Bridging the gap between Course Work and Real Life Problems
Under the guidance of Prof. Milind Sohoni

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IIT Dharwad

March 31, 2018
Today...

- **What is the current course structure?**
  - How to apply the concepts taught in classroom.
  - Connection with reality.
  - How can we enrich our curriculum?
  - Why engagement with society is important?

- **Case Studies**
  - Analysing data. The census. The railway system. The bus-depot.

- **The Dharwad City Bus Depot**
  - Various steps and its connection with our curricula.
  - Intermediate and final output.
What is the current course structure

and what is its connection to everyday problems?

• Asymptotic Notation
• Sorting and Searching
• Divide and Conquer
• Greedy Algorithms
• Graph Theory
• Dynamic Programming
• NP-completeness
• and much more......
What is the current course structure and what is its connection to everyday problems?

- Asymptotic Notation
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- Divide and Conquer
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- Dynamic Programming
- NP-completeness
- and much more......

How to adapt them to everyday life?

*Real Life Problems are manifold complex than standard textbook problems!*
What is being taught?

A rooted tree

**Rooted Tree**: $T(V, E)$, $r$ is a rooted tree iff (i) $T$ is a tree and $r \in V$ is a vertex (called the root), and (ii) there is a function call $\text{level} : V \rightarrow \mathbb{Z}$ such that (a) $\text{level}(r) = 0$, (b) $\text{level}(v) \geq 0$, and (c) each vertex $v$ of level $d > 0$ is connected to exactly one vertex $w$ of level $d - 1$. Then $w$ is called the parent of $v$ and $v$ the child of $w$. A vertex with no children is called a leaf node.

A tree with $n$ vertices has exactly $n - 1$ edges.
What is being taught?

A rooted tree

**Rooted Tree**: $T(V, E)$, $r$ is a rooted tree iff (i) $T$ is a tree and $r \in V$ is a vertex (called the **root**), and (ii) there is a function call $level : V \rightarrow \mathbb{Z}$ such that (a) $level(r) = 0$, (b) $level(v) \geq 0$, and (c) each vertex $v$ of level $d > 0$ is connected to exactly one vertex $w$ of level $d - 1$. Then $w$ is called the **parent** of $v$ and $v$ the **child** of $w$. A vertex with no children is called a **leaf node**.

A tree with $n$ vertices has exactly $n - 1$ edges.

Too much abstraction!
And what is the reality ...
And what is the reality ...

Data from Census 2011
The True Engineer

Design

- Civil
- Econo.
- Maths.
- IT

Modelling

- Analyse
- Identify Problem
- Synthesize
- Deploy

Domain Knowledge
Creative Skills
Societal Skills

Society
Engineering v/s Science

- Scientist describes society, engineer wants to change it. So how should the change be?
- Obviously which generates value, which is why we engineers need to understand society and how it operates.

Ref: “Engineering Teaching and Research and its Impact on India”, CURRENT SCIENCE, VOL. 102, NO. 11, 10 JUNE 2012 (https://www.cse.iitb.ac.in/sohoni/RD.pdf)
Problem Statement

- How do we analyse a real-life situation?
- How to use our course-material to model real-life situations.
Solutions?

Students and Case Studies

- Untapped resources of our country
- Can work in teams with the government
- Benefit of society
- Hands-on experience for students
Solutions?

Students and Case Studies

- Untapped resources of our country
- Can work in teams with the government
- Benefit of society
- Hands-on experience for students

Several development issues require good engineering methodology!
The South Western Railway Timetable

Table No. 14

Bengaluru City - Hubballi - Miraj

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<th>TRAIN NAME</th>
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<th>Yesvantpur Karwar Express via Ariskere</th>
<th>Bengaluru - Hubballi Jan Shatabdi Express</th>
<th>Mysuru - Talguppapa Town Intercity Express</th>
<th>Puduchery - Dadar Express</th>
<th>Tirunelveli - Dadar Express</th>
<th>Mysuru - Darshan Express</th>
<th>Yevsantpur Shivasamudra Express</th>
<th>Yesvantpur Barmer AC Weekly Express</th>
<th>Mysuru-Varanasi Express</th>
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https://www.cse.iitb.ac.in/cs213d/SWRTimetable.pdf
The South Western Railway Timetable

- Extremely rich data-set.
- Available in pdf format online.
- Cannot run basic computation such as number of trains operational at a given time instant!
...To Graphical Visualization

Software Used: Scilab
• Space-time representation of timetable
• Can be used to analyze bottlenecks in schedule, minimization of delays, possible collision domains.
• Time Table Optimization!
The above example was based on secondary data and its analysis. That is important too, since it trains you in understanding how to represent and what would be of interest to people and the limitations of the implementation agency, in this case, a single track. Also understand what could be changed, e.g., signal spacing and loops, but that needs primary work. The next example is different.
The Dharwad Bus Depot

• One of the eight division headquarters under North Western Karnataka Road Transport Corporation.

