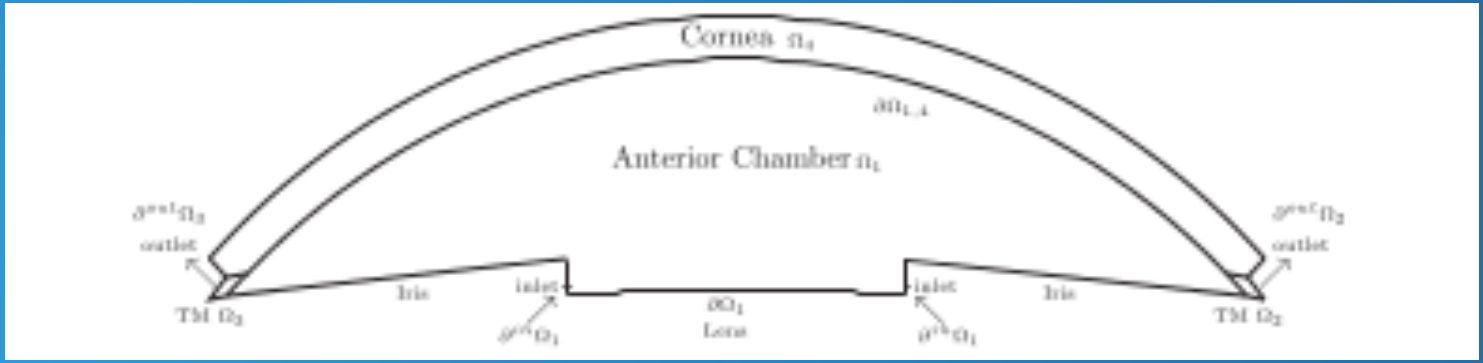
Introduction to Problem

- Glaucoma: 2nd leading cause of blindness in the world
- Risk factor for developing glaucoma:
  - high intraocular pressure (IOP) [regulated by aqueous humor at anterior chamber]
  - Strong correlation between those with diabetes and developing glaucoma
- Objective: **Model IOP under different glucose concentrations in aqueous humor**

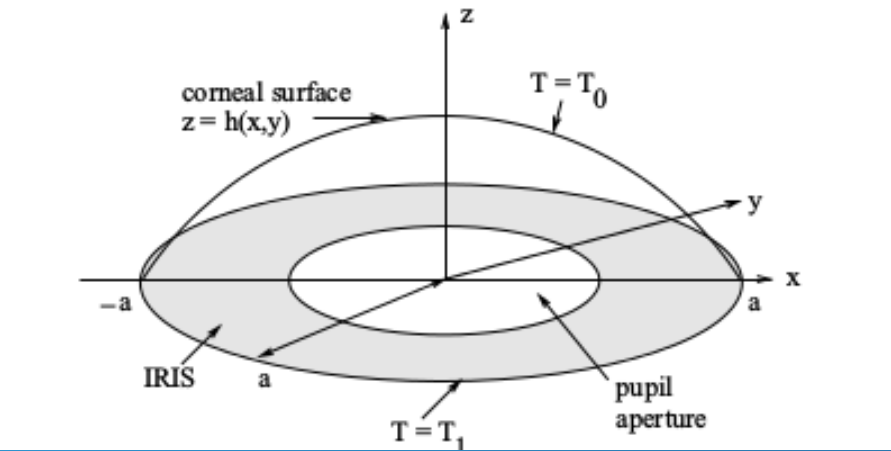
Previous Models

- 2-D Model:
  - Developed by J.A. Ferreira et. al (2014)
  - Models pressure in relation to increased resistance in Trabecular Meshwork/Schlemm's Canal
  - Does not account for buoyancy-driven flow



Previous Models

- 3-D Model:
  - Developed by Fitt and Gonzalez (2006)
  - Buoyancy-driven flow
  - Excludes Trabecular Meshwork/Schlemm's Canal



Method & Equations

- Flow of AH in anterior chamber simulated using modified Navier-Stokes equations:

$$\rho\bar{v} \cdot \nabla \bar{v} = -\nabla p + \mu\nabla^2\bar{v} + \rho_0 \bar{g}\beta(T - T_{ref})$$

$$\nabla \cdot \bar{v} = 0$$

$$\rho C_p \bar{v} \cdot \nabla T = k\nabla^2 T$$

- Flow in Trabecular Meshwork/Schlemm's canal:

