LOCAL NAVIGATION 1

LOCAL NAVIGATION

- Dynamic adaptation of global plan to local conditions
  - A.K.A. “local collision avoidance” and “pedestrian models”

LOCAL NAVIGATION

- Why do it?
- Could we use “global” motion planning techniques?
  - http://grail.cs.washington.edu/projects/crowd-flows/
  - http://gamma.cs.unc.edu/crowd/
- Issues
  - Computationally expensive
  - Assumes global knowledge of dynamic environment

LOCALITY

- Limited knowledge → local techniques
  - It is reasonable to assume agents can have global knowledge of static environment
    - UAVs can have maps
    - Robots can know the building they operate in
    - Access to google maps, etc.
  - But can they know what is happening out of sight?
    - People often drive into traffic jams because they didn't know it was there (until too late)

LOCALITY

- What is local?
  - What information matters most?
    - Imminent interaction
  - What information can you know?
    - Line-of-sight visibility
    - Aural perception (less precise, but goes around corners)
    - Explicit communication (information passing)

LOCALITY

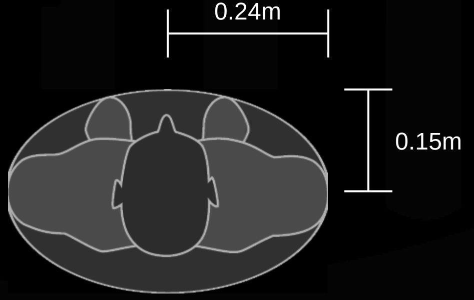
- Imminent interaction
  - Define temporally (ideal)
    - What can I possibly interact/collide with in the next τ seconds?
    - Anything beyond τ is unimportant and may lead to invalid predictions

LOCALITY

- Assume approximately uniform speeds
  - Temporal locality → spatial locality
  - Distance simply time * speed
  - PROS
    - Seems plausible
    - Computationally efficient spatial queries
  - CONS
    - Poor for scenarios with *widely* varying speeds
      - Pedestrians vs. cars
  - This is the common practice

LOCALITY

- Computational constraints
  - Assumption: spatial local neighborhood: r = 5 m
    - Roughly 3.75 seconds at average walking speed.
  - Average area of person: $A = 0.113\ m^2$
  - Maximum number of neighbors: ~700
  - Too many
  - Pick the k-nearest



LOCAL COLLISION AVOIDANCE

- Given
  - Preferred velocity
  - Local state
- Compute
  - Collision-free (feasible) velocity

LOCAL COLLISION AVOIDANCE

- Models define a mechanism for balancing the two factors
  - Represent the *effect* of preferred velocity
  - Represent the *effect* of dynamic obstacles
  - Model the interactions of the two

LOCAL COLLISION AVOIDANCE

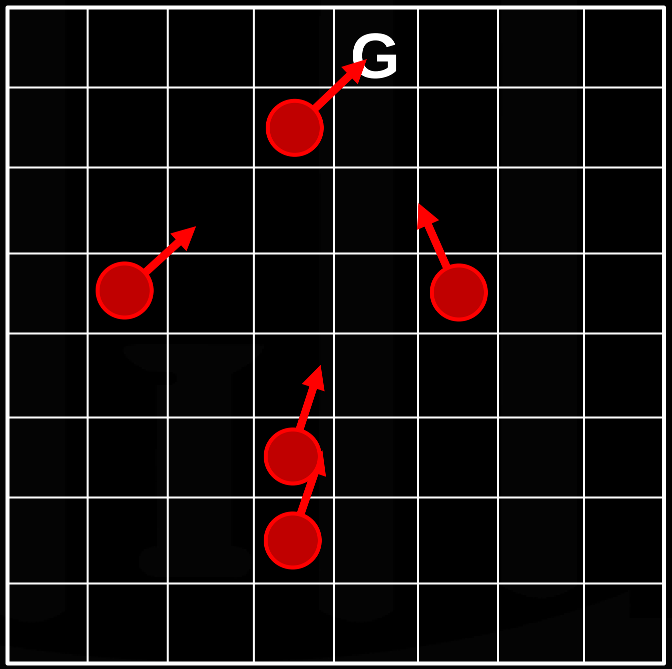
- Four classes of models
  - Cellular Automata (Today)
  - Social Forces (Today)
  - Geometric (Next week)
  - Miscellaneous (Next week)

