent variables (i.e., one of the four aspects of organizational performance). The observed effects (or lack of effects) of IT on particular types of performance within each company, are then explained by level of IT investment, IT capacity (i.e., availability of hardware and software), and all other IT and organizational conditions present in that company.

3. Results

As mentioned earlier, for each organization, the study performs linear regressions between the two multi-valued IT variables and each of the four performance aspects. The regression results are summarized in a graphical form in Figure 2.



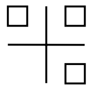
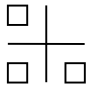
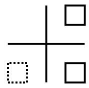
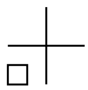
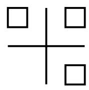
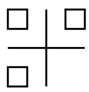
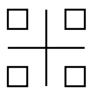
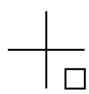
Firm G Firm H

Figure 2 Regression Results

Each quadrant represents a particular aspect of organizational performance included in the research model. That is, the top-right quadrant represents adaptability performance, the bottom-right quadrant represents productivity performance, the bottom-left quadrant represents integration performance, and lastly the top-left quadrant represents employee cohesion and development performance. The existence of a box indicates that the two IT variables, together, have statistical significance (i.e., the regression significance is less that 0.05) to predict the particular performance. In other words, the IT variables have a statistically significant effect on such performance. For example, at company H, the user competence and IT staff competence variables, together, have a statistical significance to predict only the productivity effectiveness of the company. In other words, the findings indicate an effect of IT on only the effectiveness of the company in its productivity performance. The box in the bottom-left quadrant of firm C is drawn using a dotted-line because the significance of the IT-integration performance regression of firm C is equal to 0.057. Obviously, this significance value is not less than, yet very close to, the 0.05 cut-off point.

As discussed earlier, the observed IT effects or lack of effects will be explained by IT and organizational conditions of particular companies. To make the rationalization easy to comprehend the regression results, values of IT variables, and other observed conditions are summarized and reported in Table 3. The table looks rather simple, however its content is actually a result of long and demanding research investigations.

Table 3 Summary of Results

firm	invest ment	PC	soft ware	user	IT staff	stage	outstanding characteristics	performance	effects
A	100 (60+ 40)	0.8	A	3.17	B	3	Aggressive competitor, Versatile and Initiative focused Company	Excellent due to aggressive marketing strategy enabled by strong financial power	
B	103 (6+ 97)	0.63	A	2.89	A	3	Persistent and Conservative Competitor, Stable rather than Versatile company	Starting to take a lead in certain segments	
C	114 (51+ 63)	1	A	3.72	B	3	Have a highly competitive working atmosphere	Facing stagnation in sales growth but having many more opportunities in the horizon	
D	100 (40+ 60)	0.8	A	3.72	C	4	Have a noticeable tension between IT and user staff	Notably dissatisfactory due to the difficulty in changing their trade practice	
E	27 (7+ 20)	0.21	A	3.38	B	4	Has expanded into many different business domains	Hindered by the current economic meltdown but still surviving	
F	108 (29+ 79)	0.56	B+	3.49	B	4	Had a recent market repositioning of a major product	Somewhat hindered by the economic drop but continues to maintain a strong competitive position due to market repositioning of a major product	
G	49 (20+ 29)	0.58	A	3.39	B	3	Have significant differences in business practice across divisions	Having high growth in recent years but facing substantial drop this year due to governmental regulations	
H	No data	0.73	A	3.46	A	4	Have a high concern for data confidentiality	Somewhat hindered by the economy but continues to maintain a strong competitive position	

Unit Investment (present year) = thousand bath per employee
PC (including all types of end-user computer) = computer per employee

User = user computer competency scores (0 = inability 5 = excellence)

The 'investment' column reports IT budget per employee of each firm. The two figures in the parenthesis refer to IT capital investment per employee and IT expense per employee consecutively. Please note that the investment figures are reported in thousand baht. The 'PC' column reports end-using computer per employee ratios of particular firms. In the 'software' column, letter grades are used to illustrate software variety and novelty of the firms. Apparently, the eight companies being studied do not have much difference in terms of its software advancement.All of these firms have all the common office applications such as word processor, spreadsheet, presentation software, e-mail, etc. available. Some of these companies have video conferencing technology in place. Also, customized data queries are available to the employee users in many of these firms.In comparison to other business companies in Thailand, these eight companies are quite advanced in regard to their IT technology. However, among these eight, firm F is slightly less advanced in its software variety and novelty.

