


 National University of Singapore

**The Tourist Problem:
And Fun with Graph Modeling**

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Experience the fun of problem solving

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The Tourist Problem

❑ Organization

- ❖ The Tourist Problem
- ❖ Analysis and Simplifications
- ❖ Problem Modeling (with *Graphs*)
- ❖ Solving the *Graph* Model
- ❖ Mapping back the Solution
- ❖ Moral of the Story

Experience the fun of problem solving

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The Tourist Problem (KL/PJ)...

Given: A list of parents, each with his/her list of places to visit.
To do: Schedule guided tours for them so that each parent visits all the places in his/her list.

An Instance of Tourist Problem	
Tourist	Places of Interest
Aaron	KLCC, SL ^{TP} , BB
Betty	MW ^{TP} , BH, SL ^{TP}
Cathy	tC, Bgs, MVM
David	BH, MW ^{TP} , MVM
Evans	MW ^{TP} , BH, KLCC
Frances	SL ^{TP} , KLCC, BB
Gary	MW ^{TP} , MVM
Harry	BH, MW ^{TP}

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The Tourist Problem (KL/PJ Entities)

❑ Good to know the entities we are dealing with...

- ❖ The Tourists:
 $T = \{ A, B, C, D, E, F, G, H \}$
- ❖ The Attractions (Places):
 $P = \{ BB, Bgs, BH, KLCC, MVM, MW^{TP}, SL^{TP}, tC \}$

... Places of Attraction ...			
Place	Common Name	Place	Common Name
SL ^{TP}	Sunway Lagoon ^{TP}	MW ^{TP}	Mines Wonderland ^{TP}
BB	Bukit Bintang	BH	Berjaya Hill
MVM	Mid Valley Mall	Bgs	Bangsar
KLCC	KL City Centre	tC	The Curve

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The Tourist Problem...

Given: A list of tourist, each with his/her list of places to visit.
To do: Schedule bus rides for them so that each tourist visits all the places in his/her list.

An Instance of Tourist Problem	
Tourist	Places of Interest
Aaron	SZG, BG, JB
Betty	CG, JG, BG
Cathy	VC, SI, OR
David	JG, CG, OR
Evans	CG, JG, SZG
Frances	BG, SZG, JB
Gary	CG, OR
Harry	JG, CG

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The Tourist Problem (Entities)

❑ Good to know the entities we are dealing with...

- ❖ The Tourists:
 $T = \{ A, B, C, D, E, F, G, H \}$
- ❖ The Attractions (Places):
 $P = \{ BG, CG, JB, JG, OR, SI, VC, SZG \}$

... Places of Attraction ...			
Place	Common Name	Place	Common Name
BG	Botanical Gardens	CG	Chinese Gardens
JB	Jurong Birdpark	JG	Japanese Gardens
OR	Orchard Road	SI	Sentosa Island
SZG	Spore Zoological Gardens	VC	VivoCity

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The Tourist Problem (Analysis...)

Some Simplifications: Consider

❖ Aaron { SZG, BG, JB }
 Frances { SZG, BG, JB }

Also consider

❖ David { JG, CG, OR }
 Gary { CG, OR }

An Instance of Tourist Problem

Tourist	Places of Interest
Aaron	SZG, BG, JB
Betty	CG, JG, BG
Cathy	VC, SI, OR
David	JG, CG, OR
Evans	CG, JG, SZG
Frances	BG, SZG, JB
Gary	CG, OR
Harry	JG, CG

Simplification Rule:

If $P(T_1) \subseteq P(T_2)$, then tourist T_1 can just "follows" tourist T_2 . Thus, we can omit T_1 from consideration.

Oh, can also omit Harry

❖ Betty { CG, JG, BG }
 Harry { CG, JG }

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The (Reduced) Tourist Problem...

Given: A list of tourist, each with his/her list of places to visit.

To do: Schedule bus rides for them so that each tourist visits all the places in his/her list.

An Instance of Tourist Problem

Tourist	Places of Interest
Aaron	SZG, BG, JB
Betty	CG, JG, BG
Cathy	VC, SI, OR
David	JG, CG, OR
Evans	CG, JG, SZG

$T = \{ A, B, C, D, E \}$

$P = \{ BG, CG, JB, JG, OR, SI, VC, SZG \}$

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The Tourist Problem – v0

Given: A list of tourist, each with his/her list of places to visit.

To do: Schedule bus rides for them so that each tourist visits all the places in his/her list.

