Making expert thinking visible

Salman Durrani

SMIEEE SFHEA MIEAUST

Senior Lecturer

Research School of Engineering, CECS

Australian National University

ANU CMBE & CPMS & CECS Teaching and Learning Colloquium

Tuesday, 2 June 2015

Outline

- **Background**
  - Discipline background
  - Cognitive apprenticeship model
- **Making thinking visible: Strategies to engage students**
  - Document Camera
  - Industry leading simulation tools
- **Making thinking visible: Strategies for lecturers**
- **Conclusions**

Electronic Engineering

ENGN2218 Electronic System and Design (180 students in Sem 1, 2015).

Electronic engineering deals with the use of devices and systems to generate, measure and transmit electrical signals.

25 Microchips That Shook the World

A list of some of the most innovative, intriguing, and inspiring integrated circuits

By Brian Santo
Posted 1 May 2009 | 13:30 GMT

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spectrum.ieee.org/semiconductors/processors/25-microchips-that-shook-the-world

Electronic Engineering

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25 Microchips That Shook the World

A list of some of the most innovative, intriguing, and inspiring integrated circuits

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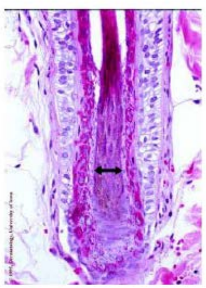
1. **Bipolar Junction Transistors**:
   - **One of the greatest inventions in modern history. Invented in 1947; Nobel Prize in 1956**
2. **Op-amp**:
   - **741 op-amp listed at NO. 6**
3. **Digital Electronics**:.
   - **70% of chips listed are Digital electronics chips**
4. **555 Timer**:
   - **555 Timer listed at NO. 1 in the list of Top 25 Chips ever invented !!**

Electronic Engineering

© **Dr. Philipp Zhang, Chief Scientist, Huawei Technologies**

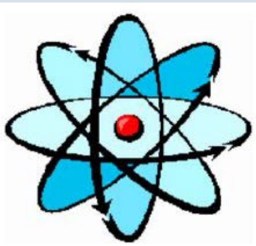
(Keynote talk at 22nd IEEE ICT conference in Sydney, April 2015)

Chips in Mobile Terminals



Hair

10 000 nm



Atom

0.1 nm

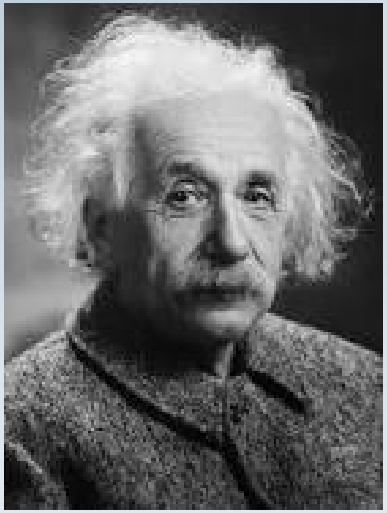
<table>
<tr><th>Chips</th><th>2011</th><th>2013</th><th>2015</th></tr>
<tr><td>Application Processor</td><td rowspan="2">45nm (Dual Core)</td><td rowspan="5">28nm (Quad Core)</td><td rowspan="7">14/16nm (Octa Core)</td></tr>
<tr><td>Baseband Processor</td></tr>
<tr><td>WiFi</td><td rowspan="3">65nm</td></tr>
<tr><td>BT/FM</td></tr>
<tr><td>GPS</td></tr>
<tr><td>NFC Controller</td><td></td><td>40nm</td></tr>
<tr><td>RF/Transceiver</td><td>40nm</td><td>28nm</td></tr>
<tr><td>DRAM</td><td>20nm</td><td>15nm</td><td>10nm</td></tr>
<tr><td>NAND Flash</td><td>20nm</td><td>15nm</td><td>10nm</td></tr>
<tr><td>Audio/Video Codec</td><td rowspan="2">180nm</td><td rowspan="3">130nm</td><td rowspan="5">65nm</td></tr>
<tr><td>Power Management IC</td></tr>
<tr><td>Noise Cancellation IC</td><td rowspan="2">130nm</td></tr>
<tr><td>Touchscreen Controller</td><td>90nm</td></tr>
<tr><td>Gesture Recognition</td><td rowspan="2">250nm</td><td>90nm</td></tr>
<tr><td>e-Compass/e-Gyroscope</td><td>180nm</td><td>180nm</td></tr>
<tr><td>Total Devices</td><td>8</td><td>9</td><td>5</td></tr>
</table>