The figures shown in the 'user' column are the mean scores of user computer efficacy measured by the computer self-efficacy scale. The possible score range is from 0 to 5.Zero represents inability; whereas 5 represents excellence. The 'ITstaff' column displays, in letter grades, the user-perceived competencies of the IT staff in providing IT services. Apparently, firm D is considerably inferior in this respect. Within firm D, data collected via the employee questionnaires indicate substantial dissatisfactions of the users towards their company's IT staff. Additional insights collected through the interviews are consistent with the questionnaires' results.The 'stage' column describes the stage of the life-cycle of each organization. The number '3' refers to the stage of formalization and control (growth); whereas the number '4' refers to the stage of elaboration of structure (maturity). The 'outstanding characteristics' column summarizes observed characteristics of individual organizations. The 'performance' column describes current business performance of the eight firms. Finally, the last 'effects' column displays, in a graphical forms, the IT effects appeared in particular organizations.

4. Discussion

4.1 Pattern of IT effects

Referring to Table 3, one can see that all of the companies succeed in gaining IT effects on at least one of the aspects of performance effectiveness. Evidently, the pattern of IT effects of a particular organization is generally different from that of another organization. That is, of all the eight participating companies, only two of them (i.e., A and E) obtain the same pattern of IT effects.

Most interestingly, the study finds evidence which indicates that there are associations between organizational practices, resulting effects of IT, and business performance of organizations. For example, within firm A, there appears to be an alignment between the obtained IT effects and the business emphases of the company. That is, as mentioned in the table, A is an aggressive market competitor. Furthermore, within the company, initiatives are encouraged and valued. Therefore, it is not surprising to find that within this company, IT is not used in a way that results in integration enhancement. Reasonably, integration effectiveness, which has its focus on stabilization and control, should not be of substantial interest to the company that largely values inventiveness and readiness to compete aggressively in its market.

Besides firm A, firm B is the other company that still is doing exceptionally well despite the current national economic slump. As one may see, the pattern of IT effects of firm B differs from that of firm A. For firm B, the effects are on productivity, integration, and employee cohesion and development but not adaptability effectiveness. Though both companies are doing well, they are distinctively different with regards to their competing schemes. That is, firm A is a speedy attacker; whereas firm B is a persistent player. Furthermore, these two opponent companies are also substantially different in their internal working tradition. That is, for A, cross-functional job rotation is more or less a company norm; whereas for firm B, it is rare. For example, the current HR director of firm A actually had his education in mechanical engineering and initially began his career with the company in the manufacturing function. Conversely, in firm B, it is unusual to find an employee with an educational background that is inconsistent with her/his job position. The HR director of firm B stated that the company believes in finding the right person with the right educational qualification for the job and once a person is appointed to a certain position within a certain function, she/he will normally be staying within that function. The difference in job rotation practices further indicates the difference in organizational characteristics between these two firms. By and large, firm A is a versatile organization; whereas B is a more stable business entity. Due to the company's marketing practice (i.e., persistent player as opposed to speedy attacker), and internal organizational characteristics (i.e, stability as opposed to versatility focus), it is not surprising that within firm B, IT is not used in a way that would result in an enhancement of the adaptability effectiveness of the firm. Again, the findings of firm B indicate an alignment between organizational practices and the resulting IT effects.

An opposite case is firm D. It is a company with an unfavorable business performance. Apparently, the present unsatisfactory performance is a result of the company's inability to effectively respond to a major change in the market environment (i.e., from traditional-trade market to modern-trade market). Evidently, the regression results of firm D indicate that there are IT effects on only integration and not any of the other three aspects of effectiveness. In other words, the detected IT effects imply that, within firm D, IT is used to enhance organizational stability and control. However, to get through this displeasing business situation, stability and control are the least important values onto which the company should hold. To survive, firm D would need to redefine its business practices and make changes instead of stabilizing and controlling existing business routine. This misalignment between the appropriate practice the company should adopt and the actual IT effects the research found may help to explain the poor business performance of the company.

The IT-performance regression findings of firm C and firm H also give additional evidence which indicates that organizational practices influence how IT is used, which in turn, determines types of IT effects organizations receive. As mentioned in the table, competition among employees within C is very intense. Therefore, it is not surprising to find no IT effect on the employee cohesion and development effectiveness of the firm. Since the employees of firm C perceive one another more or less as competitors, it is therefore unlikely for them to use IT to promote employee adherence.

Confidentiality is a central concern of firm H. As an advertising agency, it has to do all it can to protect its clients' information. A fundamental strategy of firm H is to limit access of any confidential information only to those who really need them. Therefore, there is not much information sharing across the company network. As a result, computers are generally used for producing individual work outputs such as artwork, client reports, and presentation materials. Correspondingly, the research findings indicate effects of IT only on productivity (i.e., output planning and producing) effectiveness of the company.

