Topic Selection For My Thesis

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Areas of Interest

Navier-Stokes Equations

- Newtonian – shear force has no influence on viscosity
- Isothermal – no thermal energy is lost or gained
- Incompressible – trying to compress the fluid only increases the pressure but the volume does not chage

The Equations

$$\nabla \cdot \underline{u} = 0 \qquad \text{Mass is conserved}$$

- $\underline{u}$ is a vector in (x, y, z), direction and speed of motion
- ∇ is the differentiation of $\underline{u}$ is $\nabla \cdot \underline{u} = u_x + u_y + u_z$ – divergence of the velocity
- basically just says that mass is conserved

$$\rho \frac{\partial \underline{u}}{\partial t} = -\nabla p + \mu \nabla^2 \underline{u} + \rho \underline{F} \qquad \text{Mass times acceleration = Force}$$

- Newton's second law $F = m \cdot a$ in diguise
- $\rho \frac{\partial u}{\partial t}$ is the desity times the acceleration, mass is density for fluids – kinda
- the other side holds all the forces – $-\nabla p + \mu \nabla^2 \underline{u}$ are the internal forces, the ones between the particles, and $\rho \underline{F}$ i are the external forces
- ∇p is the pressure gradient – change in pressure, fluids tend to move from points of high pressure to low pressure
- $\mu \nabla^2 \underline{u}$ is the viscosity – sliding past one another creates friction

The Problem

- the equations work, they have been around for a long time
- we simply don't know if they have a solution and we don't necessarily understand if they will have solution or not – mathematical understanding is still behind the applications
  1. Solution must exist – there has to be a way to find one
  2. Solution must be unique – there has to be only one way to solve an equation given a certain initial state
  3. Solution must be smooth – small changes in the input must only cause small changes in the output
- making assumptions about the process makes it simpler to actually use the equations
- taking averages over certain areas can also make the application simpler
- for the Clay Millennium problems – for 3D there are some solutions we can find – slow initial velocities, finite time, averaging, just not for all the conditions
- turbulence is one of the most annoying facets of navier-stokes equations
- practical usage is great, mathematically speaking we don't understand them

Possible Topics

- flow around a right-angle corner where there is a singularity at the inner point, velocity is infinite

-

Reynold's Number

$$\mathrm{Re} = \frac{\rho \cdot L \cdot U}{\mu}$$

density, length scale, velocity divided by viscosity

- when Reynold's Number is high or low, the same fluid moves differently
- these numbers are generally really low or really high – low means ~10, high means ~10.000
- turbulence means $Re > 1.000}
- if Re >> 1, the second formula becomes

$$\frac{\partial \underline{u}}{\partial t} = -\nabla p + \frac{1}{\mathrm{Re}}\mu\nabla^2\underline{u}$$

- the system is not non-dimensionalized – all the unites are gone
- this is anything with turbulence, like air moving around stuff
- now there are no units and all things can now be compared
- if one number is bigger than the other, it has more influence and counts more
- for large Re the viscosity does not matter
- for Re << 1, the second formula becomes

$$\mathrm{Re}\frac{\partial \underline{u}}{\partial t} = -\nabla p + \nabla^2\underline{u}$$

- in this case the non-linear component is lost, this make is super easy to solve (comparably at least)
- in this case the acceleration does not matter because Re is really small
- now time is no longer in our equations – this means equations are reversible
- very high viscosity can do this – honey and most types of syrups

Where does river water go when it hits the ocean?

- does the river turn right (North) or left (Southern) or straight (Equator)
- two features, whirlpool where the water enters, then flow to the right
- what is the width, speed, depth of the river

The Papers

1. Numerical Solution of the Navier-Stokes Equations, A. J. Chorin, http://www.jstor.com/stable/2004575
   - numerical solutions to n-s equations
   - Bernard convection
   - incompressible flow
   - time-dependent
2. Instability Theory of the Navier-Stokes-Poisson Equations, J. Jang & I. Tice, https://dx.doi.org/10.2140/apde.2013.6.1121
   - Lane-Emden stationary gaseous star configurations
   - linear and non-linear dynamical instability results
   - Navier-Stokes-Poisson – hydrodynamical model of a star
3. Localization and Compactness properties of the Navier-Stokes global regularity problem, T. Tao, https://dx.doi.org/10.2140/apde.2013.6.25
   - global regularity problem
   - localized energy and entropy estimates of the Navier-Stokes equations

4. Embedded Boundary Method for the Navier-Stokes Equations on a time-dependent domain, G. H. Miller & D. Trebotich, COMM. APP. MATH. AND COMP. SCI. Vol. 7, No. 1, 2012
   - flow simulation of incompressible Navier-Stokes equations

Compression and Decompression Algorithms

1. Lossless Astronomical Image Compression and the Effects of Noise, W. D. Pence, R. Seaman, & R. L. White, https://www.jstor.org/stable/10.1086/599023
   - evaluation of lossless compression techniques
   - compression efficiency
   - noise in picture
   - average number of bits of noise for each pixel value
   - synthetic picture then analysed
2. Epsilon Entropy and Data Compression, E. C. Posner, E. R. Rodemich, http://www.jstor.com/stable/2240137
   - epsilon entropy – now much data is needed for good description to within ϵ
3. Vision and the Coding of Natural Images: brain secrets to image compression, B. A. Olshausen, D. J. Field, http://www.jstor.com/stable/27858027
   - using neuroscience to investigate how animals and nature encode and compress images
   - understand and then copy how humans recognize shapes and objects
4. Data Compression: Something for Nothing, J. MacCormick, http://www.jstor.com/stable/j.ctt7t71s.10
   - history and basics of compression algorithm
5. Data Compression, C. C. McGeoch, https://www.jstor.org/stable/2324310
   - short basics of computer science
6. Fast Sinc transform and image reconstruction from nonuniform samples in k-space, L. Greengard, J.-Y. Lee, & S. Inati, COMM. APP. MATH. AND COMP. SCI. Vol. 1, No. 1, 2006
   - sinc transform is a solution in image reconstruction, image processing, it's precise but slow
   - here is the fast sinc transform that performs convolution on data in $O(N \log N)$ for N data points

Maxwell's Equations

1. Real-Space Green's Function Method for the numerical solution of Maxwell's Equations, B. Lo, V. Minden, & P. Colella, https://dx.doi.org/10.2140/camcos.2016.11.143
   - free-space Maxwell equations in 3D
   - Helmholtz decomposition
   - Duhamel's formula

Computer Science

1. Algorithm of traffic signs recognition based on the rapid transform, J. Gamec, D. Urdzik, & M. Gamcova, DOI: 10.2478/s13537-012-0019-3
   - 5 stage model to recognize traffic signs