Windvane Derivation

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I. Windvane Equation Discussion

I made a quick derivation of the effect of heel angle on the out-of-plane wind vane measurement, proposed by Tanner in [1].

Consider the apparent wind vector to be broken into a component in the forward direction and a component in the starboard direction. For this derivation, consider "starboard" and "forward" to be parallel to the surface of the water, determined solely by yaw. Wind can be assumed to flow parallel to the surface as well. The windvane's direction θ is determined by the components along the windvane's local X and Y coordinates, so that, as shown in Fig. 1,

$$\theta = \text{atan2}(wind_x, wind_y).$$

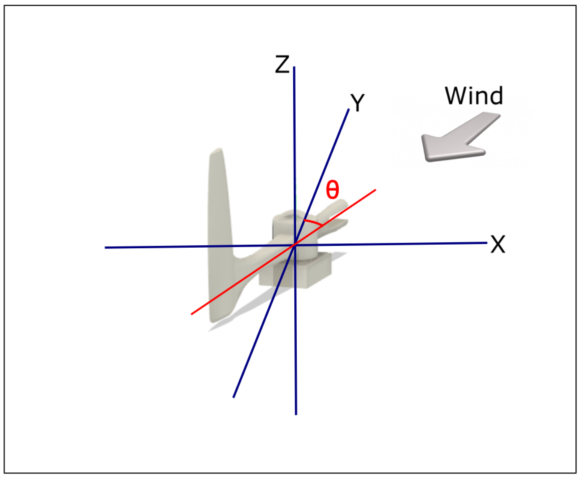

Fig. 1. Windvane principle of operation.

When there is no heel, pitch, or mast twist, the windvane's X and Y dimensions align perfectly with the boat's starboard and forward directions. However, when the boat is heeled by an angle β while keeping level trim, less of the wind's force lies in the X direction. The component in the Y direction remains the same, as can be seen in the lower-left hand sub-figure of Fig. 2.

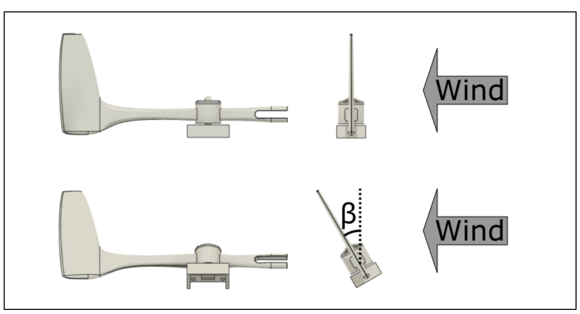

Fig. 2. Wind action on windvane while boat is flat (top sub-fig) and heeled (bottom sub-fig).

This result implies that the X-component of the windvane's direction is the product of the wind's starboard component and the cosine of β. Thus,

$$\theta = \text{atan2}(wind_{starboard} * \cos(\beta), wind_{forward}).$$

In order to determine the actual apparent wind angle from the indicated angle θ, we rearrange and find that

$$\tan(\theta)/\cos(\beta) = wind_{starboard}/wind_{forward}.$$

Since the tangent of the right hand side is the actual apparent wind angle, this equation is equivalent to the one I found in literature. Numerical errors could be handled with the standard math libraries by implementing this as

$$AWA_{actual} = \text{atan2}(\sin(\theta), \cos(\theta) * \cos(\beta)),$$

which would ensure that a θ value of $\pi/2$ would result in a computed actual AWA of $\pi/2$. Additionally, this method is moderately computationally expensive.

There remains an extreme sensitivity to perturbations of θ when θ is near zero and β is near $\pi/2$. This accurately reflects the inherent lack of useful information from vertical-axis windvanes at high angles of heel, but it would be likely to screw things up since windvane dynamics and boat motion can cause regular perturbations.

As a result, this equation should only be applied online at moderate heel angles. Maybe this could be enforced with fuzzy logic or a simple if check. As long as the domain is limited, it could make sense to simply apply a correction to the estimated AWA based on a Taylor approximation to limit the expensive trigonometry.

Alternatively, a really good method to resolve this is to leave the true wind estimation function as is, since it works just fine.

References

[1] https://uu.diva-portal.org/smash/get/diva2:850625/FULLTEXT01.pdf