Referring to Table 3, one can see that firm G is the only company that succeeds in gaining positive IT effects on all of the four aspects of performance. Nonetheless, of all the eight companies included in the study, it is not the company with the best business performance. There are two main reasons for their under-expected performance. First, many of the medicine products of firm G are imported, therefore the company sales are hindered by the new governmental restriction against imported medicines. Second, one of its very successful product, baby formula, is also imported. Due to the recent devaluation of Thai baht, its costs have dramatically increased. Unfortunately, baby formula pricing is under governmental regulation. As a result, firm G cannot instantly and freely adjust the price according to the new costs. With an attempt to maintain the product presence in the market, the company decides to sell this product even at less than costs. The findings of firm G suggest that the success of an organization in gaining substantial IT effects on its performance effectiveness is definitely not an adequate determinant of its success in the business competition. Obviously, there are many more factors that can affect the business success of a firm.

By and large, the research finds that organizational characteristics, to an extent, help explain the pattern of IT effects of organizations. The phrase "to an extent" is emphasized because within this study, the researcher is able to explain patterns of IT effects of some, but not all, of the organizations. In the case of firm F, for instance, it is not obvious to the researcher why, within this company, there are no effects of IT on productivity performance of the firm. Similarly, in the case of company E where the pattern of the effects is identical to that of A, the researcher found no profound evidence to explain why the pattern is as it is. The only clue the researcher has is that this company has been expanding into many new business domains since its establishment a century ago. This history of many domain expansions might have made integration an unimportant value to the company.

The study cannot use organizational practices to explain all of the patterns of IT effects. Yet, by and large, the evidence which indicates the association between organizational practices and IT effects is too substantial to ignore. In certain organizations where the researcher cannot relate the pattern of the effects to certain organizational factors there is perhaps no dominating characteristic. Instead, many factors might have been simultaneously and equally playing a role in shaping the company's use of IT. In such cases, it would be difficult to associate the resulting IT effects to any particular factors.

To summarize this discussion, the following suggestions are drawn:

1.Organizational practices(e.g.,competing strategy, working tradition, employee disposition) influence how IT is used, which consequently determines the type of effects an organization obtains. This statement is graphically presented in Figure 3. As mention earlier, during the course of the data collection (from September 1997 to June 1998), Thailand was facing a critical economic setback. It is possible that this economic crisis increased the chance of this cross-sectional study to detect the organizational practices-IT use/effects association. The organizational practices-IT use/effects turnaround time might have been shortened by the urgent need to survive.

2. Misalignment between the type of performance effectiveness that IT enhances and the desired type of effectiveness the organization seeks (i.e., as found in firm D), contributes to poor business performance.

3. The success of an organization in gaining positive IT effects on its performance effectiveness is not an adequate determinant of its success in business competition. There are many more factors besides IT (e.g., product cost structure, govermental regulation, economic condition) that affect business outcomes of organizations.

4.2 Ingredients of IT Success

The study found no evidence to suggest that either IT investment, availability of user computers, or efficacy of employees in using computers alone can predict the success of organizations in gaining IT effects (see ‘investment’, ‘PC’, ‘user’, and ‘effects’ columns of Table 3). In other words, there appears to be no association between any of these variables or ingredients and the success of organizations in gaining IT effects. For example, firm A and firm D are the two firms with exactly the same level of IT investment, however they are very different in their IT success. That is, firm A receives IT effects on three of the four performance aspects; whereas D receives the effects on only one of the effects. Nonetheless, one limitation of this study is that it considers only the present year investments of the companies; whereas accumulative investments are not included in the investigation.

Likewise, neither computers per employee ratio nor employee computer efficacy is a determinant of IT success. With regard to software advancement, due to the lack substantial differences among the firms, the study cannot draw any specific conclusion.

Interesting findings lie in the influence of quality of IT services on the effects of IT on organizational performance. The study results suggest that the quality of IT services is one ingredient that has a substantial consequence on IT effects. By comparing the seven marketing-manufacturing firms (firm A to G) with a similar nature of IT use, one can clearly see that company D has the least success in achieving IT effects. The user-perceived quality of IT services of firm D is distinctly lower than those of the other firms. It is reasonable to suggest that this deficiency of IT service quality contributes to the downfall because firm D is not inferior to other firms with respect to the availability of any other ingredients such as investment, hardware, software, and computer efficacy of employees.

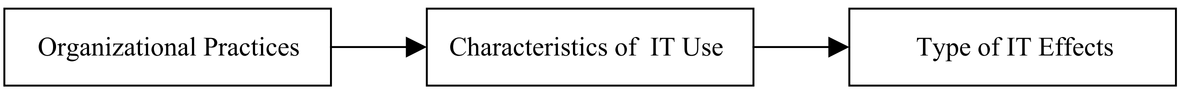


Figure 3 The Influence of Organizational Practices

Besides IT service quality, the study detects that organizational characteristics are also key to IT effects. As discussed earlier in the pattern of IT effects sub-section, organizational practices influence characteristics of IT use, which in turn, influence type of IT effects. In the case of firm H, there are IT effects on only the productivity aspect of performance. However this observed scarcity of IT effects is not caused by a deficiency in any of the direct IT ingredients. Rather, it is a result of the restriction on the use of IT due to the information confidentiality concern of the company.

