Mapping and Summing Physical Forces

It has emerged that some readers are not as familiar with the procedures involved in mapping, measuring, and summating physical forces as had been assumed. The following note has therefore been prepared with the help of Luciano Gallon, to whom heartfelt thanks are due.

The most basic illustration we can think of is predicting in which direction, and with what force, a group made up of two boys pulling on ropes attached to a goat's collar will move – see Figure 6.

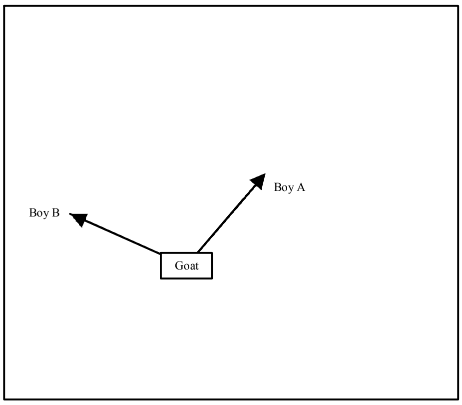

Figure 6
Two Boys and a Goat

To progress the analysis, both the direction and strengths the three forces can be represented as in Figure 7, where the lengths of the lines (vectors) shows how strongly each is pulling in the direction shown.

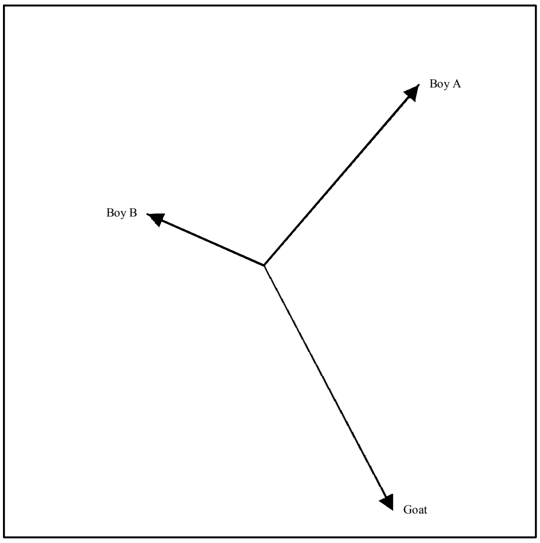

Figure 7
The Struggle between the Boys and the Goat Expressed in Vectors

The direction and strength of the outcome of this struggle can be calculated by dropping perpendiculars onto any two dimensions (or orthogonal axes) inserted into Figure 7 at random (Figure 8). Summing these intersects, or coordinates, (i.e. $A_x + B_x + G_x$ and $A_y + B_y + G_y$) (treating coordinates to the left of the origin on the X axis and below the origin on the Y axis as negative) gives the coordinates (R_x and R_y) of the final vector resulting from the struggle (**R** in Figure 8). This shows the strength and direction of the outcome. (In this case, the goat wins!)

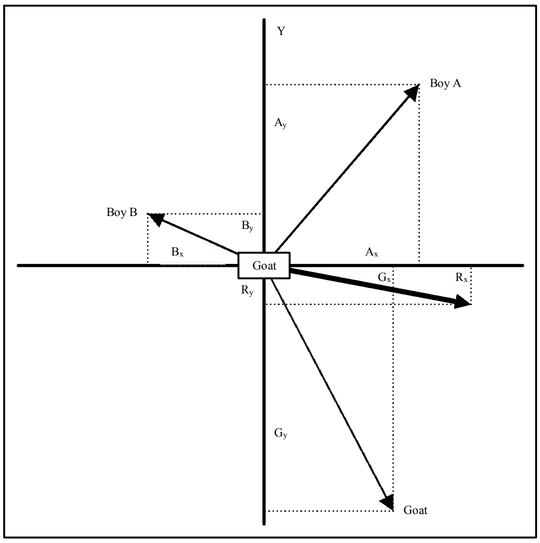

Figure 8
Calculating the Outcome of the Struggle with the Goat

Mapping and summating the forces acting on a sailing boat is more complicated, but the process is the same. Even an oversimplified diagram has to include the force of the wind on the sails, the resulting thrust on the mast and, via the ropes attached to the outer corner of the sail, toward the stern of the boat, the effect of the rudder, and, most importantly from the point of view of our discussion here, the force of the sea on the keel (see Figure 9).

