Around the World*

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ABSTRACT: What must a balloonist do in order to fly "around the world"? It proves surprisingly difficult to provide necessary and sufficient conditions that capture the ordinary concept of circumnavigation. A number of criteria and analyses are discussed, including the account endorsed by the official F.A.I. regulations. The *circumnavigation problem* in the philosophy of geography may turn out not to be purely geometrical.

On the morning of March 20 1999 in the skies over Mauritania, the Breitling Orbiter 3 reached longitude nine degrees and twenty-seven minutes west, and its two crew members, Bertrand Piccard and Brian Jones, became the first balloonists to complete a non-stop circumnavigation of the globe. The balloon had been launched nineteen days earlier at Chateau d'Oex in Switzerland. After flying south from Switzerland to North Africa, Orbiter 3 maintained a very straight course eastward around the world. This path took the balloon from North Africa over South East Asia, the Pacific Ocean, Central America and the Atlantic Ocean back to North Africa. For almost the entire journey the balloon remained in the fairly narrow region between latitudes twenty degrees and thirty degrees north, dipping below the twentieth parallel only for a short period while crossing the Pacific. Having completed their circumnavigation, Piccard and Jones pushed on,

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finally landing the next day in the Southwestern Sahara near the town of Mut in Egypt. The total distance they had covered was just over twenty-nine thousand miles.

It seems intuitively clear from the description just given that Orbiter 3's attempt at a circumnavigation of the globe was indeed successful. But what exactly was it that Piccard and Jones had set out to do? It proves surprisingly difficult to give an analysis of the notion of circumnavigation that accords with untutored intuition. Finding an adequate solution to this *circumnavigation problem* not only poses an interesting conceptual puzzle. It is fairly pressing from a practical viewpoint as well, for the stakes in round-the-world ballooning are high. Piccard and Jones were awarded for their effort a prize of one million U.S. dollars that had been offered by a major brewing company for the first successful circumnavigation.

So what, precisely, does a balloonist have to do in order to "fly around the world"?

Orbiter 3's flight path crossed every meridian of longititude. But it would be a mistake to think that this criterion represents a sufficient condition for circumnavigation. It is not enough to start at a particular meridian and proceed east (or west) crossing each line of longitude in turn until one has returned to the meridian at which one started. Someone who launched a balloon a mile from the North Pole and then sailed around the pole in a circle of radius one mile would have crossed each line of longitude, but obviously this would not count as having circumnavigated the globe.

The requirement that one cross every meridian does not seem to be a necessary one either. A flight path that took a balloon in a great circle around the earth from North Pole to South Pole and back again would seem to be a perfectly good circumnavigation.

The meridian-crossing criterion offends what one might think is a fairly clear intuition about circumnavigation, namely: that the notion of circumnavigation ought to respect the spherical symmetry of the situation.[1] The spherical symmetry condition might be put like this: it should not be possible to transform a flight path from a successful circumnavigation into a failure simply by sliding it rigidly around the surface of the globe. Note that since the Orbiter's flight path lies entirely in the northern hemisphere, it is possible to slide that flight path rigidly around the earth's surface to leave it entirely in the western hemisphere. Thus translated, it would cross no meridian in the eastern hemisphere and hence would not cross every meridian.

Any great circle flight should certainly count as a circumnavigation. Adding the converse requirement would result in an analysis that satisfied the spherical symmetry condition. Slide a great circle rigidly around the surface of a sphere and it remains a great circle. But that analysis would be too strict. The great circle standard is sufficient but not necessary for circumnavigation. Balloons tend to follow a meandering course, subject to the vagaries of the winds. So the conditions for circumnavigation should not require anything like great circle precision.

Perhaps, however, it is possible to take the great circle paradigm as a starting point for a more complicated analysis of some sort, an analysis that also allowed flight paths that meander, but that in some clear sense do more than is required by the great circle standard. Here is one such idea:

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[1] For simplicity I shall assume that the earth is spherical in shape for the purposes of this discussion. In fact that is not quite true; the earth bulges slightly around the equator.

Proposal 1:   A flight path circumnavigates the globe if and only if there is no way of dividing the globe into two hemispheres such that the entire flight path lies above only one hemisphere.

This analysis would allow, for example, paths that depart from a great circle by meandering off to either side of that circle. And it would allow many other kinds of path as well; too many in fact. Proposal 1 is insufficient as an analysis of circumnavigation. That is evident from the following example of a flight path which would satisfy Proposal 1, but which clearly wouldn't count as a flight around the world.