Teaching & Learning Philosophy

Since electronic engineering is a rapidly evolving discipline, what approach can we take to best prepare our students?

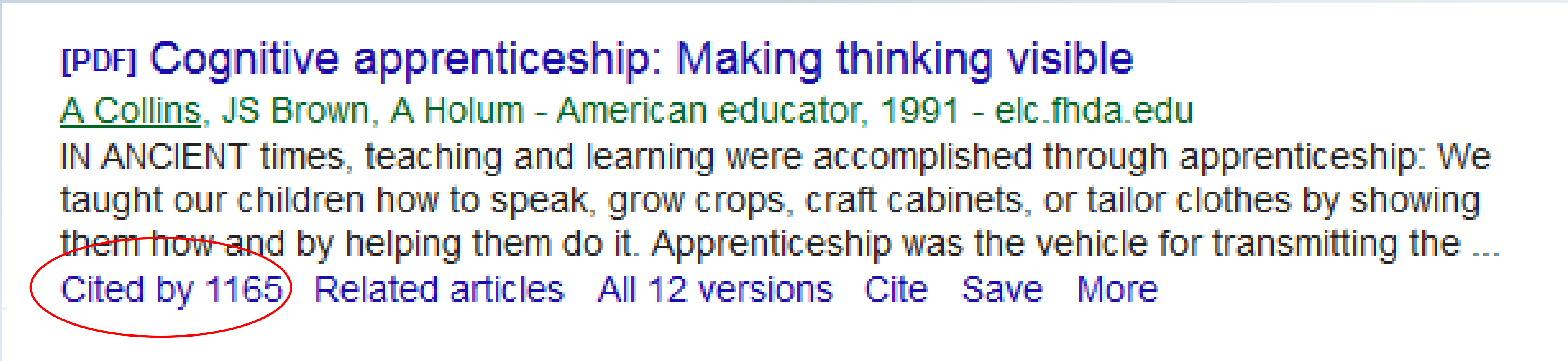
Teaching & Learning Philosophy

Education is what you are left with after you have forgotten the course content.



Cognitive Apprenticeship

Cognitive apprenticeship is a structured model of learning with the basic goal of "**walking the students through the processes that our minds automatically go through as experts**".


[PDF] Cognitive apprenticeship: Making thinking visible
A Collins, JS Brown, A Holum - American educator, 1991 - elc.fhda.edu
IN ANCIENT times, teaching and learning were accomplished through apprenticeship: We taught our children how to speak, grow crops, craft cabinets, or tailor clothes by showing them how and by helping them do it. Apprenticeship was the vehicle for transmitting the ...
Cited by 1165 Related articles All 12 versions Cite Save More

Cognitive Apprenticeship

"Teaching methods should be designed to give students the opportunity to observe, engage in, and invent or discover **expert strategies in context**".

Modeling teacher performs a task so students can observe

Coaching teacher observes and facilitates while students perform a task

Scaffolding teacher provides supports to help the student perform a task

Articulation teacher encourages students to verbalize their knowledge and thinking

Reflection teacher enables students to compare their performance with others

Exploration teacher invites students to pose and solve their own problems

Cognitive Apprenticeship

- Teaching our Future Professionals to “Think like a Physicist” (2014)

Dr John Debs & Dr Nick Robins Citation for Outstanding Contribution to Student Learning	Research School of Physics CPMS	Portfolio 1.1MB

- Enabling students to think like experts in the field of electronic engineering (2012)

Dr Salman Durrani Award for Teaching Excellence	Research School of Engineering CECS	Portfolio 111KB

