



Graphs (undirected) (directed) 0-722-33 G = (V, E)(u,v) ∈ E if u →v

Parameters: n=1V  $m = |E| (m \leq n^2)$ 



facebookfriend graph
$$n = 2.91$$
 billion users(undirected) $avg$  user has 338 friends $m = 500$  billion edgesQuestion: Who are my friends?



Ridgen Ve റ്റ X Sign in  $\odot$ ⋳  $\mathbf{T}$ Q Search along the route 😫 Groceries 🛛 🙆 Things to do Building 59 Shyh Wang Hall Best 6 min 15 min 6 min Mind Coffee 0 Seoul Hotdog 0 Yifang Taiwan Fruit Tea, 2516 Bancroft W Foothill Dining ↑, Hearst Ave Cory Hall 0 Lower Hearst Soda Hall, Berkeley, CA 94709 O Stern Hall Parking Structure North Gate Hall Θ Hearst Ave æ Add destination Stern Hall Scule Rd University House Hearst Ave O'Brien H Foothill Student Velow Hearst Memorial O Mining Building Options Housing 9 Stanley Hall P Foothill Lot C Evans Hall Send directions to your phone CODY link Mri Trailer O Bowles Hall 0 Memorial via Sather Rd 15 min C Latimer Hall Glade 0.6 mile Gayley Rd a Shing Center Details Hilgard University D. C Li Ka Shing Center South Dr via Eshleman Rd 15 min Ŕ Chou Hall 🕤 Maxwell Family Field 🔾 0.6 mile 0 Θ lell-&-clock towe Free-Speech-Bikew \* 15 min via Barrow Ln 14 min Ŕ 0.6 miles Crescent Lawn 0.6 mile Valley Life Sciences Building UC Berkeley ค 方 14 min 0.6 miles University of 15 min Optometry Ln Koret Visitor California 0.6 miles All routes are mostly flat Berkelev Melvin Calvin Laboratory V rt Museum A Moses Hall Ishi Court Film Archive Morrison Hall Wurster Hall Peppertree-Way Dwinelle Hall Memoria Old Art Galler Sather Gate **Central Heating Plant** Iconic campus gate 0 O Hellman Tennis Center G Inte Cesar Chavez Student Center 0 UC Berkeley 1 Alumni House Ludwig's Fountain Hearst Memorial School of Law Stu Gordon Stadium 😂 0 Bancroft Way Gymnasium Θ ASUC Student 0 Θ Caffè Strada Bancroft Way Cal Performances 😫 Edwards Stadium Bancroft Way ۲ Recreational O Sports Facility Woo Hon Fai Hall Yifang Taiwan Fruit Tea O + Bancroft Way Durant Ave Θ -Bancroft Way Durant Ave Acacia International Google Fraternity at University... Cheney Hall ANP

Google Maps Q: Shortest path to boba?



entrance u

Representing graphs on computers V= {1,..., n }

(1) adjacency matrix representation  $\Rightarrow$  Aij  $A_{ij} = \begin{cases} 1 & if (i,j) \in E \\ 0 & 0 & ... \end{cases}$ n (unordered) (2) adjacency list representation (linked list



1. Is there a path from u to V?

2. Is G connected?

3. What are G's connected components?



| explore (G, U)<br>Visited [U] = true      | boolean array visited [1] |
|---|---------------------------|
|   |                           |
| for V s.t. (U,V)EE<br>if visitedEV]=false |                           |
| explore (G, Y)                            |                           |

dfs(G) boolean array visited [n] (init to all 0's) explore (G, U) Visited [U] = true for VEV if visited [V] = false explore (G,V) for v s.t. (u,v) EF if visited [v]=false explore(G,v)

(j's connected components (undirected) Computing (3 connected (O) Components) boolean array visited [n] (init to Jall O's) Count=1 explore (G, U) Visited [U] = true dfs(6)ccnumEu]= count int array ccnum[n] for ve V if visited [v] = false for v s.t. (u,v) EF if visited [v]=false explore(G,v) explac (G, V) Count= count + )





Runtime of DFS Only call explore (G, J) exactly once, for each J Runtime of explore (G, u) · set visited Eul-true O(1) time enumerate u's neighbors
O(deg(u)) time (linked list)  $total = \sum_{U \in V} O(1 + deg(u))$ - O(n+m) time

DFS tree explore (G, U) Visited [U] = true **d**+ SLG boolean array visited [n] (init to all 0's) precu] = clock Clock = Clock = clock+1 int array pre[n], post[n] for  $\gamma$  st.  $(u,v) \in E$ if visited (v) = false for vev if visited[v]=false explore (G, V) Post[u] = clock clock = clock +1 explore (G,v)