Technical Representation in China: Tools and Techniques of the Trade

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Coming up with something new in technology requires at least some ability to manipulate visual images. One must be able to imagine what the new or improved part, tool, or machine will look like, what it will do, how it will do it. For those only modestly capable of visual imagining, drawings are an indispensable aid to visual thinking. But even those far more gifted, whether they be contemporary engineers or great technical pioneers of the past such as a Leonardo, still find it valuable to turn their ideas into drawings. Being able to work out one’s ideas on paper becomes all the more indispensable as technology becomes more complex. And the better the drawing “language” at the command of the inventor or engineer, the more effectively drawing can serve as an aid to visual thinking.

Use of drawings to think out engineering ideas was rare before the Renaissance in the West, and at any time before the twentieth century in China.¹ On the other hand, the use of drawings to record the results if not the process of such thinking was somewhat more common, in part because it was recognized, implicitly or explicitly, that technical knowledge held by only a relatively small number of people could easily be lost and that illustrations of the technology could help prevent this from happening.² Moreover, good illustrations of tools, machines

¹ Golas 2001, 58.
² For an explicit statement of this idea, see the preface to the 嚴守義 Aobo tu 熱波圖 (Illustrated Boiling of Sea Water; ca. 1335) in Yoshida 1993, 112.
and techniques were recognized as a means of spreading knowledge of more advanced technologies and even perhaps as stimuli to further improvements.

In China, the availability of technological illustrations surged dramatically in the Song (960-1279) period. The gradual growth of woodblock printing from the seventh century onward culminated at that time with the publishing of vast numbers of books, many of a quality never surpassed in later centuries. Moreover, since printing with woodcuts made it as easy to reproduce illustrations as text, and since illustrations helped to sell books, which were often printed privately to make a profit, it is not surprising that illustrations of many different kinds were increasingly found in the books of the period. Many of them were illustrations related in one way or another to technology. To be sure, no small number of these illustrations were by any standard of realism quite primitive, but the sheer quantity of production, involving vastly greater numbers of illustrators and carvers than ever before, promoted a general rise in skills especially at the high end of the market where illustrations of very high quality were often to be found. Moreover, the appearance at this time of increasingly complex technology offered a challenge to illustrators to develop drawing techniques in order to capture that technology in illustrations.

Political and social developments in the Tang and Song also encouraged the production of more and better technical illustrations. With the development of the civil service examination system and a resurgence of Confucianism, this period witnessed the appearance of a new kind of official who owed his position in large part to mastery, and often internalization, of Confucian teachings. These teachings stressed among other things the obligation of officials to devote themselves to the welfare of the people in their charge. This injunction, together with the opportunities offered by the economic surge that went hand-in-hand with technological advance, encouraged many officials to direct their efforts to promoting new technological practices that promised to improve the livelihood of ordinary people. Among the much better means officials now had at their disposal to carry out this task were printed books that were now accessible to ever larger numbers of readers because of a significant rise in rates of literacy.

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4 Golas 2001, 52.
5 Other uses for woodblock illustrations included popular prints and the illustrated paper money bills that came into being in the eleventh century. For printing the latter, copper plates were also used; Yu 1997, 3: 296.
6 The surviving versions of just six works of the eleventh and twelfth centuries (one on weaponry, one on an astronomical clock-tower, one on architecture and three on archaeological remains, mainly vessels), contain some 1,675 illustrations; even excluding the archaeological works, the more clearly technical illustrations of the remaining three works total some 425 illustrations; see the chart in Liu 1991, 239.
7 Golas 2001, 54-55.
The greater availability of illustrated works must have encouraged a higher appreciation of the value of illustrations of all kinds for controlling and assimilating information and even for conveying information that was impossible to express simply in words. That this should be the case was vigorously advocated by Zheng Qiao 鄭 楕 (1104-1162), the compiler of the great encyclopedic history of institutions, the Tongzhi 通 志 (Comprehensive Treatises), which appeared in 1149. Zheng argued that illustrations (of all kinds, including charts, plans, etc.) should be seen as complementary to written texts and equally important in the conveying of knowledge. He specifically listed sixteen fields of learning in which he considered reliance on illustrations to be absolutely indispensable. These fields included not only obvious subjects such as astronomy and the study of all kinds of objects, natural and man-made, but also less obvious topics such as official ranks, financial accounting, and law. In a culture obsessed with the importance of the written word, Zheng's efforts were somewhat quixotic, and seem to have had little long-term influence. Nevertheless, that such ideas enjoyed at least some circulation in the Song was likely not only a reflection of the wider availability of illustrations at that time but also in turn served as a stimulus for the production of more illustrations.

