Galileo's use of experimentation and the limits of nature

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As has often been commented upon, the mere idea of experiments having evidential value is not straightforward from an orthodox Aristotelian point of view, due to the ontological gap separating artificial from natural phenomena. Yet, more recent scholarship has stressed that this gap could also be crossed in a number of ways, since according to Aristotle art was supposed to "imitate" or "complement" nature. In my presentation I'll analyze the multifaceted relations between art and nature as presented in some late sixteenth–early seventeenth century texts on mechanics (the mathematical science of the simple machines, going back to antiquity (pseudo-Aristotle, Archimedes, Pappus, …)). A focus on this specific field is especially relevant as Galileo Galilei's innovative use of experiments is arguably rooted in this tradition. The general aim of the presentation is to come to a more nuanced view on the relationship between the changing epistemic value of experiments in the work of Galileo and the fluid boundaries between art and nature.

Central to my analysis will be another idea of Aristotelian origin, that of art "overcoming", or "going against" nature – as in machines which allow one to raise a heavy body using a lighter body. Guidobaldo del Monte, in his 1588 commentary on Archimedes' treatise on the equilibrium of plane figures, offers a particularly nice way of linking this with the idea of art "complementing" and "imitating" nature, when he states that art overcomes nature "through nature". After all, a machine actually operates by exploiting the natural properties of matter – it does nothing else but place heavy bodies in a specific, "artificial" configuration (complementing nature) after which it lets just nature run its course (through nature), the effect of which can be understood mathematically as follows: the artificial configuration of the bodies always has one common centre of gravity, which centre wants to unite itself with the centre of the world, as is the case for all heavy bodies (imitating nature); depending on the relative position of the centre of gravity and a fixed point, the fulcrum of the machine, one of the bodies will move down and the other up (potentially contrary to nature, with the lighter moving the heavier).

Guidobaldo, who considered himself a faithful Aristotelian, was a good friend, early patron, and sometime collaborator of the young Galileo. In his own treatise on the simple machines (written somewhere in the 1590's), which is to a large extent modeled on Guidobaldo's 1577 Mechanicorum Liber, Galileo adds one crucial conceptual innovation to Guidobaldo's mathematical explanations. At one point Guidobaldo had mentioned (without further comment) a mathematical corollary as following from the proportions characterizing the multiplication of force with a machine: whatever is gained in weight (moved) is lost in time (of motion). Galileo recognizes in this statement a fact of much greater significance and foregrounds it as a general compensation principle in all his explanations of the operation of the simple machines. While not adding significant mathematical content to Guidobaldo's treatment, this opens up a very different interpretative perspective on this content.

One way to characterize this new perspective is as follows: the compensation principle expresses the limits of what can be achieved with a machine. According to Galileo's new conceptualization, the mathematical science of machines no longer expresses what we can achieve with natural bodies, but rather what we cannot achieve. We can thus surmise that Galileo in the first place saw the introduction of a general compensation principle as a fruitful move because this threw an interesting light on the objective limits of what can be achieved with any machine. This comes out most clearly in the introduction to his treatise, where he explicitly links these limits with the impossibility of "cheating on nature”. The gains to be achieved with the use of a machine are purely pragmatic, but always essentially constrained by nature as that which imposes objective limits. The juxtaposition of Guidobaldo and Galileo is thus extremely revealing: while sharing a mathematical structure, they develop a very different discourse about the relation between this structure and the idea of nature – rather than art overcoming nature, nature now imposes limits on art. At no place does Galileo extend this discourse in a full-fledged natural philosophy that reaches the same level of subtlety and generality as Aristotle’s, but the contours of his alternative can be clearly discerned nonetheless.

In the last part of my presentation I will then connect this new interpretation of the science of mechanics with the potential evidential worth of artificial experiments. In a nutshell: as the operation of a machine is now thought of as subject to inviolable invariances, instruments such as a lever or a balance gain a new representative power, which they could not possess within an Aristotelian framework, opening up the possibility of seeing them as essentially analogous to “natural” phenomena – they can stand for what happens “in nature”. Put differently, as the basic principles of mechanical science express the limits of our manipulative capabilities, it becomes natural to investigate these exactly through manipulations. It is through our way of interacting with it that nature now can first truly show itself. This allows mathematical instruments that had been primarily practical problem-solving tools to function now also as full fledged investigative tools.