From: **Andy Ruina** ruina@cornell.edu
Subject: Re: about sailing
Date: May 4, 2019 at 6:39 PM
To: Veit Elser ve10@cornell.edu, Erich Mueller erich.mueller@cornell.edu
Cc: Matias Waller matias.waller@ha.ax, Rebecca Hanna Jiang rhj47@cornell.edu

AR

Ooops. Typo at the very end. I grew up with the phrase "signal to noise ratio".

Veit and Erich: May 4, 2019

Please share with the whole class.

1) First, thanks for being such a nice audience for my class. Really a pleasure for me.

2) The article about my friend Jim Papadopoulos the bike guy:
https://www.scientificamerican.com/article/the-bicycle-problem-that-nearly-broke-mathematics/

3) If anyone took any notes it would be nice to recall at least the titles and general topics of the lectures.

4) QUESTIONS About Sailing. I got some questions from Matias.

Q: Why do you think people still talk about the ability of boats to sail at a tighter angle towards the (real) wind, say 20-30 degrees, as something positive?
a) It is a sign of high performance (high L/D for sail and keel).
b) It is useful when you are trying to round a point or bouey and don't want to tack

Q: Is it mostly out of comfort and ease that people with pretty efficient sailboats (not skötbåts [old slow wood open heavy fishing boats]) sail directly downwind instead of beating at an angle?
Only the very best boats can go faster by tacking. Maybe only the catamarans and hydrofoils. And fancy monohulls. Here is one:
https://www.imoca.org/en/imoca-boat/
Which has a polar that gives advantage to tacking downwind (sideways polar plot).
https://www.researchgate.net/figure/Velocity-prediction-polar-plot-for-true-wind-angles-from-0-to-180-and-true-wind-speeds_fig1_255596181
I think this is more typical of a good boat.
https://www.yumpu.com/en/document/view/5195402/performance-package-hprojectsproduction-hanse-yachts

Q: For robotic sailboats there would be no point in sailing directly downwind (except that it could keep you closer to a line of reference)?
Depending on the boat, it might be faster to go directly downwind. But, for our rigid-wing boats: a) they are particularly unstable directly downwind, and
b) I think they may be slower, but I am not sure.

Q: Do you have a good reference about this (the 78 under revision?)
That's on the internets. http://ruina.tam.cornell.edu/research/topics/miscellaneous/
And there is also lots more about DDWFTTW.
I don't know a reference for the circular polar thm besides that obscure book I showed in class. And the paper in revision on my computer.

5) FORGOT to say about sailing.
I started with wings and went to propellers. I could have gone the other way around. Another cute thing.
For windmills and propellers we have

$$P = cFV$$

P = power in or out of boat, F = propulsive or drag force, V = relative velocity. c is more or less than one
depending on whether you are using power or generating it. So you have a boat with two spinning propellers,
one up and one down. Use that for interactions with air and water
and you get restrictions on speed going upwind and downwind. I said all that.

Now, instead of, say, a windmill going round and round you could have an oscillatory blade windmill.
And you could make an oscillating propeller, going back and forth. Now choose the gearing so the
two blades have the same speed relative to the boat as they go back and forth. Well, connect them
to each other. Now take away the boat. And you have invented a sailboat.

That is, a tacking sailboat is a reciprocating wind mill connected to a reciprocating propeller with no moving parts.
Pretty clever simplification

6) JOKE
For sailboats, propellers, windmills and airplanes one wants a high "lift to

drag ratio". That's a phrase "lift to drag ratio".
It's key, like in signal processing where one wants a high "signal to noise ratio". That's a known phrase too. Once in grad school a group of us were stealing a piano. Hard to move such a heavy thing. But it was covert so we had to do it quietly. But it was funny doing that stealing, so we were laughing and making lots of noise and the piano wasn't going anywhere. My girlfriend at the time, Debbie Mason said, "Wait, wait, this isn't right, we need a higher lift to noise ratio."
OK, at least _I_ thought it was funny. Maybe because my dad was an electrical engineer so I grew up with the phrase "lift to drag ratio", and that was the era when I first wrote my unfinished sailing paper and was pre-occupied with "lift to drag ratio".

– Andy Ruina, Mechanical Engineering
ruina@cornell.edu; +1 607 327-0013
http://ruina.tam.cornell.edu; skype: andyruina
566 Upson Hall, Cornell U, Ithaca, NY 14853
227 Bryant Ave, Ithaca, NY 14850