Finally, technological illustration also improved at this time because of the greater command over the techniques of their craft that Chinese artists had been acquiring for centuries, including the ability to portray objects with greater verisimilitude. This occurred despite the fact that, from earliest times, Chinese painting theory tended to devalue paintings that focused on the accurate or detailed representation of inanimate objects. Such skill was absolutely crucial to the production of increasingly accurate and precise technological illustrations, and the challenge was especially great in a time when increasing technological complexity of itself not infrequently outran the skills of those who would attempt to picture it on paper. Thus the finest Chinese efforts in technological illustration during the eleventh to fourteenth centuries dynasties achieved a sophistication and a precision that not only would never be surpassed but, indeed, would seldom be equaled down to the twentieth century.

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8 Vogel n.d. (see under “Systematizations of the Concept of tu during the Song”); Liu 1992.

9 Such paintings were seen as lifeless compared with figure or landscape paintings; Ledderose 1973, 79. In the Song period and later, the emergence of a whole new painting aesthetic that thoroughly devalued representation in painting relegated such efforts overwhelmingly to the domain of craftsmen painters whose creations were seen by definition as inferior to those of the literati who alone produced painting worthy of admiration by the cognoscenti. See Bush 1971.

10 For a good statement of this problem, though from a later period, see Wang Zheng's 王 僖 plait on the difficulty of drawing the verge and foliot assembly; Golas 2001, 48.

11 I am using here technological and not aesthetic criteria.
After the fourteenth century, we see a divergence in the historical trajectories of woodblock printing and technical representation. The technology of woodblock printing continued to improve, with the development of color woodblock prints in the seventeenth century as one of its greatest achievements. One searches in vain, however, for any significant overall improvement in the accuracy, precision or completeness of technical illustrations after the Yuan (1279-1368). Indeed, the illustrations that survive seldom match, from a technological point of view, the best productions of the Song and Yuan, and are often demonstrably inferior to them, as we shall see shortly. One can detect no continuing traditions of technological illustration leading to improved representations over time. Indeed, tradition often worked in the opposite direction. We find many examples of Dieter Kuhn’s astute generalization: “An incorrect picture handed down through the centuries is certainly the most convincing proof of a tradition.”

The contrast could hardly be more dramatic with the history of technical illustration in Europe which tended to lag behind what Chinese artists were capable of in the tenth to the fourteenth centuries but which, by a steady process of cumulative improvements, achieved a major breakthrough in the fifteenth and sixteenth centuries. I would like to suggest in this paper that a study of the tools and techniques used by illustrators together with an examination of the reproduction processes for technical illustrations will provide clues to at least part of the explanation for why stagnation overtook Chinese technological illustration in the Ming (1368-1644) and Qing (1644-1911) periods.