Counterexample 1:   The balloon starts at some point on the equator, it flies east along the equator until it has gone just more than halfway around the world. The balloon then makes a tiny circle, turns around and retraces its path back along the equator to the starting point.

Some straightforward attempts to patch up Proposal 1 also fail. For example:

Proposal 2: A flight path circumnavigates the globe if and only if (i) there is no way of dividing the globe into two hemispheres such that the flight path lies entirely above one hemisphere; and (ii) there is some great circle such that (a) each point in the flight path may be mapped uniquely to the closest point lying on that circle and (b) the result of this mapping covers the entire circle.

This is still insufficient, as we see from:

Counterexample 2: The balloon starts at the North Pole and flies south along the meridian one degree west of Greenwich to the South Pole, around which it makes a tiny circle. It then flies back along the meridian one degree east of Greenwich to the North Pole.

As in Counterexample 1, going halfway around the world and back again does not constitute a circumnavigation. Separating the paths out and back by two degrees does not make a difference either; this is still not a circumnavigation. Adding the tiny circle around the South Pole ensures that there is no way of dividing the globe into two hemispheres such that the flight path lies entirely above one hemisphere. Hence clause (i) is satisfied. As for clause (ii), consider the great circle *C* that runs around the meridians ninety degrees east and ninety degrees west of Greenwich. For each point *p* on the outward part of the flight path, the unique closest point to *p* on *C* lies on the meridian ninety degrees west. For each point *q* on the return part of the flight path, the unique closest point to *q* on C lies on the meridian ninety degrees east. This mapping covers the entire circle *C*.

Another kind of analysis starts from the observation that a closed flight path which divides the surface of the earth into two regions of equal area would also count as a paradigm example of a circumnavigating route. Of course this "equal area" requirement, like the great circle requirement, is by itself too restrictive. But perhaps there is some way of refining the idea to make it work. For example:

Proposal 3: For any two points *p* and *q* on the flight path, define the *pq* shortening of the flight path to be the result of replacing that section of the flight path between *p* and *q* by the shorter great circle arc linking *p* and *q*. Then a flight path circumnavigates the globe if and only if for every $\varepsilon > 0$, there is a finite sequence of points $p_1, p_2, \ldots\ p_n$ such that the result of the $p_1 p_2$ shortening, followed by the $p_2 p_3$ shortening, . . . followed by the $p_{n-1} p_n$ shortening, is a path which divides the surface of the earth into two regions whose difference in area is less than ε.

But this doesn't work either. In fact it also falls to Counterexample 1, since the return path along the equator from the turnaround point to the starting point shortens to the remaining untraversed segment of the equator, resulting in a shortening of the flight path which is a great circle (the equator itself). And it doesn't help to adjust Proposal 3 by insisting that shortening be "local" along the path. We can simply replace the return path in Counterexample 1 with an arc that stays close to the equator but remains always north of it. Such a return path can then be shortened by a series of small local deformations that, once again, eventually transform it into the shorter great circle arc between the starting point and the turnaround point.

Now it is interesting to note that the actual route followed by Piccard and Jones fails to satisfy each of the three analyses proposed so far. Those analyses were rejected on grounds of insufficiency, but insofar as commonsense agrees that Piccard and Jones succeeded in their endeavor, that suggests that the three analyses also fail to provide necessary conditions for the ordinary notion of circumnavigation.

It is surprisingly difficult to capture this ordinary notion of circumnavigation. Yet with a million dollars in prize money at stake in the race to complete the first non-stop around-the-world balloon flight, surely someone has gone to the trouble of making the rules of the game precise!

And someone has. As a matter of fact, the sport of ballooning is regulated by the Ballooning Commission of the Fédération Aéronautique International. Section 1 of the F.A.I. Sporting Code covers 'aerostats', a category which includes free balloons and airships. Paragraphs 4.8.3 and 4.8.4 of this document outline the rules for around-the-world ballooning records.[2]

And this is what the F.A.I. rules have to say. A balloon has successfully circumnavigated the globe provided that, after the flight, the pilot of the balloon is able to choose:

(a) Two circular "caps" on the surface of the earth. The radius of each cap must be thirty degrees of great circle arc. Each cap must enclose one of the poles, though not necessarily at its center.

(b) A sequence of position check points along the flight path, each of which must lie outside both circular caps. The shorter great circle arc joining each successive pair of check points must also lie outside both circular caps, though the flight path itself may pass inside those caps.