CELLULAR AUTOMATA

- Game of Life
  - http://www.bitstorm.org/gameoflife/
- Applications in biology and chemistry
- Used in vehicular traffic simulation
  - (Cremer and Ludwig,1986)
- Borrowed into pedestrian simulation

CELLULAR AUTOMATA

- Decomposition of domain into a grid of cells
- Agents in a single cell
  - Cell holds one agent
- Simple rules for moving agents toward goal

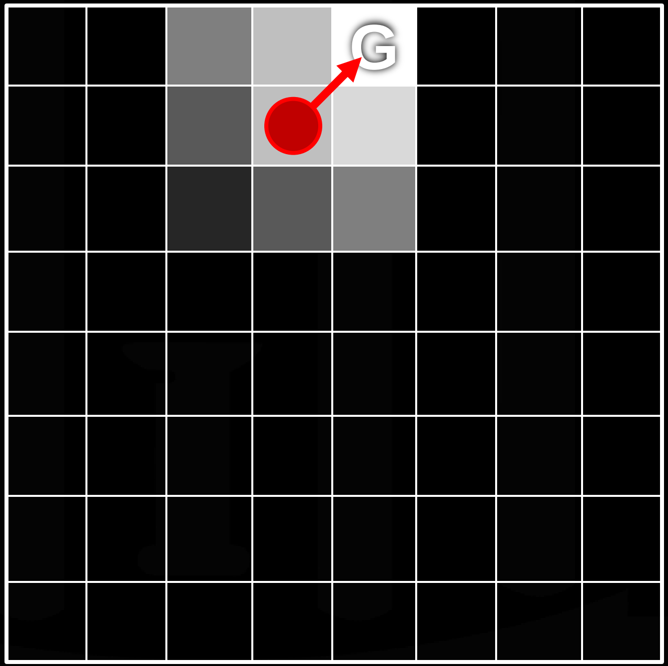


CELLULAR AUTOMATA

- Blue & Adler, (1998, 1999)
  - Simple uni- and bi-directional flow
  - Heavily rule-based
  - Rules for determining lane changes
  - Rules for “advancing”
  - Rules are all heuristic and carefully tuned to an abstract, artificial scenario
    - “lane” changes
    - Multiple-cell movements

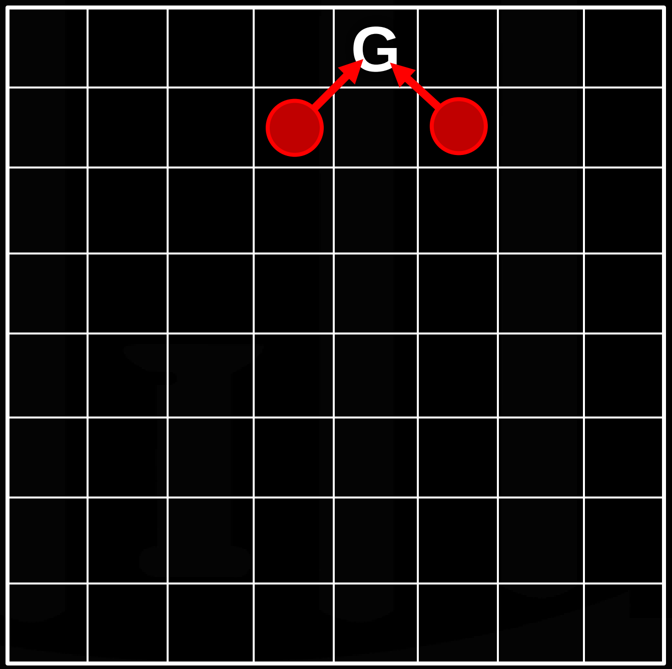
CELLULAR AUTOMATA

- Statistical CA - Burstedde et al., 2001
  - Accounting for pref. vel
  - Pref. vel → matrix of probabilities
  - Direction of travel selected probabilistically (target cell)