Evidently, the research findings do not suggest that an organization's stage of the life-cycle can predict the pattern of IT effects. That is, there is no similarity in the pattern of effects among the firms at the same stage. Moreover, some firms at a different stage (i.e., A versus E), indeed, have an identical IT effect pattern.

Same-staged organizations may be different in their characteristics. For instance, A and B, which are both in a formalization and control (growth) stage, are substantially different in their business practices. Therefore, it is not necessary that same-staged organizations would use IT in the same manner and consequently receive similar patterns of IT effects. Likewise, different-staged companies may share some characteristics in common. Therefore, it is possible for different-staged organizations to use IT in a similar manner and receive similar patterns of IT effects.

5. Concluding Remarks

By not restricting the definitions of IT and performance to IT investment and profit attainment, the study found positive IT effects. More interestingly, the study detected that the contextual conditions of particular organizations have influences on the organizations' success in gaining IT effects and type of effects they received. The evidence found implies that IT seems to have become an integral and indivisible element of a compound organizational entity. Therefore, it is noticeable that the use of IT within any particular organizations is shaped by their overall practices and behaviors.

These research findings stimulate the need to include more composite IT and performance measures and examination of contextual conditions to study the IT-organizational performance relation. The evidence found suggests that restrictive measures of IT and organizational performance, as well as omission of contextual exploration may have contributed to the discrepancy in the previous research findings.

References

Brown, R.M., Gatian, A.W., and Hicks, Jr., J.O., "Strategic Information Systems and Financial Performance," *Journal of Management Information Systems*, 11(4), 1995, pp. 215-248.

Compeau, D.R. and Higgins, C.A., "Computer Self-Efficacy: Development of a Measure and Initial Test," *MIS Quarterly*, 19(2), 1995, pp. 189-211.

Kivijarvi, H. and Saarinen, T., "Investment in Information Systems and the Financial Performance of the Firm," *Information & Management*, 28, 1995, pp. 143-163.

Pitt, L.F., Watson, R.T., and Kavan, C.B., "Service Quality: A Measure of Information Systems Effectiveness," *MIS Quarterly*, 19(2), 1995, pp. 173-187.

Quinn, R.E. and Cameron, K., "Organizational Life Cycles and Shifting Criteria of Effectiveness: Some Preliminary Evidence," *Management Science*, 29(1), 1983, pp. 33-51

Rohrbaugh, J., "Operationalizing the Competing Values Approach: Measuring Performance in the Employment Services," *Public Productivity Review*, June 1981, pp. 141-159.

Machine Vision for Automated Visual Inspection of Cotton Quality in Textile Industries Using Color Isodiscrimination Contour

Prinya Tantaswadi
Department of Electrical Engineering
Sirindhorn International Institute of Technology,
Thammasat University
Pathumthani 12121, Thailand

ABSTRACT – Application of machine vision for automated visual inspection of cotton quality in textile industries is proposed. This automated visual inspection can be done by analysis of cotton image. The analysis involves color discrimination between cotton and impurities. Colors can be quantitatively described by color coordinates. Generally, human observers cannot discriminate between two colors if they can be described within an isodiscrimination contour. To inspect the quality of cotton, the cotton image will be analyzed for impurities using this isodiscrimination contour. The issues of signal processing and illuminations will also be discussed. These factors can contribute to errors in the inspection system. Also, a method for significantly improving speed of image processing will be mentioned.

KEY WORDS – Machine Vision, Color Identification, Isodiscrimination Contour, Textile Industry, Automated Visual Inspection, and Color Lookup Table

บทคัดย่อ -- บทความนี้เสนอการประยุกต์ ใช้งาน Machine Vision ในการตรวจสอบคุณภาพของฝ้าย ซึ่งสามารถทำได้โดยการวิเคราะห์ภาพสีของฝ้าย โดยการใช้การแยกสีของฝ้ายและสิ่งเจือปน สีทุกสีสามารถระบุได้โดย color coordinate เราไม่สามารถแยกความแตกต่างระหว่างสองสีได้ถ้าสีสองสีมี coordinates อยู่ภายใน color isodiscrimination contour เราใช้หลักการนี้วิเคราะห์ภาพสีของฝ้ายเพื่อหาสิ่งเจือปนในฝ้าย บทความนี้กล่าวถึงการวิเคราะห์ภาพสีและผลของการส่องสว่าง และจะกล่าวถึงปัจจัยหลักที่ทำให้การวิเคราะห์ผิดผลาด รวมถึงเสนอวิธีที่ทำให้การวิเคราะห์นี้เร็วขึ้นโดยใช้ color lookup table ซึ่งสร้างจากหลักการ color isodiscrimination contour

คำสำคัญ – Machine Vision, การระบุสี, Isodiscrimination contour, อุตสาหกรรมสิ่งทอ, Automated Visual Inspection, Color Lookup Table

1. Introduction

Applications of automated visual inspection of color images have been limited by several factors for use in industry. Those factors are hardware complexity, high cost, large memory requirements and long processing time [1,2]. The application of low-cost machine vision for automated visual inspection of cotton quality in textile industries is proposed. This inspection of cotton quality can be done by identifying cotton and impurities using color image processing. Impurities should be separated from cotton before processed to the final product. The analysis involves color discrimination between cotton and impurities. Colors can be quantitatively described by color coordinates.Criterion for color discrimination or identifying impurities will be based on the Commission Internationale de l'Eclairag(CIE) standard. Then CIE-Luv color coordinates will be used.

