Friction: an engineer's perspective on weaving grass rope bridges

Friction: An engineer’s perspective on weaving grass rope bridges

Introduction: The grass rope bridge

In a remote area of the Peruvian Andes, 120 miles southeast of the regional capital Cuzco, a rickety rope bridge sags and sways precariously over a deep gorge. Beneath is a muddy raging torrent, sure to sweep away any unfortunate traveller careless or unlucky enough to fall in. This is the so-called ‘last remaining *keshwa chaca*’, a design of bridge dating back at least 500 years to the time of the Inca Empire. Crossing the Apurimac river (the ‘Great Speaker’) near the villages of Huinchiri and Percaro, it has survived only through the ongoing work of the local communities who come together in an annual festival to cut down the old decaying bridge and build a new one, recreating the traditional design. The lightweight construction means that it is only suitable for people and llamas, so in 1968 a new steel bridge was installed a few hundred meters away to take the increasing number of vehicles in the area (Gade 1972). But far from being an anachronism, or even simply a tourist attraction (which it most certainly is) the *keshwa chaca* is now, and always has been, a nexus of social regeneration and reinforcement.

This type of bridge was common throughout the high Andes in the early 17th century, astonishing the Spanish Conquistadors as they went about their ruinous plundering (Poma de Ayala 1936 [c.1615]). The reason why the bridges were seen with such amazement was the fact that they were woven anew each year entirely from the locally abundant *qqoya* grass. Today the annual ceremony still takes place - each of the local communities produces an agreed amount of rope for the bridge, usually based on 40 arm-lengths per household (Finch 2002). Making the rope is a technical business, literally passing through many hands before it is finished. The grass is first softened by pounding and soaking, often carried out by children, and then spun into pencil diameter cordage by adult women. Once sufficient grass cord has been produced, which McIntyre estimates to be about 22,000 feet in length (about 7km), this is then passed on to the men, who twist bunches of 24 cords into ropes of about 25mm diameter. These are then further combined into the two main types of cable: a 2-rope twisted hand-cable, and a 3-rope plaited deck-cable (McIntyre 1973; Finch 2002). Gade, in reviewing the 16th Century Spanish sources, says that “the older men braided the cables, leaving the younger men with the more laborious job of stretching them across the channel.” (1972:98). The larger ropes are gradually pulled tight and fixed together with grass cord, before the bridge is finished with a brushwood-matting deck.

Figure 1: The Keshwa Chaca

Friction (part 1)

When I started my PhD in 2008 and was in the early throes of reading and thinking about different bodies of literature that would ultimately support my thesis (Ewart 2011), I read a recently published book by Anna Lowenhaupt Tsing. It was called ‘Friction: An Ethnography of Global Connection’, with the word ‘Friction’ in bold red above a photograph of deforestation by fire taking place in Indonesia. It was relevant to my studies for two reasons. Firstly, it was set in the Indonesian province of Kalimantan (the Eastern part of the large island of Borneo), which was relatively close to the area where I did my own anthropological fieldwork, in Sarawak (the Malaysian province on the western side of Borneo). Secondly, it described an ethnographer’s view of a changing world, which to some extent mirrored my own interests in the adoption of new engineering practices and materials by a remote community. Tsing's 'Friction' remains one of my favourite books, ranging from the shocking tragedy of the ecological disaster taking place in Indonesia, to the extraordinary stoicism of the local people who see the world and their own lives changing, determined to save something for posterity.

My interest was piqued further by the use of the term 'friction'. As an engineer, I was aware of the concept of friction as physical force acting between two surfaces, so was curious to see how this could be translated from the physical to the social sciences. Tsing's book, as the sub-title tells us, is a nuanced examination of globalization, considering the process from many angles rather than just that of the apparently dominant (Euro-American) culture. "Instead, a study of global connections shows the grip of the encounter: friction", and "speaking of friction is a reminder of the importance of interaction in defining movement, cultural form, and agency." (2005: 5-6). As a cross-disciplinary term, 'friction' is quite appealing to the anthropologist, replacing the two physical surfaces with two cultural surfaces and metaphor-izing some of the characteristics of friction, such as heat and resistance, to become people 'rubbing each other up the wrong way', or the idea of global trade flowing freely and thus being 'frictionless'.