Limitations of Chinese Technical Illustration

James Cahill has pointed out that early Chinese paintings “typically convey far more visual information than later ones [...]”. Interestingly, he selects two paintings with considerable technological content as examples. The first (fig. 1) is a tenth- or eleventh-century portrayal by an anonymous artist of a quite elaborate flour mill powered by two horizontal water wheels. Cahill suggests that this painting provides us with enough visual information to “reconstruct the entire apparatus, as well as the social organization surrounding it.” This may be something of an exaggeration, but there is no doubt that this painting is richer and more accurate in details (though less consistent in its perspective) than a very similar painting (fig. 2) from two or three centuries later by an anonymous Yuan artist. Above all, the figures in the earlier painting seem much more pur-

12 Kuhn 1980, 409 n. 5.
13 Cahill 1994, 117.
14 Cahill 1994, 121, fig. 4.7.
15 Cahill 1994, 117.
16 Cahill 1994, 121, fig. 4.8.
positive and engaged in real activities than the more decorative figures of the later painting. As far as technological clarity, however, there is little to choose between the two paintings. Either one requires for its interpretation that the viewer bring a great store of supplementary knowledge as well as some talent for guessing the nature of the various operations the artists more often suggest than actually portray. 17

This eliding of details is hardly surprising in paintings aiming mainly at the portrayal of an interesting landscape dominated by a powerful structure. The vibrancy is indeed enhanced by having a great deal of activity going on, but that activity does not need to be defined very precisely for the painting to be successful. Moreover, given the scale of these paintings, their artists would have been hard-pressed to portray technological details clearly in the space available.

Figure 1

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17 See Needham's interpretation of the later painting: Needham 1965, plate CCXL1b, facing p. 405.
Another example of elided details is the silk-reeling machine (fig. 3)\textsuperscript{18} from the thirteenth century Gengzhi tu 耕織圖 (Illustrations of Agriculture and Sericulture). This version, which is a careful 1769 copy of the late-thirteenth century rendition of this scene by the superb painter Cheng Qi 程棨, is aesthetically very satisfying and in some ways even technologically quite accurate. Yet it still leaves out some very important elements: there are no guiding eyes at the pan for the fibers to pass through and there is no driving belt running from the reel axle to the pulley assembly that presumably provided the reciprocating movement of the ramping arm that distributed the silk threads evenly over the silk-reel. Nevertheless, even a casual comparison shows it to be far superior to the almost contemporary Qing version of 1739 (fig. 4).\textsuperscript{19}

\textsuperscript{18} Pelliot 1913, plate L.
\textsuperscript{19} Franke 1913.
Sometimes, however, the artist left out much more than minor details. In the 1510 edition of the mid-eleventh century Wujing zongyao 武經緯要 (Collected Essentials of the Military Classics) is an especially remarkable example, to my knowledge first pointed out by Joseph Needham (fig. 5). This illustration endeavors to portray a “tower ship” or battleship but the ship is somewhat crippled by a poorly drawn rudder, and its masts and sails are omitted altogether!

Figure 5

Details that could not be conveniently omitted might pose insoluble problems for illustrators whose drawing techniques were incapable of rendering them accurately. This is perhaps most apparent in the case of rare, especially complicated shapes. A drawing (fig. 6) from Wang Zheng’s 王徵 Qiqi tushuo 奇器圖說 (Diagrams and Explanations of Wonderful Machines) of 1627 attempts to portray a European endless-chain bucket conveyor. When we compare it with the original drawing (fig. 7) from Jacques Besson’s engineering treatise of 1578 on which

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20 Wujing zongyao (1510 woodblock ed. included in the Siku quanshu); Needham 1971, 380, 404, and esp. 426, fig. 949.
21 Qiqi tushuo (Shoushan ge congshu ed., 1844), 3. 8b; Needham 1965, 212, fig. 465.
the artist based his copy, we see that the problems with the copy are almost endless. Note especially the handling of the crank in the upper left. The Chinese illustrator can give us only so crude an approximation as to make it incomprehensible to anyone not familiar with the original drawing or with this kind of a crank shape (i.e., virtually anyone in China who would see this illustration).