Solution: (Singapore 1-Day Tour)

Put all the tourists on one bus.
 Visit all eight places in 1 day.

An Instance of Tourist Problem

Tourist	Places of Interest
Aaron	SZG, BG, JB
Betty	CG, JG, BG
Cathy	VC, SI, OR
David	JG, CG, OR
Evans	CG, JG, SZG

What's Good: It works! One bus, one-day.

What's Bad: Too rushed. NO time to see anything!

Not interesting!

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The Tourist Problem – v0.5

Given: A list of tourist, each with his/her list of places to visit.

To do: Schedule bus rides for them so that each tourist visits all the places in his/her list, *and*

C1: Each tourist visits *at most one place a day*.

Simple Solution:

Schedule *one trip to every place every day*.

An Instance of Tourist Problem

Tourist	Places of Interest
Aaron	SZG, BG, JB
Betty	CG, JG, BG
Cathy	VC, SI, OR
David	JG, CG, OR
Evans	CG, JG, SZG

What's Good: It works! Finish in 3 days. (*minimum!*)

What's Bad: Wasteful! 24 bus trips.

Also, not so interesting!

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The Tourist Problem – v0.8

Given: A list of tourist, each with his/her list of places to visit.

To do: Schedule bus rides for them so that each tourist visits all the places in his/her list,

C1: Each tourist visits *at most one place a day*, *and*

C2: There is *at most one bus trip to each place*

Simple Solution:

Schedule *one trip per day*, each to a *different place*.

An Instance of Tourist Problem

Tourist	Places of Interest
Aaron	SZG, BG, JB
Betty	CG, JG, BG
Cathy	VC, SI, OR
David	JG, CG, OR
Evans	CG, JG, SZG

What's Good: It works! 8 trips.

What's Bad: It takes 8 days!

But wait... Did you see something interesting?

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The Tourist Problem – v1.0

Given: A list of tourist, each with his/her list of places to visit.

To do: Schedule bus rides for them so that each tourist visits all the places in his/her list,

C1: Each tourist visits *at most one place a day*,

C2: There is *at most one bus trip to each place*, *and*

C3: *minimize the number of days to complete mission.*

Observation:

On the same day, cannot schedule SZG and BG can schedule SZG and OR

An Instance of Tourist Problem

Tourist	Places of Interest
Aaron	SZG, BG, JB
Betty	CG, JG, BG
Cathy	VC, SI, OR
David	JG, CG, OR
Evans	CG, JG, SZG

How to model all these constraints?

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Activity Period #1:

Bus Scheduling DIY (Do It Yourself) (5 minutes)

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Review of Activity #1

- How many days did you use?
 - ❖ ____ days
- What was the main difficulty?
 - ❖ What if we are talking about 100 tourists?
 - ❖ ... and 20 different attractions?
- Was there a lot of repetitive task?
 - ❖ How was the task?
- How can we do better?

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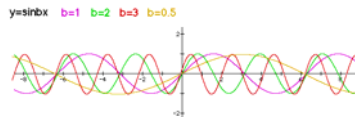
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The Graph Model

□ What is a graph?

- ❖ eg: $y = \sin(bx)$



□ No. Not this type of graph.

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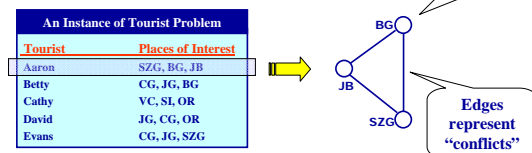
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The Graph Model

□ Graph $G = (V, E)$

- ❖ V is a set of vertices, nodes (circles)
- ❖ E is a set of edges (connections)



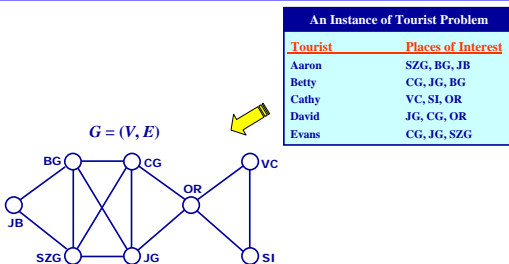
In our graph, nodes are places, and edges in the graph means conflicts.

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Graph Model for the Tourist Problem



The graph $G = (V, E)$ captures all the conflicts for our tourist problem instance.