2. Identifying Impurities

The automated visual inspection system of cotton quality consists of color video camera and an image acquisition board working within a personal computer (PC). The color camera transfers the color video signals to the image acquisition board. This board provides conversion of images to an RGB format. We apply a CIE-Luv criterion, which bases on perception of human observer that cannot discriminate between two colors if they can be described within isodiscrimination contour. Firstly, the qualitative description of color in RGB and CIE-Luv coordinates will be discussed. Secondly, the fundamental of CIE-Luv isodiscrimination contour will be calculated for the inspection of cotton quality. Finally, a lookup table of cotton color will be created isodiscrimination contour for cotton color identification.

One of popular color coordinates for computer applications is RGB coordinate. However, an Euclidean distance in this coordinate cannot be used for color comparison, while the distance in the CIE-Luv coordinate can. The RGB to Luv transformation can be expressed as [3]

$$L = \begin{cases} 116(\frac{Y}{Y_n})^{1/3} - 16 & (\frac{Y}{Y_n}) > 0.008856 \\ 903.3(\frac{Y}{Y_n}) & (\frac{Y}{Y_n}) < 0.008856 \end{cases} ,(1)$$

$$u = 13L(\frac{4X}{X+15Y+3Z} - \frac{4X_n}{X_n+15Y_n+3Z_n}), (2)$$

$$v = 13L(\frac{9Y}{X+15Y+3Z} - \frac{9Y_n}{X_n+15Y_n+3Z_n}), (3)$$

where X_n, Y_n, and Z_n are constants of values 0.358, 1.0, and 1.09, respectively. The definition of *X*, *Y*, and *Z* can be described by

$$X = 0.4306*R + 0.3415*G + 0.1784*B, (4)$$
$$Y = 0.2220*R + 0.7067*G + 0.0713*B, (5)$$
$$Z = 0.0202*R + 0.1295*G + 0.9394*B, (6)$$

where R, G, and B are values of red, green, and blue, respectively, in the RGB coordinate. Each prime color (R, G, or B) has 256 different values (ranging from 0 to 255) or 2^8 and can be represented by 8 bits of binary data in computer. The 24-bit (three 8-bit representations of R, G, and B) RGB color coordinate will be used for our system. Color images of inspected cotton, consisting of piece (s) of cotton and background, are transferred to the PC. Then, color of each image pixel will be processed and identified whether it is cotton, impurities, or background color.

<u>Criterion for the Same Color: Isodiscrimination Contour</u>

The Euclidean distance of two colors (between reference and measured color) in CIE-Luv coordinate is given by

$$\Delta E_{Luv} = \sqrt{(\Delta L)^2 + (\Delta u)^2 + (\Delta v)^2}, \quad (7)$$

where Δ quantities on the right hand side of the equation represent differences between the corresponding coordinates of the two colors. For color comparison, if value of the Euclidean distance in CIE-Luv coordinate, which was shown experimentally for color discrimination of human perception, is 3, two colors can be reliably discerned by a human observer. We can generate CIE-Luv values, within the threshold distance of 3, into a lookup table (LUT). It is also known as isodiscrimination contour. The identifying impurities can be done by comparing the color of each pixel (in RGB coordinate) to all possible colors of cotton in the lookup table. If the color of the pixel is not in the lookup table, it is determined as impurities. Therefore, the more the number of RGB values in the lookup table, the more accurate the identifying but the longer the processing time.

For example, calculation of lookup table can be done as follows:

I. A color with RGB coordinates of R=255,G=249, and B=255 or (255,249,255) is chosen as cotton color because of its the most frequently occurring of cotton color.
II. Transformation of RGB to CIE-Luv coordinate. Substitute R=255, G=249, and B=255 in equations (4), (5), and (6) to obtain the values of X, Y, and Z. Then, applying the values of X, Y, and Z in equations (1), (2), and (3) results in L=99.35, u=1.42, v=-1.71, respectively.
III. Euclidean distance ($\Delta E_{Luv} < 3$) results in isodiscrimination contour shown below Ranges of L, u, and v are as follows: L is between 96.35 and 102.35, u is between –1.58 and 4.44, and v is between –4.71, -1.29, respectively.