- 2009 ALTC Grant (UQ, Griffith, USYD)

Investigating the theory (and practice) of pedagogic resonance: making disciplinary thinking visible within university classrooms

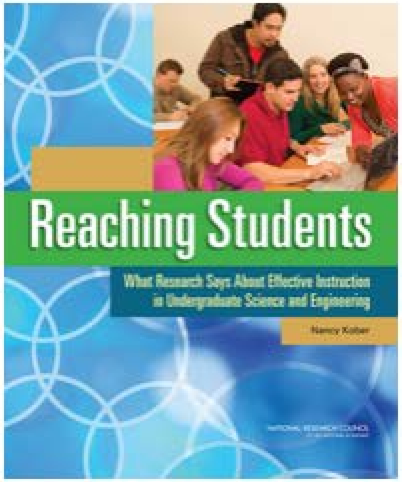
Project Information

Year Funded:	2009
Grant (ex GST):	$217,000

http://chelt.anu.edu.au/promoting-excellence/awards/vc/recipients/2015

Cognitive Apprenticeship

- Recent Book:



Reaching Students:

What Research Says About Effective Instruction in Undergraduate Science and Engineering (2015)

Status: Final Book

Downloads: 10,986

This PDF is available from The National Academies Press at http://www.nap.edu/catalog.php?record_id=18687

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- **Background**
    - o Discipline background
    - o Cognitive apprenticeship model

- **Making thinking visible: Strategies to engage students**
    - o Document Camera
    - o Industry leading simulation tools

- **Making thinking visible: Strategies for lecturers**

- **Conclusions**

Making thinking visible

Modeling teacher performs a task so students can observe

- The understanding of electronic engineering systems is underpinned by relevant mathematical equations.
- Using relevant mathematical equations to solve real-world problems is a critical aspect of electronic engineering.
- Textbooks contain excellent but ‘static’ solved problems, with intuition behind certain steps missing.

Making thinking visible

- ENGN3226 Digital Communications

where the signal is now represented by the vector $\mathbf{s}_m$ with components s_{mk}, $k = 1, 2, \ldots, N$. Their values depend on which of the M signals was transmitted. The components of $\mathbf{n}$, i.e., $\{n_k\}$, are random variables that arise from the presence of the additive noise.

In fact, we can express the received signal $r(t)$ in the interval $0 \le t \le T$ as

$$r(t) = \sum_{k=1}^{N} s_{mk}\psi_k(t) + \sum_{k=1}^{N} n_k\psi_k(t) + n'(t)$$
$$= \sum_{k=1}^{N} r_k\psi_k(t) + n'(t) \qquad (7.5.5)$$

The term $n'(t)$, defined as

$$n'(t) = n(t) - \sum_{k=1}^{N} n_k\psi_k(t) \qquad (7.5.6)$$

is a zero-mean, Gaussian noise process that represents the difference between the original noise process $n(t)$ and that part which corresponds to the projection of $n(t)$ onto the basis functions $\{\psi_k(t)\}$. We will show below that $n'(t)$ is irrelevant to the decision as to which signal was transmitted. Consequently, the decision may be based entirely on the correlator output signal and noise components $r_k = s_{mk} + n_k$, $k = 1, 2, \ldots, N$.

Since the signals $\{s_m(t)\}$ are deterministic, the signal components are deterministic. The noise components $\{n_k\}$ are Gaussian. Their mean values are

$$E[n_k] = \int_0^T E[n(t)]\psi_k(t)\,dt = 0 \qquad (7.5.7)$$

for all k. Their covariances are

$$E[n_k n_m] = \int_0^T\int_0^T E[n(t)n(\tau)]\psi_k(t)\psi_m(\tau)\,dt\,d\tau$$
$$= \int_0^T\int_0^T \frac{N_0}{2}\delta(t-\tau)\psi_k(t)\psi_m(\tau)\,dt\,d\tau$$
$$= \frac{N_0}{2}\int_0^T \psi_k(t)\psi_m(t)\,dt$$
$$= \frac{N_0}{2}\delta_{mk} \qquad (7.5.8)$$

where $\delta_{mk} = 1$ when $m = k$ and zero otherwise. Therefore, the N noise components $\{n_k\}$ are zero-mean, uncorrelated Gaussian random variables with a common variance $\sigma_n^2 = N_0/2$, and

$$f(\mathbf{n}) = \prod_{i=1}^{N} f(n_i) = \frac{1}{(\pi N_0)^{N/2}} e^{-\sum_{i=1}^{N} \frac{n_i^2}{N_0}}$$