The social sciences in general and anthropology as a discipline in particular, sometimes struggle to explain quite complex views of the world. Belief systems that are alien to us can be difficult to comprehend, while the mundane everyday life that we experience can be equally hard to see for its greater significance. It gets no easier to understand when the solution comes from academics agonizing over competing theoretical approaches or writing dense monographs. So resorting to familiar metaphors is a useful way to explain and think through social issues. However, although it might be a useful metaphor for anthropologists, friction is also an engineering term, and can demonstrate the possibilities of investigating the world around us through technical production. We can build on the 'anthropology of technology' literature of the 1990s (e.g. Lemonnier 1993), and the 'design anthropology' of the last decade (e.g. Gunn et al 2013), to say nothing of the work of many (especially French) scholars of the mid 20th century (e.g. Leroi-Gourhan 1993 [1964]). Admittedly, disciplinary boundaries are formidable, since anthropology traditionally seems to draw more aspiring scholars from the humanities than the natural sciences, but that leaves plenty of scope for the future.

Friction (part 2)

Before discussing why engineering friction (as opposed to its metaphorical namesake) is worthy of anthropological study, I will first explain what it is. Having said that, I am aware that at this point a sizeable proportion of my readers, when faced with the prospect of something mathematical will be seriously thinking about skipping forward either to the next pictures, or even worse to the next chapter. To counteract this impulse, I will draw on another author, Tim Ingold, and particularly his use of objects and materials in his work as prompts for thinking. The sub-discipline of anthropology that I am particularly interested in has been called 'Material Culture studies', and involves studying the way that social and cultural relations are mediated by objects/things and materials. This involved some rather esoteric debates about the usefulness and meaning of terms such as 'materiality', or the distinction between a thing and an object, to which Tim contributed most generously. In one such article he illustrates his thoughts by using a specific object to demonstrate the changing nature of materiality, suggesting it is not a fixed property but an ongoing story, exposed to the flow of the world around us (Ingold 2007; see also Miller 2007). The material object he used was a wet stone, and it was with this in mind that I fixed upon a material of my own with which to entice you: an A4 piece of paper. Or rather, two pieces of paper, which will serve to illustrate some of the principles of friction, and cause me to reflect on the nature of friction as a material property.

To do so, please humour me by finding two pieces of plain A4, taking the first piece of paper and laying it horizontally on your table in front of you ('landscape' orientation). Then lie the second piece of paper end-to-end beside the first; next slide it over the first by about one third, so the two pieces appear to form one extended horizontal sheet, overlapping in the middle. Now tightly roll the two overlapping pieces of paper lengthways, working away from you is easiest, so you end up with one long thin tube. Finally, to prevent it from unrolling, squash it flat. What you have now is the start of a paper rope. To demonstrate the power of friction, grab one end of your paper rope (squashed roll) in each hand and pull hard!

At this point there are generally three possible outcomes: one, the two pieces of paper pull apart easily and you frown, slightly bemused; two, you pull hard and manage to pull them apart with a struggle; three, you pull as hard as you can and cannot pull them apart. In fact, you may end up ripping the paper while still leaving the rolled/squashed joint intact. When I have tried this with groups of students, very few if any manage to achieve the last of the three outcomes and are immediately suspicious that I have tricked them in some way. Of course there is no trick, it is all down to the friction between the two pieces of paper. And here's where the maths comes in: the *frictional force* (F) acting against your attempt to pull the paper apart is quantified as the *product* (i.e. numbers multiplied together) of the *coefficient of friction* (μ) between the two surfaces, and the *normal reaction* (R) between those two objects.

As an equation, we would write: $\mathbf{F = \mu \times R}$

You can think of μ as a measure of how slippery the surfaces are, and R as the amount of force pushing them together. If the frictional force exceeds the inherent strength of rolled paper, then you will rip rather than separate the two pieces of paper. If on the other hand, your rolling was not tight enough (the value of 'R' is relatively small), or you chose particularly slippery paper ('μ' has a lower value), then your frictional force is reduced and the two pieces of paper will slide apart unscathed. With a little practice, you will be able to roll together two pieces of paper tightly enough so that you will not be able to pull them apart, and you too will be able to impress your friends and family (or students) with this demonstration of the power of friction!

An Anthropology of Friction

How then can this be useful when thinking about the Keshwa Chaca described in the opening of this paper? If we think about the annual recreation of the bridge, then it is easy to reflect on the socio-cultural significance of what is happening: each household contributes to a larger communal effort; the status of the bridge has changed from common transport infrastructure to regional icon; the economic benefits of appealing to the new breed of adventure traveller; the bridge festival as an opportunity for social enactment and engagement, etc. But there is also the physical act of production, and it is this that particularly interests me. Now we are armed with some basic knowledge of engineering friction, we are in a much better place to consider how and why this rope has been made.