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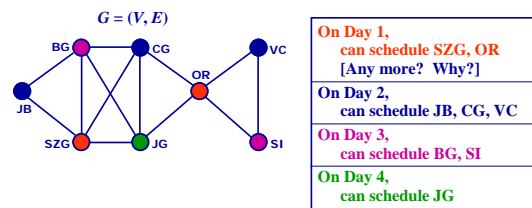
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Graph Model for the Tourist Problem

□ What's good about the graph model?

- ❖ very simple !
- ❖ easy to spot conflicts and the *non-conflicts*



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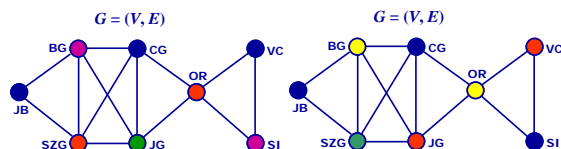
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Graph Coloring Problem

- Given a graph $G = (V, E)$, colour the vertices in V so that any two vertices that are connected by an edge in E will have different colors.

We want to *minimize* the number of colors.



Number of colours used to colour the graph G = Number of days needed to complete the schedule

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Activity Period #2:

Graph Colouring Exercises

(10 minutes)

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Review of Activity #2

- Is Graph Colouring fun?
 - ❖ Did you *really* use *different* colours?
- How many colours was did you use (Q1)?
- What about the cycles (Q2):
 - ❖ Q2(a): C_6 (a cycle of length 6)?
 - ❖ Q2(b): C_5 (a cycle of length 5)?
 - ❖ What else can you say?
- What about the graph in Q3?
- What about Q4?
 - ❖ Why

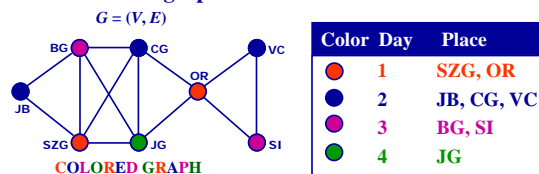
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Get Solution to Tourist Problem - 1

- Coloured graph \Rightarrow "Bus Schedule"



1. What about the list of tourists on each bus?
Can we get it from the graph model?
NO. *Why* NOT.

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The Tourist Problem...

An Instance of Tourist Problem

Tourist	Places of Interest
Aaron	SZG, BG, JB
Betty	CG, JG, BG
Cathy	VC, SI, OR
David	JG, CG, OR
Evans	CG, JG, SZG
Frances	BG, SZG, JB
Gary	CG, OR
Harry	JG, CG

Alternative Representation

Tourist	BG	CG	JB	JG	OR	SI	SZG	VC
Aaron	X		X				X	
Betty	X	X		X				
Cathy					X	X		X
David		X		X	X			
Evans		X		X			X	
Frances	X		X				X	
Gary		X			X			
Harry		X		X				

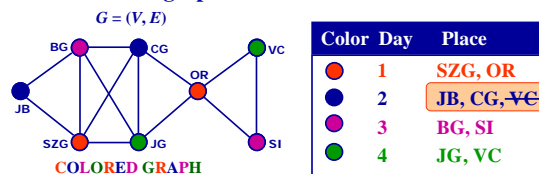
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Get Solutions to Tourist Problem (2)

- Coloured graph \Rightarrow "Bus Schedule"



1. What about the list of tourists on each bus?
2. What if you only have 2 buses?
• can colour vertex VC green.

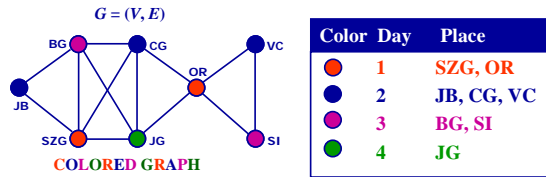
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Get Solutions to Tourist Problem (3)

□ Coloured graph \Rightarrow "Bus Schedule"



1. What about the list of tourists on each bus?
 2. What if you only have 2 buses?
 3. What if BG is closed on Day 3?
- Can we re-order the colours?

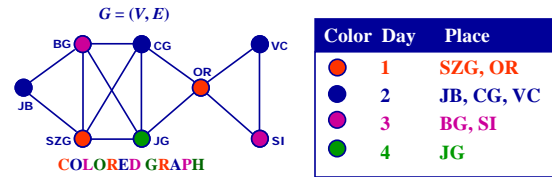
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Get Solutions to Tourist Problem (3)

□ Coloured graph \Rightarrow "Bus Schedule"



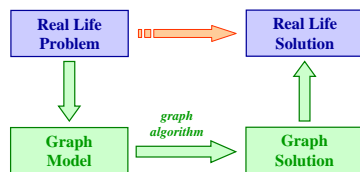
1. What about the list of tourists on each bus?
2. What if you only have 2 buses?
3. What if BG is closed on Day 3?
4. Can we use fewer colours (fewer days)?