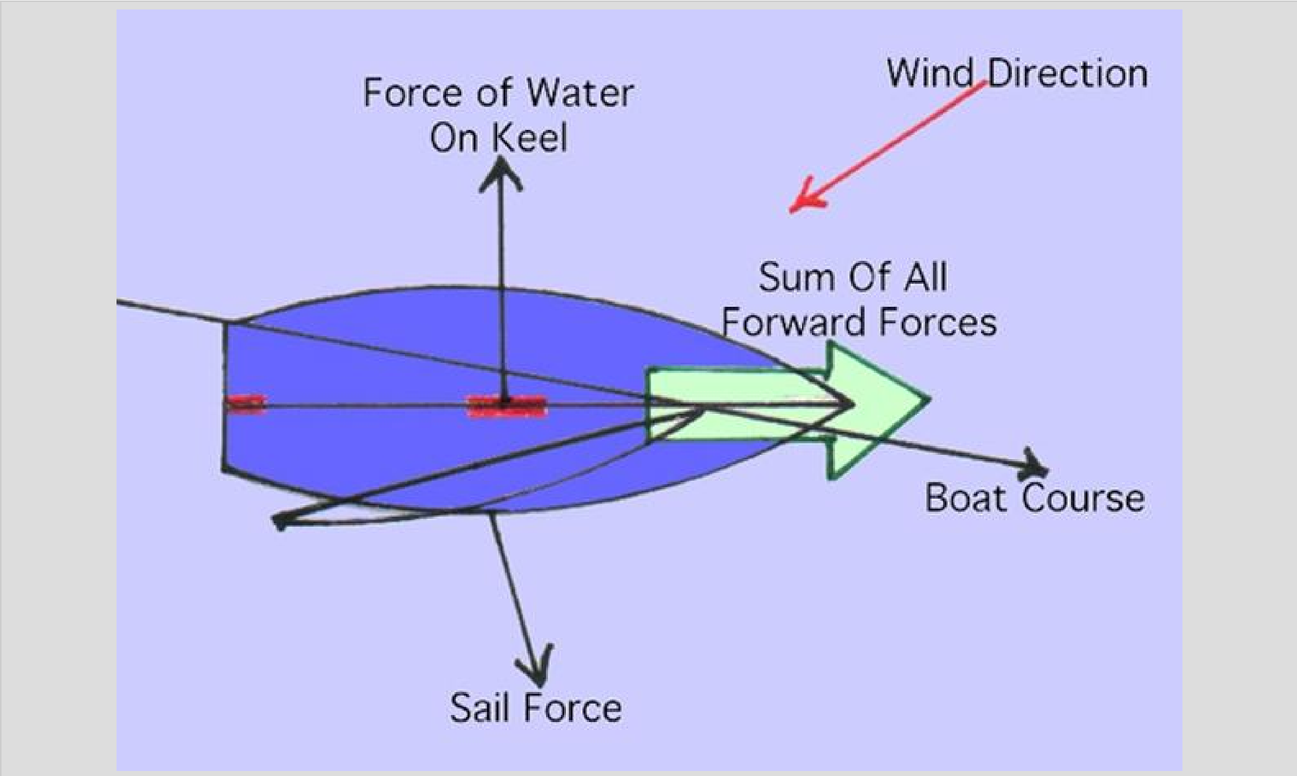

Figure 9
Forces Acting on a Sailing Boat

Why is the keel so important to us?

Prior to Newton, not only had the concept of "force" – so obvious to us now – not been articulated, the movement of sailing boats was to a much greater extent than later in the lap of the Gods. Boats could only sail *with* the wind. If their captains wanted to reach a destination upwind, they had to have-to and pray for a favourable wind.

The first thing Newton did was show that what he hypothesised to be a "force" in this invisible wind could be *measured.* He did this by first jumping with the wind and measuring how far he could jump and then jumping into the wind and making a similar measurement. The difference between the two gave him the strength of the wind.

(In the context of this discussion it is worth noting that a key thing Franklin did in order to substantiate the concept of "electricity" was to show that its strength could be assessed – "measured*"* – from the relative strengths of the electric shocks he experienced in his arms.)

Back to Newton and sailing boats.

Among other things, Newton also formulated a number of "laws of motion".

Among these, was the law that "To every force there is an equal and opposite reaction".

Now. Where is the equal and opposite reaction to the force of the wind on the sailing boat?

In the sea?

OK. If so, how can it be harnessed?

Answer "By adding a keel to the sailing boat". And that is precisely what is shown in Figure 6. Harnessing the invisible force in the sea is key to getting the boat to sail *into* the wind.

It is important to note that *none* of the above is "common sense" … indeed, from the common sense perspective that preceded Newton, it is just madness … I mean, its just crazy to suggest that there is a force in the sea! The necessary developments could not have been taken unless Newton had articulated the concept of force and shown that it was measurable and behaved in predictable – law-like - ways.

Newton went on to do something else which is even closer to what we are trying to do here – namely to map the forces determining the orbits of the planets and compute their cumulative strengths.

First, he needed the concept of "gravity". Then he had again to demonstrate that it could be measured. And then that the results were consistent. Indeed they were. Indeed they were. And very surprising: bags of coal and desert spoons if dropped from the top of a tower, reached the ground at the same time. (Actually, this last discovery had been made earlier, but we do not need to concern ourselves with this here.)

And then he had to find a way of integrating all the interacting pulls of every planet on every other.

To perform that task he had to invent calculus.

We do not have to do that.

But my thesis *is* that we *do* have to embrace an exactly parallel series of problems if we wish to develop better ways of thinking about the nature, measurement, and harnessing of social forces.