The first point to note is that the Keshwa Chaca is in the high Andes, well above the treeline – the highest point at which trees will grow. This is obvious from early Spanish illustrations, (Pomo de Ayala 1936:356), which show only bare mountain peaks. As a structural element, a stout trunk would be immediately useful in making the simplest of bridges, what is known as a beam bridge, by laying it so that it reaches either side. In this region, such large trees are not locally available, so sourcing them as a construction material would be physically difficult and probably require political wrangling to transport over long distances and through different administrations. What does grow in abundance is *qqoya* grass, a type of tough and long stemmed grass. However, this is not obvious as a bridge-making material, and as we saw with our paper-rope, strength varies according to the exact method of production. A very strong rope only needs one weak point to become a very weak rope.

It is quite difficult to explain in words a physical action. Even in the simple paper rolling exercise I described above, I am convinced that my attempt to write down in a limited number of words what is in fact a very simple physical action will confuse a fair proportion of those who try it. This will become apparent when I try to explain how rope is made from grass for the *keshwa chaca*. There are a number of videos of the bridge and its annual reconstruction, such as the Youtube video added by Atlas Obscura in 2015 (see References for URL) that show this, although often without a great deal of detail. The grass is woven by taking small handfuls of grass stalks and separating them into two loose bundles. The two bundles are squeezed between the hands as the hands are rubbed together, one moved towards the body and the other away from the body. This action causes each of the two bunches to twist their stalks together, whilst at the same time they are wrapped around each other forming a cord. The whole sequence takes a fraction of a second and requires no deliberate thought on the part of the women doing the weaving, continuing as she does to continue laughing and talking to her neighbours. Once a certain length of the stalks has been twisted together, the weaver has to introduce more grass, ensuring that the length of overlap provides sufficient friction to bind the strands when put into tension, just like our experiment with the two pieces of paper.

Figure 2 – Women weaving grass rope

We could use friction as a metaphor for the way that the annual bridge ceremony brings communities together or creates conflict, maintains identity or allows easy movement through the landscape, and it might work well as a heuristic device. But I think we can learn more about the *keshwa chaca* by considering friction as an engineering phenomenon. Understanding the basic components of frictional forces - the coefficient of friction (how slippery the surfaces are), and the normal reaction (the force pressing the surfaces together) puts a different perspective on the grass rope as a socio-technical artefact. We can see friction as a material property that the bridge engineers have learned to manipulate to their advantage as part of their technical production. The processing described in the introduction (soaking, pounding etc.) and the weaving actions described above, have come about over generations through engagement with the grass and a sensitive understanding of the properties that it reveals as a material. With a better sense of the way that frictional forces have been harnessed to create this extraordinary bridge, we can gain a greater depth of insight, and appreciation for the skills developed by these communities than would be possible if we remained ignorant of the engineering behind it.

References

Atlas Obscura. 2015. *Keshwa Chaca – The last Incan rope bridge.* Youtube video. Available at: https://www.youtube.com/watch?v=pvo4iLDAERg [accessed 13th March 2019)

Ewart, I.J. 2011. *An Anthropology of Engineering*. Unpublished DPhil thesis. University of Oxford.

Finch, R. 2002. Keshwa Chaca, straw bridge of the Incas. *South American Explorer*, 69: 6-13.

Gade, D.W. 1972. Bridge types in the central Andes. *Annals of the Association of American Geographers*, 62(1): 94-109.

Gunn, W., Otto, T. and Smith, R.C. (eds.) 2013. *Design Anthropology: Theory and practice.* London and New York: Bloomsbury.

Ingold, T. 2007. Materials against materiality. *Archaeological Dialogues*, 14: 1-16.

Lemonnier, P. (ed.) 1993. *Technological choices: transformation in material cultures since the Neolithic.* London and New York: Routledge.

Leroi-Gourhan, A. 1993 [1964]. *Gesture and speech.* Cambridge, MA.: MIT Press.

McIntyre, L. 1973. The Lost Empire of the Incas. *National Geographic Magazine*, 144(6): 729-787.

Miller, D. 2007. Stone age or plastic age? *Archaeological Dialogues*, 14: 24-27.

Poma de Ayala, F.G. 1936 [c.1615]. *El primer neuva corónica y buen gobierno (codex péruvien illustré).* Paris: Institut d'Ethnologie, Université de Paris.

Tsing, A.L. 2005. *Friction: An ethnography of Global connection.* Princeton: Princeton University Press.

Figure 1 – The *Keshwa Chaca* crossing the Apurimac River in the Peruvian Andes. (Image courtesy of peruwildtreks.com)

Figure 2 – Women weaving grass rope during the construction of the *Keshwa Chaca.* (Image courtesy of Ric Finch)