Figure 6
Many Chinese technical illustrations are striking in their failure to handle even the most simple mechanical linkages with any kind of precision or verisimilitude. We see this in one of the *Gengzhi tu* illustrations (fig. 8)\(^2^3\) from the Ming 1607 encyclopedia *Bianyong xuehai qunyu* 便用學海群玉 (Seas of Knowledge and Piles of Jade for Convenient Use). If one is familiar with this kind of arrangement (and the artist could well have consciously or unconsciously felt that most of his viewers would be), it is easy enough to understand what is going on (hulling of the rice, called here *zuomi* 做米). Compare how much better Cheng Qi has depicted the process (fig. 9).\(^2^4\) Even if one had never seen this particular machine, the information provided in this illustration would make it possible to construct an exact copy down even to how the powering assembly was attached to the basket (presumably to allow for repair or replacement?).

\(^2^3\) Reproduced in Kuhn 1976, 358.

\(^2^4\) Pelliot 1913, plate XXVIII.
Here, too, the earlier illustration of Cheng Qi also conveys a much greater sense of real people doing real work.

Figure 8
Now if one speculates (we have no evidence) on why the encyclopedia illustration is so much inferior as a technological illustration, a quite possible explanation is that the artist, for whatever reasons, simply placed no value on technological accuracy. But it appears that he also placed no value on persuasive representation in general, or so the path of the rice from the basket to the hulling apparatus would suggest. Perhaps such lack of concern lay behind what could well be the main reason for the failure of the artist to produce a more realistic picture: lack of skill or technique (perhaps combined with a certain amount of carelessness). Most likely the creator of the encyclopedia illustration had simply never learned how to draw linkages realistically as in Cheng Qi’s illustration.

An even more difficult challenge in portraying a linkage appears in an illustration of a silk reeling machine (called the “soundless roller”) from the 1742 Binfeng guangyi 鼓風廣義 (Expanded Explanations of the Silk-making Craft

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25 One is reminded of the statement of Roderick Whitfield about the artists who made later copies of the most famous of Chinese genre paintings, the twelfth-century Qingming shanghe tu 清明上河圖 (Going Upriver during the Qingming Festival): “their purpose is to amuse and not to inform or record […].” Whitfield 1965, 30.
of Bin [Shaanxi]; fig. 10). This was a hand-powered machine used to wind silk fibers from cocoons onto a silk-reel. Fortunately, we have also a superb reconstruction of the machine by Dieter Kuhn (fig. 11).\footnote{For both illustrations, see Kuhn 1981, 82-83.} If Kuhn’s reconstruction is correct, the artist was called on to portray right-angle gearing. Now, an inability to portray gearing in a reasonably accurate, believable or even understandable form is a very common weakness in Chinese illustrations of machines. But here the artist has also to cope with the small size of the linkage assembly relative to the entire illustration. Note that Kuhn felt the need to provide a separate drawing enlarging this detail (even tilting the perspective slightly to make it even clearer). Without such an enlarged component drawing, the artist could at best suggest the gearing arrangement, which was all that even Kuhn could do in his overall drawing of the reconstruction.

\textbf{Figure 10}

![Diagram of silk spinning machine]

Courtesy of T'oung Pao, Leiden
This brings us to the further problem of the handling of fine details in general, whether or not they have anything to do with linkage. Staying with the same illustration, we can ask just what the figure on the left is holding in her right hand. Kuhn suggests it is a fixed handle for turning the silk-reel. I suspect that, if the proportions and placements of the drawing are roughly correct, this might have been simply some kind of propelling stick. Otherwise, turning the reel with the fixed handle would appear to be quite clumsy, even perhaps requiring the figure to rise at least a little from her seat at each revolution of the reel. In any case, one cannot say definitely on the basis of the illustration; the detail is just not there.\textsuperscript{27} As the number of details increased when machines grew more complex, those who did technological illustrations found themselves faced with ever greater challenges, though it is highly questionable whether most of them spent much time worrying about it.