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Graph Modelling...



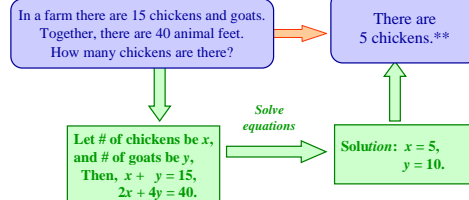
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Modelling...

□ Nothing new. You do it *all* the time.



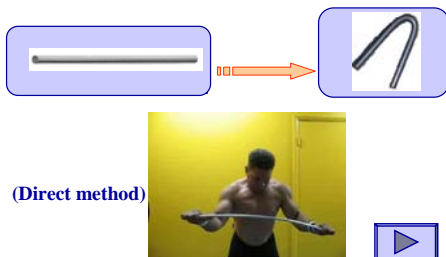
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Modelling: Another example

□ Bend a steel bar



Man bending steel rod

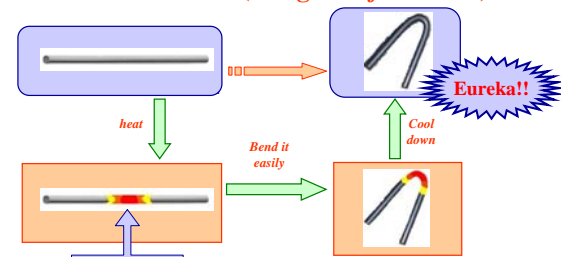
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Modelling: Another example (2)

□ Bend a steel bar (using transformation)

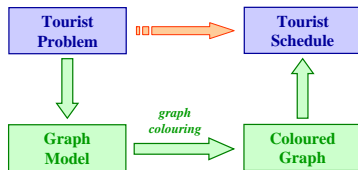


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Tourist Problem & Graph Colouring



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Modelling in Tourist Problem

Recap: Our Graph modelling...

Graph Model	Tourist Problem			
Nodes	places			
Edges / Conflicts	tourist want to visit both places			
Colors	bus trips to places			
Others	The tourists			

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Moral of the Story

- ❑ **The Tourist Problem:**
 - ❖ Some problems are **EASY**. (*don't* complicate them)
 - ❖ Get a **simple** solution first.
then *analyze it, improve it, refine it.*
 - ❖ Solution depend on the questions asked
 - ❖ It is important to **ask questions**.
 - ❖ Theoretical *modeling and analysis* are beneficial
- ❑ **Modeling**
 - ❖ Abstract modeling *simplifies* problem and solution!
 - ❖ Abstract model is *transferable*.
 - ❖ Models don't answer everything.

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Graph Colouring & Applications

- ❑ Where *else* is Graph Colouring used?
 - ❖ The Tourist Problem [done]
 - ❖ Map Colouring
 - ❖ Fish in a Tank
 - ❖ Frequency assignment in wireless networks
 - ❖ Time Table Scheduling
 - ❖ And a whole lot more...

Experience the fun of problem solving

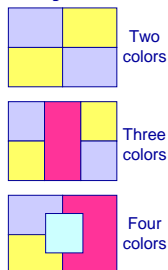
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The Map Coloring Problem

We want to color countries, oceans, lakes, and islands on a map so that no two adjacent areas have the same color.



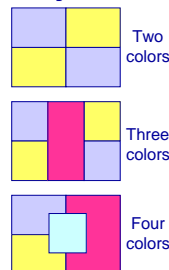
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The Map Coloring Problem

We want to color countries, oceans, lakes, and islands on a map so that no two adjacent areas have the same color.

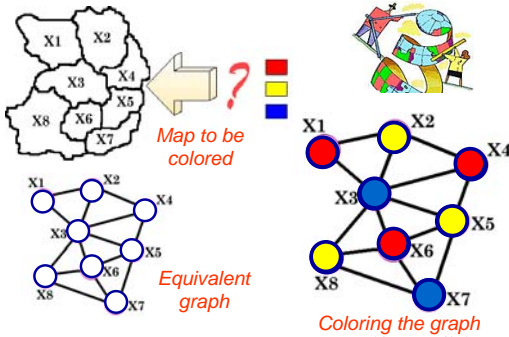


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Map and Graph Coloring



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The Four Color Theorem

Question:

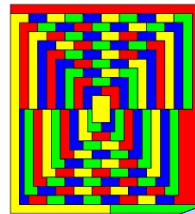
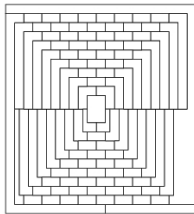
Can **all** map be coloured using only four colours?