• operates 208 schedules with strength of 228 vehicles.

• covers 55k kms and is utilising the services of 1000 regular employees, which includes Officers, Supervisory and Administrative staff, Mechanical staff and Drivers and Conductors.

• Plethora of natural data generated on a daily basis.
Basic Data-sets
Basic Data-sets

- Daily Operation Statistics
- Summary of revenue collection, EPKM (earnings per km), vehicle allocation, cancellations/late departures.
Basic Data-sets

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<td>6665007</td>
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**Fueling:**
Basic Data-sets

- Log sheet
- To be filled in by the conductor after every trip.
- Contains stopwise distribution of ridership.
Basic Data-sets

| CC | FM | 1 - 07:05 | 7:20 | - | 0:00 | 89 | CITY | CBT | SOMESHWAR TMP | CBT | TEJASHWI NAGAR | CBT | TEJASHWI NAGAR | CBT | SARASWATIPUR | CBT | TEJASHWI NAGAR | CBT | TEJASHWI NAGAR | CBT | TEJASHWI NAGAR | CBT | TEJASHWI NAGAR | CBT | S.R.NAGAR | CBT |
|----|----|----------|------|---|-----|---|-----|-----|--------------|-----|-------------|-----|--------------|-----|-------------|-----|--------------|-----|--------------|-----|-------------|-----|---------|-----|
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Form IV(The city bus schedule)
Form IV: Our first Data-set

The Schedule

- **SCH.NO.**: The Schedule Number (Typical schedule is 8 hours long.)
- **TRIP**: trip number
  - **FROM** and **TO**: The first and last stops.
  - **KM**: distance covered
  - **DEP** and **ARR**: departure and arrival timings
  - **VIA**: place en route

Very linear representation of data.

- No information about sub-stops.
- Does not describe the spatial distribution of route-data.
- Insufficient for proper analysis.
Questions

It is natural to generate many domain specific questions of value:

- **Passenger**: What is the route to travel from Ganesh Temple to Central School, starting at 7:15 AM, in the minimum possible time?
- **Depot Manager**: How to maximize the profit subject to budget constraints?
- **Planning Committee**: Which are the more profitable areas to add a new bus route?
- **Researcher**: How much percentage of the rural population has access to a bus within 500m?
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- **Researcher**: How much percentage of the rural population has access to a bus within 500m?

We will answer the first question through this study and do preliminary work to answer the other questions.
Work done at IIT Dharwad

The 39 students of the course CS213 (Jan. 2017-May. 2017), at IIT Dharwad map Dharwad city bus routes.

- They first analyze the 8000-line city bus schedule.
- prepare a summary and allocate routes
- travel them and generate kml files
- and finally compile them together.
## Summary and Route Allocation

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75 distinct routes were allocated to the students, out of which 12 were reported to be disfunctional or duplicate.
A graph $G(V, E)$ is eminently suitable to represent locations (as vertices) and paths between locations (as edges).
The Representation

- The place \((v)\) represents an actual location and contains location data (latitude-longitude \((\text{lat-long})\)), name and other attributes specific to the place and the route on which it lies.
- An edge consists of two places \((v_1, v_2)\) and a track between them.
- A route consists of a sequence of places, connected by the edges.
The Representation

- A service from $v_i$ to $v_j$, $S(v_i, v_j, t_0, d)$, consists of a route followed by a bus along with the start time ($t_0$) and the trip duration ($d$).
- Finally, a schedule is a set of services carried out by a single bus.
Figure: The KML tracks generated from real-time GPS tracking.
Some Issues

• The KML tracks are irregular and not aligned to official road polylines.
• Multiple coordinates and multiple names for the same stops.
• Names in the schedule are not standardized.
• Data not fit for graph representation.
Cleanup

- **Clustering of Stops**
  We used a clustering algorithm (see breadth-first search) using connected components to cluster stops within 50 m into unique stops.
Cleanup

- **Fitting the GPS generated tracks with the Google Map Roads**
  It was decided that the edges between places (whose preliminary lat-longs and names are now available) will follow existing roads, i.e., polylines as shown by Google Maps. To align the tracks with the official road polylines, we used a Google API.
Cleanup

- **Inserting stops into polylines**
  As the data was generated from one trip only, many buses did not stop at all the stops which lie on the route depending on the ridership that day. So, we then wrote a program which took all the stops, computed its minimum distance from the track and inserted it into the track $O_i$ if the distance was less than some chosen epsilon.
After Cleanup
Question Revisited

Question: How can you reach Srinagar from High Court in the minimum possible time starting at time $t_0$?
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This can be modelled as a graph theory problem.

