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Introduction

- The field of concurrency was started by Dijkstra
- Concurrency: study of systems of interacting computer programs which share resources and run concurrently
  - "at the same time" not exactly at the same time, the OS scheduler switches apps
  - "interacting" exchange information and agree on certain things
    - car wash, the machine and car wash must interact to let it know where it is and when to do certain things
    - message passing
      - send/receive
    - shared memory
      - read/assign to variable or memory location
- Problems with the granny example of one set of needles:
  - DEADLOCK: each granny takes a needle and waits indefinitely until the other one has freed the one she has
  - LIVELOCK: Each granny takes a needle, sees the other granny has the other needle and returns it, repeats indefinitely
    - Infinite Loop, instructions being executed, system isn't making any progress (neither granny gets two needles)
  - STARVATION: One of the grannies always takes the needle before the other one
  - There are other concurrency problems that can arise, but these are the most common
    - Synchronization include other problems (ferry problem)
- thread.start() <- 1
  thread.start() <- 2
  - We don't know which thread will run first, thread.start just spawns thread, scheduler will decide which runs first
- ***SEE l2ex1.groovy***
  - Any combination is possible so long as A comes before B and C comes before D because of context switching between threads and scheduling
  - m are num instructions in first thread
    n are num instructions in second thread
    # of possible interleavings of instructions:

$$\frac{(m+n)!}{m!n!} = \frac{m+n}{n}$$

  - Synchronization: making sure it prints ABCD (use semaphores)
- Transition Systems
  - (s, ->, I)
    - S is a set of states
    - -> C_ SxS is a transition relation
    - I C_ S set of initial states
  - ***See transition ex1, ex2, ex3, and ex4 on ipad l2***
  - ***for more code see l2ex3***
- Can now do exercise booklet
- Quiz Friday