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Does four colour suffices?



April Fool Joke!

Martin Gardner published in Scientific American (April 1975) this map of 110 regions. He claimed that the map **requires five colors** and constitutes a counterexample to the four-color theorem.

However, the coloring of Wagon, obtained algorithmically using *Mathematica*, clearly shows that this map is, in fact, four-colorable.

Source: <http://mathworld.wolfram.com/Four-ColorTheorem.html>

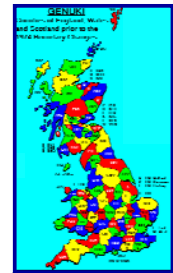
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150 years of history...

- 1852 Conjecture (Guthrie → DeMorgan)
- 1878 Publication (Cayley)
- 1879 First proof (Kempe)
- 1880 Second proof (Tait)
- 1890 Rebuttal (Heawood)
- 1891 Second rebuttal (Petersen)
- 1913 Reducibility, connexity (Birkhoff)
- 1922 Up to 25 regions (Franklin)
- 1969 Discharging (Heesch)
- 1976 Four Color Thm (Appel & Haken) @ UIUC
- 1995 Streamlining (Robertson & al.)
- 2005 COQ proof (Gonthier)

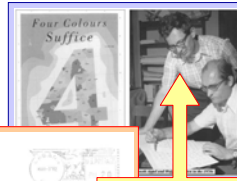


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Four Color Theorem Proof @ UIUC



In Fall 1979, I took a course CS313 Combinatorics by Prof. Ken Appel

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Activity Period #3:

Map Colouring &
Fish in a Tank
(10 minutes)

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Review of Hands-on Activity #3

- ❑ How many colours did the map need?
❖ You should never need more than 4 colours
- ❑ Did you know about the
“Four-Colour Theorem”?
- ❑ How many fish tanks did you need?

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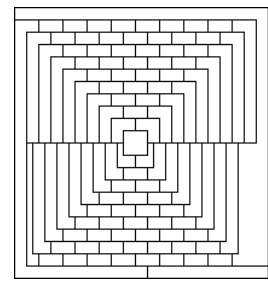
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Activity 5: Color These Maps

Use as few colors as possible



Real map: One color already used



Made-up map

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Summary of Problem Modelling

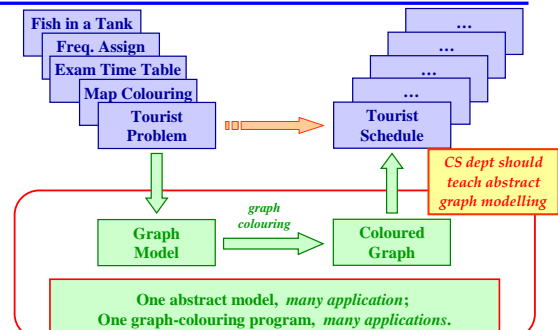
	Tourist Problem	Fish in a tank	Frequency Assignment	Map Coloring
Nodes	places	fishes	radio stations	Countries
Edges / Conflicts	tourist want to visit both places	cannot be placed in same tank	interference if placed too near	share a common border
Colors	bus trips to places	fish tanks	signal frequencies	color
Others	The tourists	--		

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Why CS dept teach abstract problems?



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References...

On Graph Coloring and Applications:

1. <http://www.geom.uiuc.edu/~zarembe/graph3.html>
2. <http://www.colorado.edu/education/DMP/activities/graph/ddchnd03.html>
3. Lots of other links available

On the Four Color Theorem:

1. http://en.wikipedia.org/wiki/Four_color_theorem
2. <http://www.maa.org/reviews/fourcolors.html>
3. <http://www.math.gatech.edu/~thomas/FC/fourcolor.html>
4. <http://www.mathpages.com/home/kmath266/kmath266.htm>

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**End of Talk on
Tourist Problem!**

*If you want to contact me,
go email, MSN, FB at leongfw@comp.nus.edu.sg*



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