$$\alpha = \frac{\mu}{\Delta p}\Delta e\bar{v} - f(g_c)$$

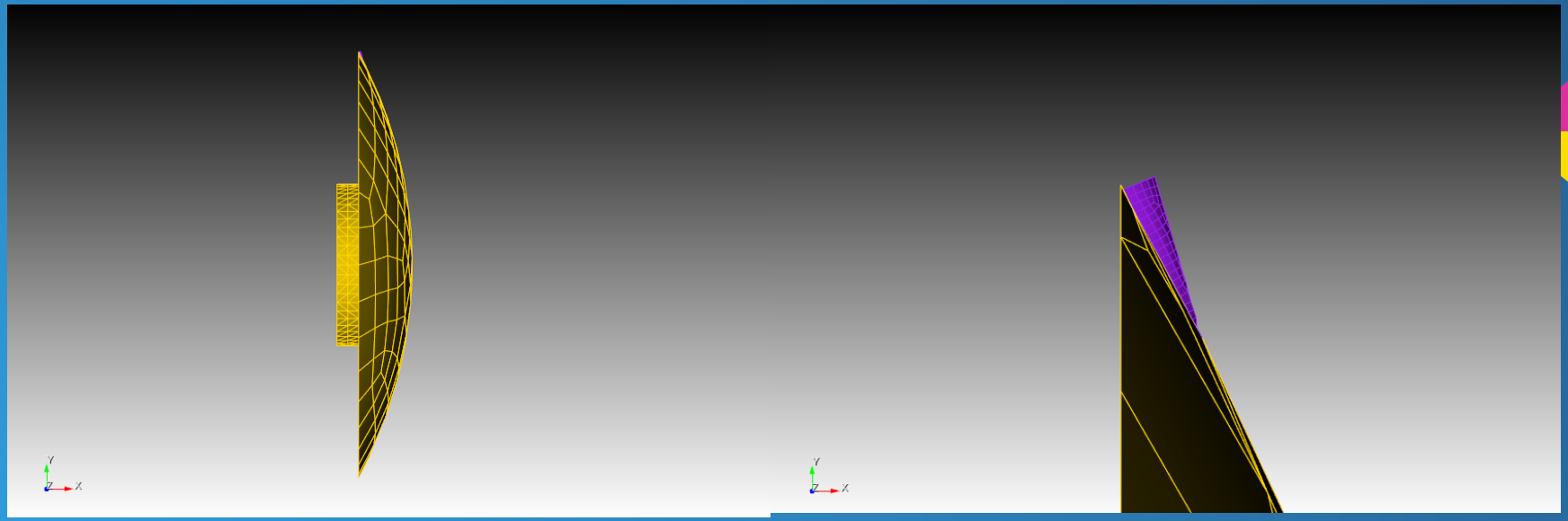
Parameters

Parameter	Value
Initial Velocity	1.2 mm/s
Outlet Pressure	1200 Pa
Reference Temperature	22 C
Aqueous Humor Density	1000 kg/m3
Aqueous Humor Viscosity	0.001 kg/(ms)
Aqueous Humor Specific Heat	4182 J/(kgK) [water property]
Aqueous Humor Thermal Conductivity	0.6 W/ (mK)
Glucose Concentration	99.1001 mg/dL (healthy eye); 144.1456 mg/dL (type 2 diabetic eye)

Hardware and Software

- Hardware:
  - Star1 (serial)
  - Darter (parallel)
- Software:
  - FEATool
  - Deal.II - FEM software library
  - Cubit-mesh generator
  - Cosmol Multiphysics Tool

Example Mesh (Cubit)



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References

Canning, C. R. (2002, 12). Fluid flow in the anterior chamber of a human eye. *Mathematical Medicine and Biology, 19*(1), 31-60. doi: 10.1093/imammb19.1.31

Crowder, T.r., and V.j. Ervin. "Numerical Simulations of Fluid Pressure in the Human Eye." *Applied Mathematics and Computation* 219.24 (2013): 11119-1133. Print.

Ferreira, J.a., P. De Oliveira, P.m. Da Silva, and J.n. Murta. "Numerical Simulation of Aqueous Humor Flow: From Healthy to Pathologic Situations." *Applied Mathematics and Computation* 226 (2014): 777-92. Print.

Heys, J. J., Barocas, V. H., & Taravella, M. J. (2001, 12). Modeling Passive Mechanical Interaction Between Aqueous Humor and Iris. *Journal of Biomechanical Engineering, 123*(6), 540. doi:

References

Fitt, A. D., and G. Gonzalez. "Fluid Mechanics of the Human Eye: Aqueous Humour Flow in The Anterior Chamber." *Bulletin of Mathematical Biology* 68.1 (2006): 53-71. Print.

Sayon Roy, Richard Kao, and Tsuyoshi Sato. "Effect of High Glucose on Telomerase Activity in Human Endothelial Cells." *Diabetes Research and Clinical Practice* 50 (2000): 368. Print.

Villamarin, Adan, Sylvain Roy, Reda Hasballa, Orestis Vardoulis, Philippe Reymond, and Nikolaos Stergiopulos. "3D Simulation of the Aqueous Flow in the Human Eye." *Medical Engineering & Physics* 34.10 (2012): 1462-470. Print.