- Here the vertices ($V$) are the bus stops.
- Let $v_0$ = Srinagar and $v_n$ = High Court.
- There edges are the services.
- The edge weights are the trip length of the service $S(v_i, v_j, t, d)$. 
Question Revisited

- **Initialization**: The edge cost of $S(v_0, v_i, t, d) = (t - t_0) + d$ where $(t - t_0) > 0$, $\infty$ otherwise.
- **Constraint**: $(v_i, v_j)$ can be followed by $(v_j, v_k)$ iff arrival time($S(v_i, v_j, t_1, d_1)$) < departure time($S(v_j, v_k, t_2, d_2)$).
- Run **Dijkstra’s algorithm** and get the shortest path from $v_0$ to $v_n$.

Ref: https://en.wikipedia.org/wiki/Dijkstra’s_algorithm
Can we do better?

- Suppose there are $k$ routes with $n$ stops each and 1 route has $m$ trips in a day, the number of edges becomes $(n - 1) \times k \times m$.
- So the complexity of above algorithm is $O((n - 1) \times k \times m + |V|\log|V|)!$
- This is significant amount of computation if done on the average mobile phone processors.
Can we do better?

- **Solution**: Edge generation on demand.
- Note that we are only interested in the next bus.
- So instead of explicitly storing the edges for all buses, we simply compute the cost of next bus from the current time.
- This brings the complexity of the algorithm by a multiplicative factor of \( m \): **Significant Improvement**
Can we do better?

• Solution: Edge generation on demand.
• Note that we are only interested in the next bus.
• So instead of explicitly storing the edges for all buses, we simply compute the cost of next bus from the current time.
• This brings the complexity of the algorithm by a multiplicative factor of $m$: Significant Improvement

Our algorithm is ready to be implemented on a mobile phone!
Algorithm 1 Algorithm for finding bus route

procedure RoutePlanner(Graph, source, destination, start time)
    create vertex set Q
    for each vertex v in Graph do ▷ Initialization
dist[v] ← ∞ ▷ Unknown distance from source to v
    prev[v] ← UNDEFINED ▷ Previous edge in optimal path from source
    arrival_time[v] ← ∞ ▷ Stores the best arrival time at each vertex
    end for
    add v to Q ▷ All nodes initially in Q (unvisited nodes)
    dist[source] ← 0 ▷ Distance from source to source
    arrival_time[source] ← start time
    while Q is not empty do
        u ← vertex in Q with min dist[u] ▷ Node with the least distance will be selected first
        remove u from Q
        if u is destination then
            break ▷ no need of further computation
        end if
        for each edge starting from u do ▷ where v is still in Q
            length(u, v) ← waitingtime(arrival_time[u]) + length(u, v) ▷ recompute edge cost
            alt ← dist[u] + length(u, v)
            if alt < dist[v] then ▷ A shorter path to v has been found
                dist[v] ← alt
                prev[v] ← e(u, v)
                arrival_time[v] ← arrival_time[u] + length(u, v)
            end if
        end for
    end while
    return dist[], prev[]
Development of an android app for passengers
Figure: Route generated by shortest path algorithm

Dharwad High Court to Srinagar

14:00   41 m   1 stops   14:41

Dharwad High Court   Jubilee Circle

14:00   14:29

Enroute Dharwad High Court to CBT

Jubilee Circle   Srinagar

14:31   14:41

Enroute CBT to Pavate Nagar

Show in Map
Figure: Route viewed on map
Figure: Ward map of Dharwad (classified by population density) superimposed on the bus network.
The way ahead...

- Implement a similar strategy in your town/taluka to generate a database.
- Scale the database over multiple talukas.
- Encourage addition of development course projects into the curriculum.
- There are other fields that need work also: Energy sector, public transport, more water, town planning,...
- See: www.ctara.iitb.ac.in for project ideas.

For full report on Dharwad Bus Depot: https://www.cse.iitb.ac.in/sohoni/dharwadbus.pdf
Thanks