From the previous development, it follows that the correlator outputs $\{r_k\}$ conditioned on the mth signal being transmitted are Gaussian random variables with mean

$$E[r_k] = E[s_{mk} + n_k] = s_{mk} \qquad (7.5.9)$$

and equal variance

$$\sigma_r^2 = \sigma_n^2 = N_0/2 \qquad (7.5.10)$$

Since the noise components $\{n_k\}$ are uncorrelated Gaussian random variables, they are also statistically independent. As a consequence, the correlator outputs $\{r_k\}$ conditioned on the mth signal being transmitted are statistically independent Gaussian variables. Hence, the conditional probability density functions (PDFs) of the random variables $(r_1, r_2, \ldots, r_N) = \mathbf{r}$ are simply

$$f(\mathbf{r} \mid \mathbf{s}_m) = \prod_{k=1}^{N} f(r_k \mid s_{mk}), \quad m = 1, 2, \ldots, M \qquad (7.5.11)$$

where

$$f(r_k \mid s_{mk}) = \frac{1}{\sqrt{\pi N_0}} e^{-(r_k - s_{mk})^2/N_0}, \quad k = 1, 2, \ldots, N \qquad (7.5.12)$$

By substituting Equation (7.5.12) into Equation (7.5.11), we obtain the joint conditional PDFs as

$$f(\mathbf{r} \mid \mathbf{s}_m) = \frac{1}{(\pi N_0)^{N/2}} \exp\left[-\sum_{k=1}^{N}(r_k - s_{mk})^2/N_0\right] \qquad (7.5.13)$$
$$= \frac{1}{(\pi N_0)^{N/2}} \exp[-||\mathbf{r} - \mathbf{s}_m||^2/N_0], \quad m = 1, 2, \ldots, M \qquad (7.5.14)$$

As a final point, we wish to show that the correlator outputs $(r_1, r_2, \ldots, r_N)$ are *sufficient statistics* for reaching a decision on which of the M signals was transmitted; i.e., that no additional relevant information can be extracted from the remaining noise process $n'(t)$. Indeed, $n'(t)$ is uncorrelated with the N correlator outputs $\{r_k\}$; i.e.,

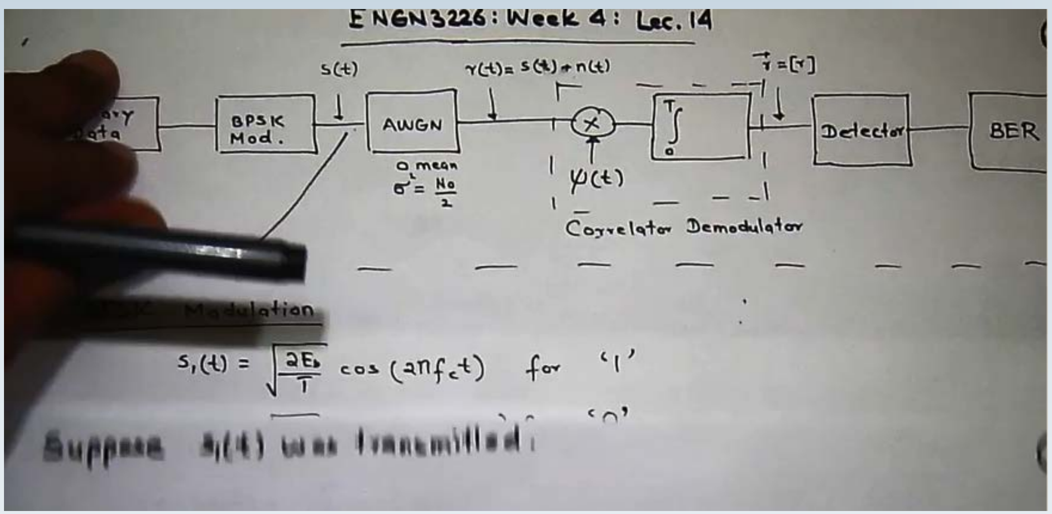
$$E[n'(t)r_k] = E[n'(t)]s_{mk} + E[n'(t)n_k]$$
$$= E[n'(t)n_k]$$
$$= E\left\{\left[n(t) - \sum_{j=1}^{N} n_j\psi_j(t)\right]n_k\right\}$$
$$= \int_0^T E[n(t)n(\tau)]\psi_k(\tau)\,d\tau - \sum_{j=1}^{N} E(n_j n_k)\psi_j(t)$$
$$= \frac{N_0}{2}\psi_k(t) - \frac{N_0}{2}\psi_k(t) = 0 \qquad (7.5.15)$$