(c) A meridian to count as the start and finish line. The flight path must cross all other meridians after crossing the start line and before crossing the finish line.

These rules seem less than completely satisfactory: They are to some extent arbitrary. They admit certain flight paths that untutored intuition would hesitate to count as

[2] I am referring to Version 1.98 of the FAI Sporting Code which includes amendments issued December 18 1998. This document may be found online at http://www.fai.org.

circumnavigating the globe. And they disallow certain flight paths that intuitively should count as going around the world.

The caps are designed to rule out the “polar scam”. But the caps constitute a solution to that problem that is arbitrary in two respects. Why should the radius of each cap be thirty degrees of radius? Why not twenty-five degrees, or forty degrees? And why should the caps be required to enclose the North and South Poles? Wouldn’t any pair of antipodal points fulfill that function equally well? This insistence on the North and South Poles is related to the equally arbitrary demand that the flight path cross all meridians, a demand that simply reflects a bias bred of our familiarity with maps on a cylindrical projection, with the cylinder centered on the earth’s axis. The F.A.I. regulations don’t respect the spherical symmetry criterion.

A flight path which ran just around the outside of one of the circular caps would count as a path around the world on the F.A.I. interpretation. But that is a judgement that does not clearly accord with intuition. The caps are quite small. Since each of the caps has a radius of thirty degrees of great circle arc, the diameter of the circle bounding each cap—measured in a straight line through the earth rather than across the earth’s surface—is one half of the earth’s diameter. (Proof: Consider a regular hexagon inscribed inside the sphere that is the surface of the earth. The length of a side of that hexagon equals the radius of the circle that is the perimeter of a circular cap. To see that that length is half the radius of the earth, imagine dividing the hexagon up into six congruent equilateral triangles). It follows that the F.A.I rules admit “circumnavigating” flight paths that are as short as half the circumference of the earth.

By sliding one of the circular caps to the point where the enclosed pole remains only barely within its bounds, we can construct some F.A.I. approved flight paths that commonsense would not regard as going around the world. I encourage the reader to sit down with a globe and an appropriately sized circular piece of wire, try out some positions for the circular cap and then sketch the result on a standard map of the world in cylindrical projection. Here are some examples. In each case the flight path is a circle that barely encloses the South Pole.

(1) From near the South Pole, proceed over Kerguelen Island, Perth, Sydney, Christchurch, and back to the South Pole.

(2) From near the South Pole, proceed to Tierra del Fuego, then on over the South Atlantic Ocean to Cape Town, and back to the South Pole via Prince Edward Island.

(3) In fact it is possible to confine the whole trip to the Southern Ocean, staying well east of Madagascar and remaining west of Western Australia. This flight path never crosses land, except for the tip of Antarctica, and the only other notable geographical features enclosed by the flight path are Crozet Island, Kerguelen Island, McDonald Island, Heard Island, Amsterdam Island and St.Paul Island.

Perhaps our ordinary concept of circumnavigation has been shaped, in part, by our familiarity with maps of the world projected onto a cylinder. Then the spherical symmetry criterion is not one that the ordinary concept must satisfy. A defender of the F.A.I. interpretation might argue that the regulations simply reflect that fact.

Furthermore, the Piccard and Jones flight is generally—if not universally— regarded as a successful circumnavigation. This suggests that the lines of analysis explored above were aiming at a notion of circumnavigation stronger than we ordinarily have in mind. Perhaps the ordinary concept of a flight "around the world" is vague. A defender of the F.A.I. interpretation might then argue that, for the purpose of formulating regulations, one admissible sharpening of the vague concept is as good as another.

Finally, from a practical viewpoint, serious attempts at a round-the-world balloon flight are constrained by certain contingent facts. One such fact is that the balloon will have to make use of the winds known as the "jet-stream" that, in the northern hemisphere, flow eastward in the middle latitudes from late December through February each year. A defender of the F.A.I. interpretation might then say that the "circumnavigation problem" is not a purely geometrical problem at all, but one which depends on other geographical considerations of a non-geometrical kind.

These responses suggest that there may really be two related problems here, only one of which is purely geometrical.

I started thinking about the circumnavigation problem in 1998 while the race to win the million-dollar prize was still underway. At that time one of my colleagues facetiously suggested that there ought to be another prize: one to be awarded to the first person who successfully formulated precisely *what* the would-be circumnavigators were trying to do, before any of them succeeded in doing it. But—unfortunately—the balloonists won.