IV. Values of CIE-Luv coordinate satisfying III and equation (7) will be converted to values of corresponding RGB coordinates. These values will be in lookup table used for recognition of cotton color of our automated inspection system. Calculate the valid Euclidean distance among the range of L, u, and v by varying the increment of 0.5.

V. After the isodiscrimination contour in CIE-Luv lookup table is prepared, conversion to RGB (the format used in color comparison of the system) lookup table.

VI. Transformation from CIE-Luv to RGB coordinate, the format obtained from the image acquisition board, can be done as follows:
Firstly, CIE-Luv can be converted to XYZ coordinate by equation (1) and (2).
Finally, XYZ can then be transformed to RGB coordinate by following relations:

$$R = 3.0633 * X - 1.3933 * Y - 0.4758 * Z, \quad (8)$$
$$G = -0.9692 * X + 1.8760 * Y - 0.0416 * Z, \quad (9)$$
$$B = 0.0679 * X - 0.2288 * Y - 1.0693 * Z, \quad (10)$$

VII. There are 450 different values in the final RGB lookup table. These numbers affect signal processing speed and accuracy of identifying impurities.

3. Implementation and Results

Automated visual inspection shown in Fig. 1 consists of color video camera, image acquisition board working within a PC, and a lighting system. The cotton is illuminated by daylight (D65- one of standard light sources using by CIE) lamps inside controlled environment because illumination or color of the light source affects apparent cotton color. Image acquisition board converts color signals from video camera to RGB format and then the computer identifies impurities in cotton by color discrimination between cotton and impurities using isodiscrimination contour mentioned earlier. Cotton with high impurities will be rejected and put in a collecting bin by rejection mechanism such as a separation flap shown in Fig. 1.

Images captured from cotton in motion (under illumination controlled environment) as shown in Fig. 1 are in 24-bit RGB format. Each image contains 180 by 126 pixels and occupies 16 by 11.25 centimeters in length and width, respectively. The resolution of each pixel is 0.089 cm (16 cms/180 pixels). Image analysis includes edge detection and finding area of cotton and identifying impurities. Fig. 2-a shows image of cotton at the center surrounded by background (dark color). We use purple as our background color to be easily distinguishable from color of cotton and impurities such as loose threads, plastics, cottonseeds, leaves, and *etc*. Impurities are to the right of the center of the image.

Threshold size of impurities is set to 0.1 cm^2 or 13 square pixels, calculated from 0.1cm^2/ [$(0.089\ cm)^2$ for 1 square pixel]. A spot of impurity is defined as at least 13 pixels connected together (one pixel can connected to eight possible adjacent pixels). If less than 13 pixels and the color is not background, the spot is regarded as noise (too small a size for a spot of impurity). Cotton is identified and assigned black color in Fig. 2-b. Background and impurities are assigned different colors (purple and white, respectively) but are shown in white color in Fig. 2-b. To identify cotton color a 24-bit RGB lookup table is used. A better method for color identification is using a 3-dimensional lookup table (3D-LUT) array to identify cotton color. The LUT is a block of random access memory (RAM) whose address inputs are corresponding to three independent coordinates of red (R), green (G), and blue (B) [1]. In the memory array, a three dimensional area of 450 values (in isodiscrimination contour) can be defined by setting the contents to logic 1. The remaining locations within the 'color cube' are set to 0. Using RGB coordinates in LUT would result in very large 'color cube' (256*256*256 bytes or 16 Megabytes of memory).
We observe the range of values in the original lookup table and come up with the minimum threshold of each color coordinate. From these values, we design an equally accurate but

smaller lookup table which results in a smaller memory array of 15,625 bytes (25*25*25 bytes). The speed of image processing is greatly improved and memory requirement is greatly reduced.

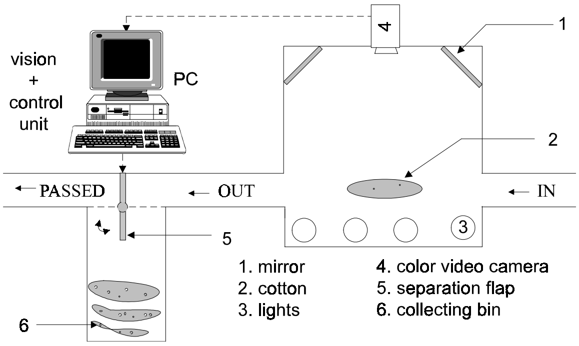
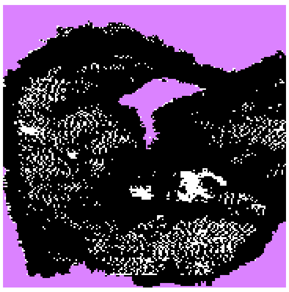


Fig.1 Experimental setup

(2-a)



(2-b)

Fig. 2 Cotton image (a) before and (b) after identifying impurities using color isodiscrimination contour.