Since $n'(t)$ and $\{r_k\}$ are Gaussian and uncorrelated, they are also statistically

Making thinking visible

Strategy 1: Bring the mathematics/proofs/problem solving to 'life' using the document camera technology.

- ENGN3226 Video Demo (1 minute)



Making thinking visible

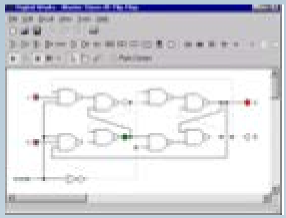
Sample Student Feedback:

- *The document camera was …very helpful when it came to learning how to use and apply new strategies. There was something very helpful in watching each step performed individually and explanations of why each step was taken. It was much more effective than the PowerPoint presentations of other courses' (Second year, 2011)*

- *'He has a way of teaching very complicated concepts in a way that would stay with you for a very, very long time' (Student comment, 2014)*

Making thinking visible

Strategy 2: Use of industry-leading simulation tools and smart phone/tablet apps.



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Making thinking visible

Strategy 2: Use of industry-leading simulation tools and smart phone/tablet apps.

- Eases students into a deeper understanding of the mathematical equations and motivates them to learn the fundamental course concepts
- Unexpected behaviour in the observed simulation results and even occasional (sometimes deliberate!) crashes lead to deeper exploration of course concepts.
- **educational applications (apps) for smart phones and tablets** allow students to create knowledge and to interact with knowledge in new and exciting ways.

Making thinking visible

ENGN2218 Video Demo (1 minute)

This approach of using industry-leading simulation tools and apps was showcased as a 30 second video in the vox pops competition at **The Higher Education Technology Agenda (THETA) Conference**, Hobart, Australia, 2013. It was selected **as one of 10 winning entries.**

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Strategies for lecturers

Pensieve is an object used to review memories (Harry Potter)

Dumbledore: "*I use the Pensieve. One simply siphons the excess thoughts from one's mind, pours them into the basin, and examines them at one's leisure. It becomes easier to spot patterns and links, you understand, when they are in this form.*"

Harry: "*You mean... that stuff's your thoughts?*"

Dumbledore: "*Certainly.*"

