Bowling Modeling

A quest for excellence…

Craig Weidert
April 16, 2007
Scientific Computing – Prof. Yong

The Game

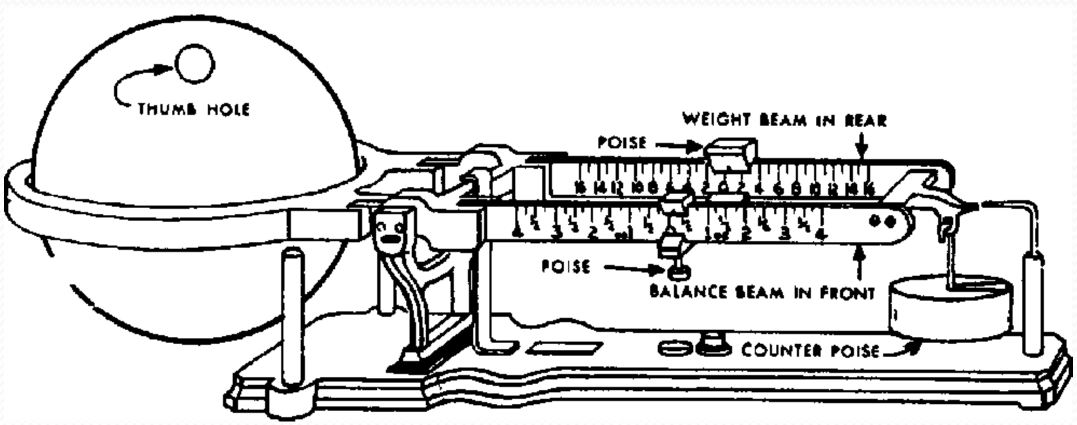
- Bowling has a rich history
- Essentially, two chances to knock down the 10 pins arranged on the lane
- Rules solidified in the early 20^{th} Century
- ~100 million players today

The Challenge

- The Lane
  - Standard dimensions: 60 feet by 42 inches
  - Oil Parameters
    - μ = .04 for first two thirds of lane
    - μ = .2 for last third of lane
- The Pins
  - Ten pins arranged in a triangle 36 inches on a side
  - 15 in tall, 4.7 inches wide, about 3 and a half pounds

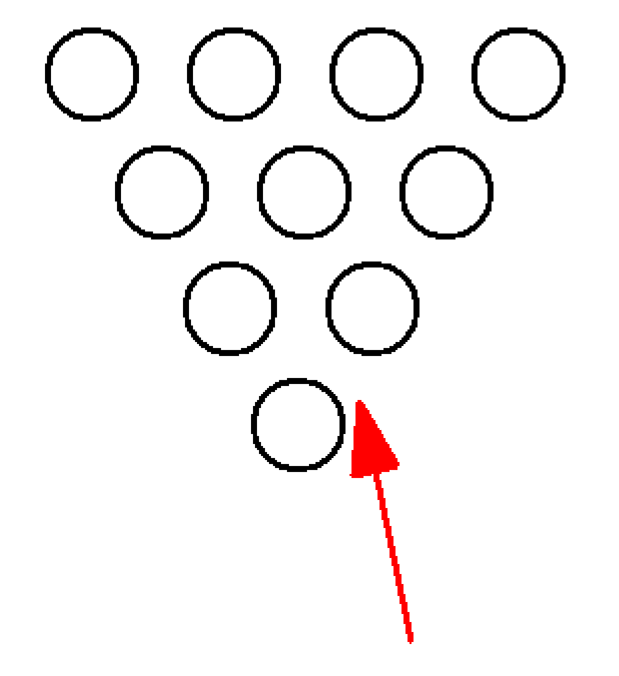
The Ball

- Made of polyester or urethane
- Radius is 4.25-4.3 inches
- 16 pound maximum
- Heavier inner core covered with outer material
- Offset center of mass
    - Less than 1 mm
    - Helps with spin



How the Pros Do It

- Splits are the worst
- Spins are more devastating
  - Throw or release the ball in such a way that spin is imparted
- Best bet: six degree pocket angle