Fig. 2-b shows satisfying result. However, some scattered white points in cotton indicates that some of the cotton values are not in the lookup table, which may result from relative large increment size of 0.5 of the isodiscrimination contour and some shadows because cotton surface is not flat. Some factors contributing to errors in the inspection system are:

I. lighting system includes illumination, brightness, and color spectrum of light source.
II. number of elements in 3D-LUT involves Euclidean distance and Luv step increment for generating isodiscrimination contour. There is trade-off between accuracy and processing time. The optimum number of elements is 450 and Euclidean distance of 3 and Luv step increment of 0.5.
III. resolution or size of each pixel in the image
IV. types of impurities such as color, surface reflectance, and size.
V. video camera setting such as exposure control, f-stop, and frame rate.

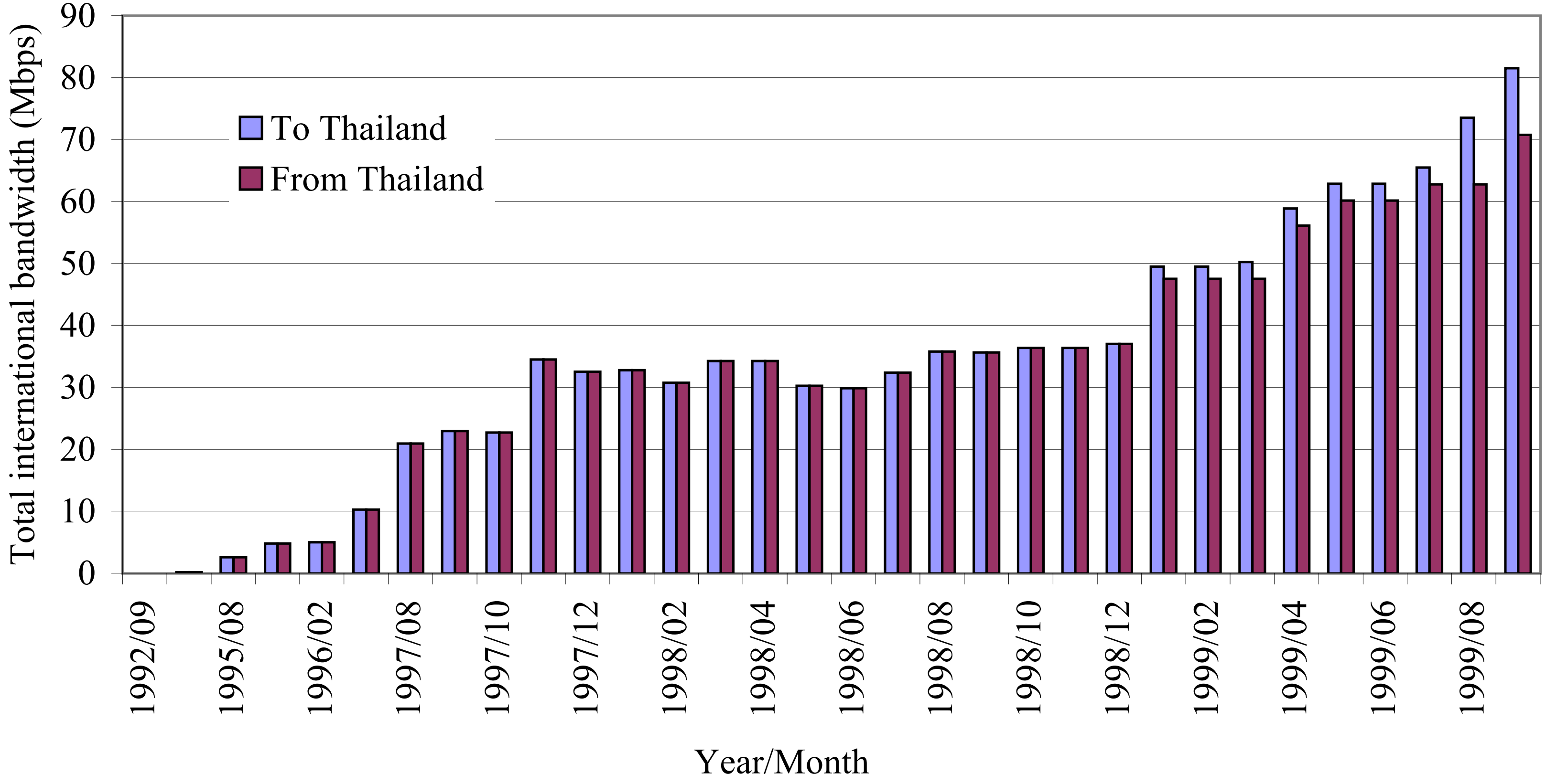
4. Conclusion

The automated visual inspection of cotton quality makes use of color isodiscrimination contour criterion. The important factors for color image processing are lighting system (under controlled environment), video camera setting, and image processing algorithms such as edge detection and reduced 3D-LUT technique.

