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A periodization of research technologies and of the emergency of genericity

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ABSTRACT

According to the historian and sociologist of science Terry Shinn, the creator of the concept of 'research technologies': "Research technologies may sometimes generate promising packets of instrumentation for yet undefined ends. They may offer technological answers to questions that have hardly been raised. Research technologists's instruments are then generic in the sense that they are base-line apparatus which can subsequently be transformed by experimenters into products tailored to specific economic ends or adapted by experimenters to further cognitive ends in academic research."[1] Genericity thus manifests one of three fundamental characteristics of research technologies. At the same time, however, each research technology emerges out of the specific disciplinary context in which it is initially developed with entirely concrete aims. Consequently, genericity does not exist from the outset but first has to form, along a path that remains to be clarified. It is produced or constructed by the actors on two levels: as an instrument in the laboratory and as a way of speaking at the representational level. This issue yields the structure of this paper. Three options for the transition of a specific technique into a generic research technology are compared. One of them proves to be the most frequent pattern of this dynamic. This is explored further, taking as paradigmatic examples 'computed tomography' (CT), 'nuclear magnetic resonance' (NMR) and its application known as 'magnetic resonance imaging' (MRI), together with several additional examples.

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1. The basic issue and three options

How does scientific instrumentation proceed from the specific context of its inception and development, to a multiplication of its applications, to genericity? As far as I can see, there are basically three options:

1. an explosive multiplication of applications,
2. a continuous, steady expansion in overall range, or
3. a stepwise broadening of application areas.

I am unaware of any plausible candidates for variant (2). The impression that is occasionally gained from superficial consideration of historical processes, of a continuous incremental development overall, always gives way, upon closer consideration, to step-like phases of development involving a considerable degree of innovation and an associated sudden broadening of areas of application. Examples of the first and third of these postulated options come quite quickly to mind. They seem to follow these patterns, at least with a certain initial plausibility. With reference to option (1), for instance: the early history of telescopes toward the end of the first decade of the seventeenth century. An eyeglass-maker in Dutch Middelburgh hit upon the idea of placing two suitable lenses in a series. The innovation by Galileo in Padua, of artificially narrowing the objective lens to improve the quality of the image, followed,[2] and just a few months after this became known, a large number of discoveries in different subfields of observational astronomy. This instrument originating

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[1] Joerges & Shinn (2001, p. 9); cf. Shinn & Joerges (2002) and Shinn (2007).

[2] The history of the discovery of the telescope is discussed in van Helden (1977); see also the contributions by Albert van Helden, Sven Dupré and Rolf Willach to van Helden et al. (2010) along with the references to the earlier literature.

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from the contexts of eyeglass-making and military applications turned into a veritable research instrument.[3] As the decades elapsed, this exemplary model of an early modern research technology rather assumed the stepwise pattern of development. It proceeded by major innovative steps, e.g., up to Huygens' air telescopes, Newton's reflector telescopes, and achromatic lens combinations employed by Gregory.[4]

2. The laser and X rays—only seemingly 'explosive'

At least at first glance, the early history of the laser, around 1960, appeared to be a history of 'explosive' innovation, starting immediately after its first successful development.[5] Likewise for the discovery of X rays along with their many applications. The first X-ray tubes were installed in hospitals just a few weeks after Wilhelm Conrad Röntgen made his discovery of 'X-Strahlen' toward the end of December 1895. Hospitals in Vienna or Hamburg, for instance, were already equipped with their own devices by March 1896. A veritable media hype supported this extremely rapid spread of this new examination technology. Reports about the discovery and its potential applications—many of them overblown—appeared in newspapers.[6] Gas-discharge physics and cathode-ray technology, the original contexts of Röntgen's discovery, were extended very rapidly in the direction of medicine. Other applications of X rays in entirely different fields, such as materials science and testing, safety engineering, and synchrotron radiation, followed later.[7]