Thus far, we have focused on some of the most common limitations of Chinese technological illustration. In some ways, however, this is the less interesting part of the story. Similar limitations bedeviled efforts at technological illustration at the same time in other parts of the world such as Europe and the countries of

\textsuperscript{27} Another possibility is that the reel is placed higher than normal so that it would appear clearly and not be obstructed by the assembly for winding the thread from the cocoons.
Islam. What is of greater interest are the sometimes remarkable advances that one catches glimpses of and that seem to portend further accomplishments in the future.

One of the perennial problems of technological illustration, and one whose solution becomes all the more imperative with the emergence of more complex technology, is how to portray what is happening in those parts of a machine that are enclosed and cannot be seen. A good example is the famous drawing of a flamethrower (fig. 12)\(^{28}\) from the *Wujing zongyao* of 1044 (though we cannot assign a certain date to the pictures that illustrate the work as it exists today). This is in fact a most remarkable drawing: if it or the original from which it may be copied actually dates from the mid-eleventh century, this could represent the oldest surviving component parts drawing in China.\(^{29}\) This can perhaps be seen as an example of more complex technology serving to stimulate an advance in technological illustration. But it still largely fails to give any idea of how most of the mechanism worked, as we see in Needham’s brilliant schematic reconstruction (fig. 13).\(^{30}\)

\(^{28}\) *Wujing zongyao* (Siku quanshu ed.), 12.66a.

\(^{29}\) For other examples from later in the same century, see Golas 1999.

\(^{30}\) Needham 1965, 148, fig. 434.
The problem here is how to show the viewer what is happening on the inside of a machine. One can do this only by the convention of treating all or part of the casing as transparent. This is the idea behind cutaway drawings where a part of the enclosure is pictured as removed or transparent, opening a window as it were to the inside of the machine. This technique was already in use in Europe in the fifteenth century, being particularly associated with Mariano Taccola (1382-ca. 1453) and Francesco Martini (1439-1501). But the cutaway technique was never, to my knowledge, devised by Chinese illustrators. Indeed, the copies of Western machines made in the seventeenth century usually suggest that Chinese illustrators were unable or unwilling to employ this technique. A drawing of a revolving bookcase (fig. 14) from Agostino Ramelli’s engineering treatise of 1588 has both an insert to the right showing the gearing arrangement to keep the bookrests at the same angle as the wheel rotated and a cutaway on the large wheel to show one of the stabilizing gear wheels. In the illustration that appears in the Qiqi tushuo (fig. 15), not only has the Chinese illustrator completely botched the gear assembly in the insert but he has also chosen to ignore the cutaway on the revolving wheel. But this is not true for all of the Qiqi tushuo drawings, some of which do use the cutaway technique effectively. A particularly good example is the animal powered stone saw-mill (fig. 16) where the cutaways include unusually effective treatment of linkages.

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33 Qiqi tushuo (Shoushan ge congshu ed., 1844), 3. 52a; Needham 1965, 548, fig. 679.
34 For another example, see Needham 1965, figs. 467 and 468, and the discussion of them in the text. Edgerton 1985, 186 ff., drawing on this same example, provides an admirable analysis which, unfortunately, is somewhat marred by exaggerated conclusions such as: “Not only do all Chinese pictures of technical subjects, in the hundreds of books published in China from the ninth to the nineteenth century, lack systematic chiaroscuro and lineal perspective, but they are just as consistently impressionistic. They only suggest the forms and functions of the things represented and never show accurate dimensions or proportions to scale” (p. 192, my emphasis). The range of accuracy and clarity in Chinese technical illustrations, even if not reaching the excellence of European Renaissance portrayals, is too great to admit of such exaggerated conclusions. Even in the Qiqi tushuo itself, there are many illustrations that represent quite accurately rather than just “suggest” not only the “forms and functions of things” but also their relative size.
35 Qiqi tushuo (Shoushan ge congshu ed., 1844), 3.53a. One wonders if this drawing is particularly well done because Wang Zheng had perhaps three illustrations of the machine to inspire him, by di Giorgio, Leonardo and Ramelli; see Needham 1965, 218.
Nevertheless, neither this nor any other of Wang Zheng’s illustrations had any significant influence on later Chinese technical illustration. Actually, the reason may well be that illustrations of enclosed machinery that treated the *entire enclosure* as transparent appeared quite early in China. Su Song’s 蘇頌 *Xin yixiang fayao* 新儀象法要 (New Armillary Sphere and Celestial Globe Essentials), the description of his great astronomical clocktower which was written in the early 1090s and first published in 1172, provides two general views of the tower. The first gives us the artist’s impression of how it actually looked (or should look when completed; fig. 17) while the second strips away the building to provide us with a general view of the machinery within (fig. 18). The same work has many component parts illustrations such as the portrayal of the clocktower’s main drive-shaft and main vertical transmission shaft (fig. 19) as well as, what is quite startling to find, a primitive exploded drawing drawn in perspective and showing the bronze horizon support and the meridian bearing rings of the celestial globe and the box within which it sat (fig. 20).