CELLULAR AUTOMATA

- Statistical CA - Burstedde et al., 2001
  - Accounting for neighbors
  - Rules
    - If target cell is already occupied, don’t move
    - If two agents have the same target, winner based on relative probabilities (loser stays still)



CELLULAR AUTOMATA

- Statistical CA - Burstedde et al., 2001
  - Complex behaviors from “floor fields”
    - Mechanism for “long-range” interaction
    - Contributes to probability matrix
  - Leads to aggregate behaviors
    - Lane formation, etc.

CELLULAR AUTOMATA

- Implications
  - Homogeneous pedestrians
    - "Same" speed, same abilities, same floor fields
      - Horizontal/vertical vs. diagonal
  - Large timestep
    - Cell size ~ 0.4 m → 0.4m/time step → 1.34 m/s in ~3 time steps → timestep = 0.3 s
  - Highly discretized paths (zig zags)
  - Density limits due to simple collision handling
    - Can't move into *currently* occupied cells

CELLULAR AUTOMATA

- Extensions
  - Hexagonal floor fields [Maniccam, 2003]
    - Replace quads with hexagons
    - Six directions with uniform speeds
  - Multi-cell agents [Kirchner et al., 2004]
    - Smaller cells
    - Agents occupy multiple cells
    - Agents move multiple cells
    - Deemed too expensive to be worth it

CELLULAR AUTOMATA

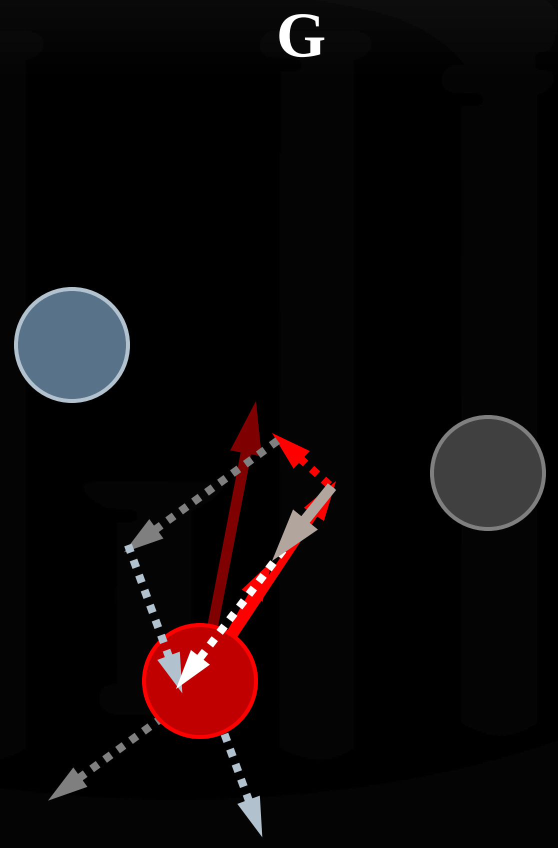
- Extensions
  - Real-coded CA [Yamamoto et al., 2007]
    - Support heterogeneous speeds
    - Improve trajectories
    - (Handling collisions unclear in the paper)

CELLULAR AUTOMATA

- Still alive and well
  - Tawaf [Sarmady et al., 2010]
  - High-level behaviors [Bandini et al., 2007]
  - Update algorithm analysis [Bandini et al., 2013]

SOCIAL FORCES

- Agent with preferred and actual velocities.
- “Driving” force pushes current velocity towards preferred velocity.
- Neighboring agents apply repulsive force.
- Forces are linearly combined and transformed into acceleration.
- Velocity changes by the acceleration.