Obviously, such a rapid and open reception of a specialized innovation in basic science is not typical. It is a rare exception. The point I would like to make here is another: even in the area of medical applications, the initial euphoria about the ability to detect bones and foreign objects inside the human body cannot conceal the fact that further progress was hardly continuous. It clearly proceeded by leaps and bounds. The expansion of X-ray applications into softer tissues, such as the internal organs, only occurred about 1900 when reliable tubes became available that had a separate anticathode, water cooling (Walter) and hardness adjustability (Firma C.H.F. Müller). X-ray diagnostics using a contrast medium commenced during the 1920s.[8] In addition to irradiation of the interior of the human body, more or less targeted topical irradiation began to be used from 1903 on, for the treatment of tumors or skin diseases.[9] Radiotherapy with specialized X-ray tubes in dermatology first began around 1900. About 1904 the company C.H.F. Müller first offered therapeutical tubes specially designed for body cavities. Not before 1907 did lead protective clothing, dosimeters, and other preventative measures to protect the operators these X-ray tubes appear, however. In too many instances did the medical staff suffer serious injury from the radiation.[10] Routine application of X rays *beyond* the field of medicine, such as in nondestructive materials testing, only began to be established around 1910, notwithstanding a few earlier experiments by Röntgen himself and by Eder and Valenta. Precise calibration of the strength and hardness of X-ray tubes, in the sense of Shinn's research-technology indicator metrology, also became possible earliest about 1912 through the researches by Max von Laue and Knipping and Friedrich, on one hand, and the parallel work by William Bragg Junior and Senior in England since 1913, on the other hand.[11] It was only by that point in time that X-ray diffraction reached the stage of a generic technology. By then it was in fact employed in far more than one discipline. Then the physical nature of X rays finally also got solved.[12] On closer examination, X-rays prove to be a good instance of a rather stepwise broadening of application areas. Despite the explosive initial dynamics, X-ray technology accumulated further areas of application along the lines of the third option above. Full genericity (per Shinn) hence existed only from 1913 on, that is, eighteen years after the discovery of X rays.

3. Another example: the CT scanner

With this second example we remain within the area of X-ray applications. Classical X-ray images are always a kind of shadow image, which explains the common usage of the terms 'skiagraphy' or 'skiascopy' during the first decade. In classical X-ray science multiple exposures taken from different angles were the only way to circumvent the problem of obstruction by bones, which X rays cannot penetrate, of parts positioned behind them. The treating physician had to combine these images to reconstruct spatial structures in the interior of the body. Three-dimensional seeing on the basis of two-dimensional projection was—and remains—a very difficult exercise and requires a learning process relying on X-ray atlases as a basis, along with years of practical experience.[13] Despite its indisputable success, X-ray technology soon generated a demand for an automated reconstruction of a three-dimensional image of the interior of the body. This only became feasible after the development of techniques in computational mathematics and experimental science. In mathematics, for example, the so-called Radon transformation is fundamental. Its namesake is the Bohemian mathematician Johan Radon (1887–1956), who had published this mathematical technique 1917 within an entirely different application context.[14] This method was rediscovered a long time afterwards when the British radio-astronomer Ronald Newbold Bracewell (1921–2007) encountered structurally the same problem in 1956 and in 1961 the American specialist in internal medicine and neurology William Henry Oldendorf (1925–1992) in entirely different research contexts:[15] How can a complex deep structure be reconstructed out of a number of perspectival views of a single object that each only permit a partial view into its depths?

The first experiments pointing toward a three-dimensional scanner were performed in the early 1960s at the Medical

[3] On early applications of the telescope see, i.e., Galileo's *Sidereus Nuncius* (1610), Biagioli (2006) and Bredekamp (2007).

[4] On these later developmental stages see, e.g., King (1955), Riekher (1957) and Learner (1991).

[5] See, e.g., Bertolotti (1983), Bromberg (1991) and Maiman (2000).

[6] See e.g., Dommann (2003), Keller (2004) and Pasveer (2006). According to Gugerli (1999), by 1896 over 1000 articles had already appeared and more than 50 books about X rays and their applications had been published.

[7] See e.g. Lemmerich (1995, chaps. C–E).

[8] See e.g., Ulrich (1995) pp. 5ff. and Hessenbruch (2000), as well as the paper on X-ray tubes and cyclotrons up to 1950 by Thorsten Kohl in Hentschel (2012, chap. 15, pp. 327–347).

[9] Freund (1903) wrote the first textbook on radiotherapy. Eisenberg (1992) covers this and other medical areas of application.

[10] Kevles (1997, p. 50) and Eisenberg (1992) provide horrific illustrations of dermatitis and skin tumors caused by X-ray irradiation.

[11] See, e.g., Eckert (2012) and the references cited there.

[12] Controversial issues: How should X rays be classified? Are they particles or waves? If the latter, are they longitudinal or transversal? At what wavelengths? are presented in Hentschel (2007, pp. 529–533) with comprehensive citations to the primary literature.

[13] See, e.g., Dommann (2003) and further sources cited there.

[14] See Cormack (1979, 1983, 1992) and the literature cited there on the rediscovery of this old paper from 1917 in 1970. The first edition of the CT textbook by Kalender (2000) limited the discussion of mathematical methods to 2D and 3D Radon transformations. These methods, based on parallel beams, were substituted in the second edition from 2006 by 2D fanned beam projections and 3D conical beam projections.

[15] See Oldendorf (1961) resp. Bracewell & Riddle (1967).