Reference

[1] Gunawardena, C.A., et al., "A Spot-Type Defect Detection and Colour Identification System for Agriculture Produce," *IEEE: IECON'91*, pp. 2531-2534.
[2] Mital, D. P., et al., "Colour Vision for Industrial Applications," *IEEE:IECON'90*, pp. 548-551.
[3] Brainard, D. H., Colorimeter in Handbook of Optics, Optical Society of America, Vol.1, 1994, pp. 26.1-26.54.

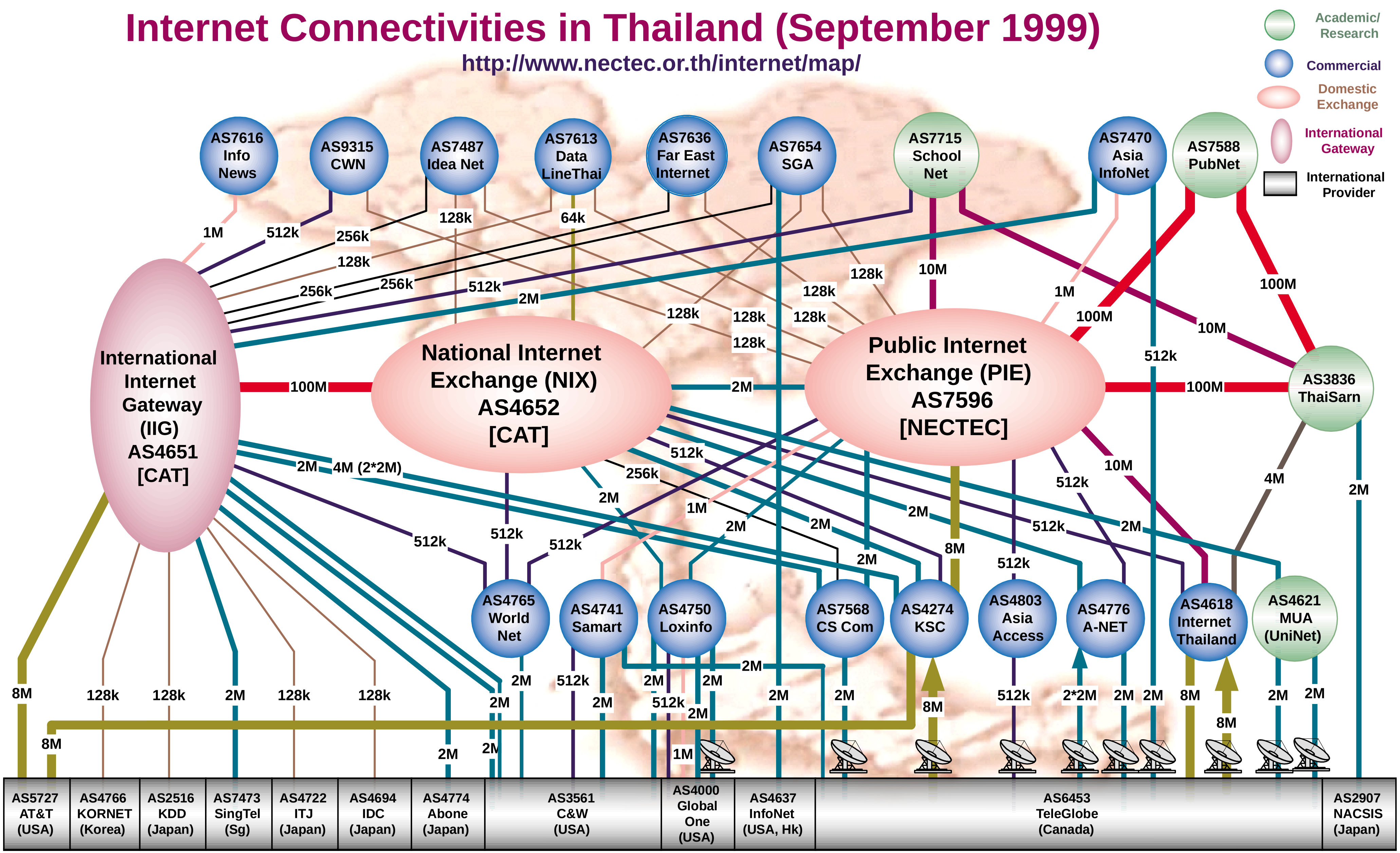
Growth of International Bandwidth of Internet in Thailand



ที่มา: Internet Information Resource Center

Internet Connectivities in Thailand (September 1999)

http://www.nectec.or.th/internet/map/



DISCLAIMER

Chart Date: 1999-09-01

ไทยสาร ThaiSarn