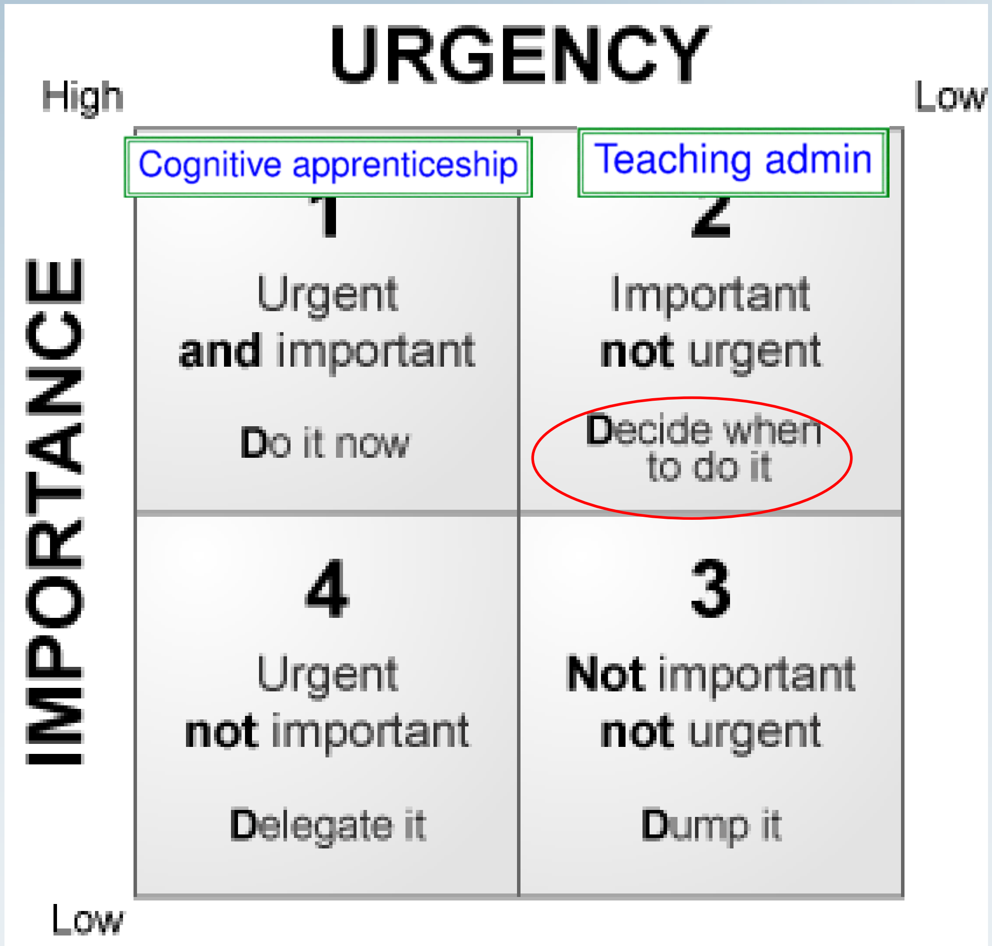
— Albus Dumbledore to Harry Potter[src]

harrypotter.wikia.com/wiki/Pensieve

Strategy 1: *For really complex expert thinking steps/reasoning, watching parts of old lecture recordings can be an effective/efficient way.*

Strategies for lecturers

Strategy 2: *Minimise time spent on teaching admin during semester while teaching.*



1. Course document/course policies
2. Tutoring budget request
3. Tutor selection/training
4. Organising guest lecturers
5. Software installation requests
6. Textbook request
7. Library reserve hold requests
8. Mid-sem exam requests
9. Final exam requests
10. SELT requests
11. Wattle website setup
12. Mastering website setup
13. Assessment items (labs, exams, quizzes etc.)

Undergraduate Research

Systematic use of the cognitive apprenticeship model of learning can bridge the gap between undergraduate education and undergraduate research!.

Published refereed research papers with 12/40 (30%) undergraduate students supervised in last 10 years.

- Recent Example:
  - **R. Pure** and S. Durrani, "Computing Exact Closed-Form Distance Distributions in Arbitrarily-Shaped Polygons with Arbitrary Reference Point," *Mathematica Journal*, June 2015. to appear.
  - **C. Wang**, S. Durrani, J. Guo and X. Zhou, "Call Completion Probability in Heterogeneous Networks with Energy Harvesting Base Stations," *Proc. International Conference on Telecomunications (ICT)*, Sydney, Australia, April 2015, pp. 191-197. (**invited paper)**

Conclusions

Cognitive apprenticeship model is an effective way to enable students to think critically and to develop expert thinking in the STEM disciplines.

In this talk, we have looked at some strategies to make the process enjoyable for both students and lecturers.

Thank you for your attention!

Contact Information:
salman.durrani@anu.edu.au
http://users.cecs.anu.edu.au/~Salman.Durrani/