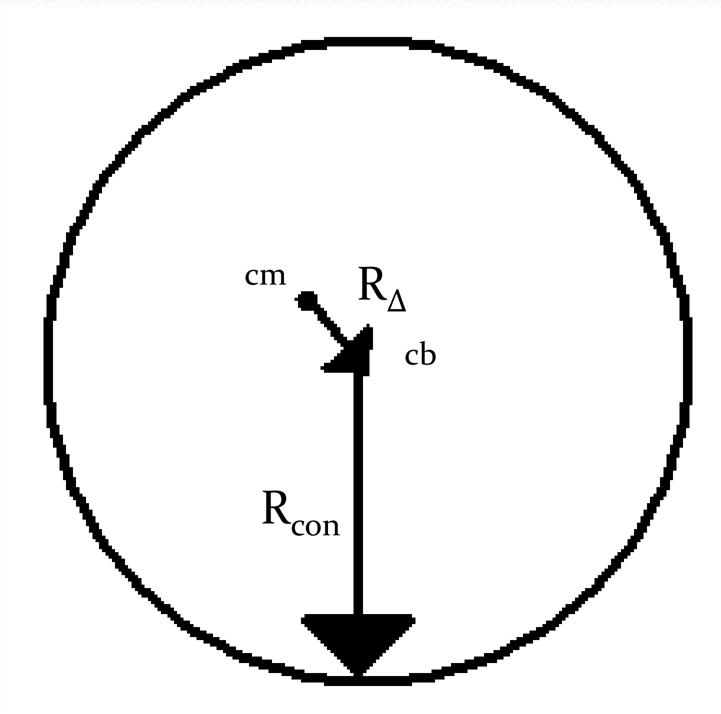


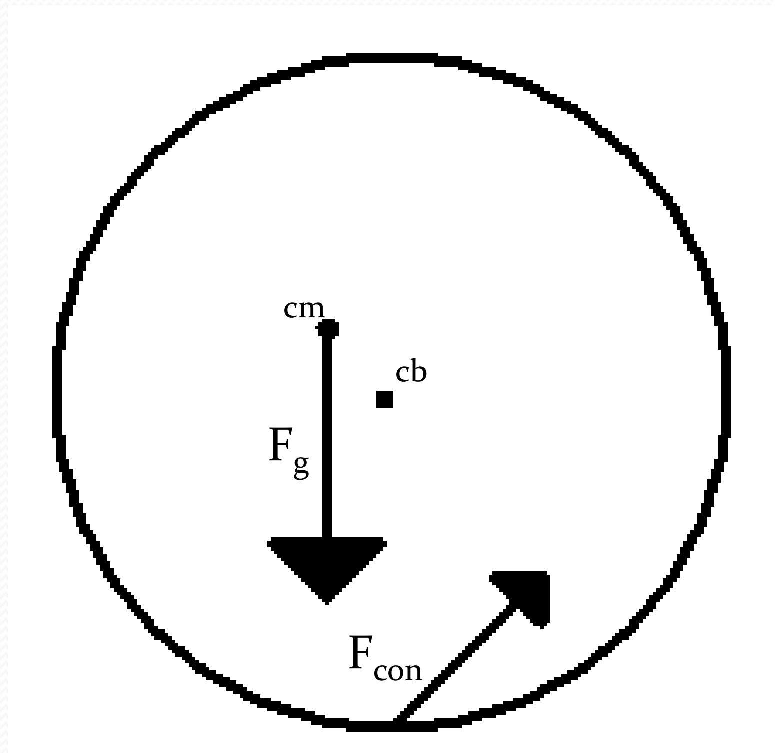
- I should like to model bowling ball paths

Previous Work

- Current literature tends to be either geared towards bowling manufacturers or to make overly simplistic assumptions
- Hopkins and Patterson
  - Ball is a uniform sphere
  - Did not consider offset center of mass or variable friction
- Zecchini and Foutch
  - No center of mass offset
- Frohlich
  - Complete as far as I know
  - Used basic standard time step of .001 second
  - All of the equations I used are from this paper

Vectors and Forces





Differential Equations

- Mass * position" = $F_{con} + F_g$
- d/dt ($I\omega$) = (r_Δ x R_{con}) x F_{con}
- If I is non-diagonal, LHS expands to:
  d/dt ($I\omega$) = ($I_o + I_{dev}$)α +ω x ($I_{dev}\omega$)
  - No ω x ($I_o\omega$) term since ω, I_o are parallel
  - ω x ($I_{dev}\omega$) is the "rolls funny" term
- At every step must calculate slippage: (R_{con} x ω) - Velo

Differential Equations (cont)

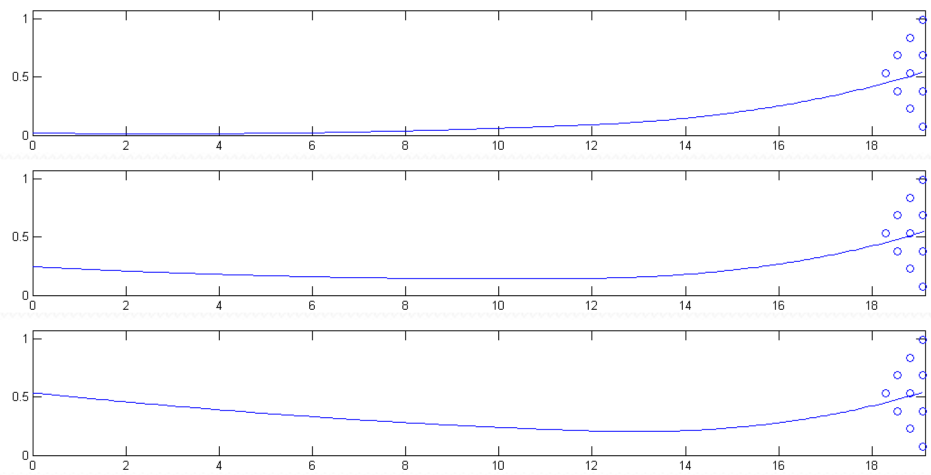
- Normal force varies
- Slipping
  - $(I_o + I_{dev} + I_\Delta + I_{\Delta\Delta})\alpha = \tau_{fric} + \tau_{dev} + \tau_\Delta + \tau_{\Delta\Delta}$
- Rolling
  - $(I_o + I_{dev} + I_{Roll} + I_\Delta)\alpha = \tau_{dev} + \tau_\Delta + \tau_{\Delta\Delta}$

Modeling Details

- Find y_o, $theta_o$, ω_o, v_o such that pocket angle, impact point were ideal
- 12 dimensional ordinary differential equation
- Used ode45
- Error: square of the difference in ideal, real angles plus square difference in y error
- Gutter avoidance

Results

- Possible to achieve desired impact point, pocket angle from multiple starting positions
  - Corresponds to thorough experimental work I have done on this project



- For all paths, a initial velocity of around 8 m/s and an ω_o of about 30 rad/s was sufficient

Difficulties / Future Work

- Moment of inertia tensor
  - Since ball is not symmetric, the moment of inertia must be a 3 by 3 matrix
    - Involves
    - Not sure whether this should be in lane frame
  - Breaking the effects of COM offset?
  - Will work on this in the next week
- Differing oil patterns on lane

Acknowledgements

- Cliff Frohlich
- Prof Yong
- Junbo Park