SOCIAL FORCE

- Arose in the 70s [Hirai & Tarui, 1975]
  - Partially inspired by sociologists attraction to field theory
- Resurgence in the 90s [Helbing and Molnár, 1995]
  - Defined many of the traits that are seen in many of the current models
- These are not potential field methods, per se
  - They planning doesn’t follow the gradient of the field
  - The field implies an *acceleration*

SOCIAL FORCE – [HELBING & MOLNAR, 1995]

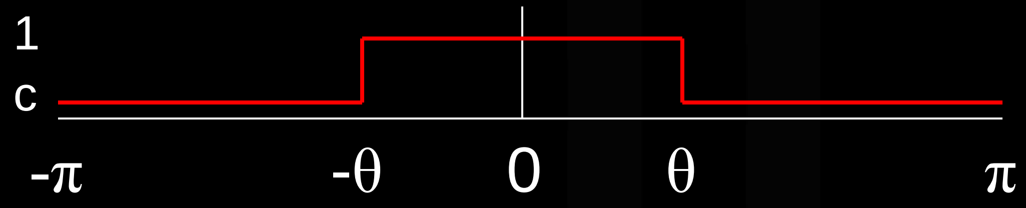
- Driving force
  - $F_d = m(v^0 - v)/\tau$
- Exponential repulsive forces
  - $F_r = Ae^{(-d/R)}$
  - A Gaussian function where $\sigma = R/\text{sqrt}(2)$
  - Infinite support (theoretically)
    - Compact support practically: 6σ
    - Exponential evaluated at $3\sigma \approx 0.011$

SOCIAL FORCE – [HELBING & MOLNAR, 1995]

- Elliptical contours of repulsion field
  - Models personal space – in front is more important than to the side
  - Treats backwards more important than side
  - Implies orientation (defined as the direction of motion)
    - Undefined for stationary agents

SOCIAL FORCE – [HELBING & MOLNAR, 1995]

- Weighted directions
  - Relative to direction of preferred velocity
  - Discontinuous: 1 or c, based on direction



- Attractive forces
- Random fluctuations
- This is *not* what you have in Menge

SOCIAL FORCE – [HELBING & MOLNAR, 1995]

- Implications
  - Full response is linear combination of individual responses
  - 2nd-order equation
    - The velocity you pick depends on the time step
  - Dense populations → stiff systems
    - Smooth compact support → high derivative at small distances
  - Parameter tuning
    - Force magnitudes depend on circumstances

SOCIAL FORCE – [HELBING & FARKAS, 2000]

- Social force simulation of escape panic
  - Removed:
    - Direction weighting
    - Elliptical force fields
    - Random perturbations
    - Attractive forces
  - Added compression and friction forces
  - This is what you have in Menge
    - Considered (by me) to be the simplest social force model

SOCIAL FORCE

- Johansson et al., 2007
  - Restores elements from the 1995 paper
    - Directional weight (varies smoothly)
    - Elliptical equipotential lines
  - Introduces relative velocity term
    - Relative velocity term
  - (This is an option for the next HW)

SOCIAL FORCE

- Chraibi et al., 2010
  - Generalized Centrifugal Force (GCF)
  - Includes a relative velocity term
  - Directional weight
  - Repulsive force based on inverse distance
  - Changes representation of agents to elliptical
    - Shape of ellipse changes w.r.t. speed
    - Faster → longer, narrower ellipse
    - Shorter → narrow, wider ellipse

SOCIAL FORCE

- Predictive
  - Karamouzas, et al. 2009 and Zanlungo, et al., 2010
    - Compute force based on *predicted* interactions
  - Computation of individual forces is similar
  - Karamouzas adds new method for combining forces
    - Iterative calculation and combination
    - Does not guarantee that they won't cancel each other out
  - (Zanlungo is also an option for the next HW)

SOCIAL FORCE

- Force-based approaches
  - Other models which use forces
    - Forces are derived from *ad hoc* rules
      - HiDAC
      - OpenSteer
      - Autonomous Pedestrians

QUESTIONS?