36 *Xin yixiang fayao* (Shoushan ge congshu ed., 1844), 3.2a.
37 *Xin yixiang fayao*, 3.4a.
38 *Xin yixiang fayao*, 3.16a.
39 *Xin yixiang fayao*, 2.3a.
Spatial arrangement, including especially the use of a clear and persuasive perspective, is another perennial challenge to the production of effective technological illustrations. To be sure, perspective can serve different functions according to the artist's purpose. In landscape painting, for example, it serves to introduce a sense of (sometimes quite considerable) distance and to relate the discrete elements of a scene one to another. This is ordinarily not of great importance in technological illustrations. But perspective, depending on whether it is well or badly used, can certainly affect the ease with which the functioning of a complicated machine can be comprehended.

For example, the problem of handling gear linkages can be compounded by the artist's inability to create a convincing or understandable perspective, as we see in the waterwheel-powered milling plant from the 1742 Shoushi tongkao 授時通考 (Compendium of Works and Days), an imperially-sponsored treatise on agriculture and related technologies (fig. 21).\(^4^0\) Although Needham in the caption to this illustration\(^4^1\) speaks of there being nine mills in this installation, on the preceding page he more carefully says "six to nine mills." Indeed, one simply cannot say for sure whether the middle wheels simply drive the outer wheels or whether they also each directly drive a mill of their own. This is a good example of how a poor handling of perspective, including the mixing up of different perspectives, complicates the reading of an illustration and, in effect, forces the interested viewer to try to "read through" it. This can sometimes be quite easy as in the illustration, also from the Shoushi tongkao, of the linkage of a hand-operated paddle wheel to sweep water up into a flume (fig. 22).\(^4^2\) With more complicated technology, however, such "reading through" is usually much more difficult.

\(^{40}\) Shoushi tongkao (Zhonghua shuju ed., 1956), 40.20a.

\(^{41}\) Needham 1965, 399, fig. 622.

\(^{42}\) Shoushi tongkao, 37.22a.
On the other hand, mixing of perspectives can sometimes work quite effectively in conveying information, as in the illustration of a well windlass from Song Yingxing's 宋應星 Tiangong kaowu 天工開物 (The Exploitation of the Works of Nature; fig. 23). The windlass is shown more or less in a frontal view but trying to follow the perspective closely can make one dizzy. Yet, when this view of the windlass is combined with a top or plan view of the plots being irrigated, we get quite a clear picture of the larger irrigation process. A linear perspective drawing would have combined both these views more elegantly (to modern eyes, at least) but not necessarily more informatively.

Figure 23

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43 Tiangong kaowu (Shijie shuju ed., 1962), 1.18b.
To return to milling plants. Other eighteenth-century Chinese artists were capable of much better efforts than that of the Shoushi tongkao. In an illustration of an animal-driven milling plant from the 1782 Palace edition of Wang Zhen’s Nongshu (Treatise on Agriculture), a central whim wheel clearly works eight mills (fig. 24).\textsuperscript{44} It is striking how well the teeth of the upper two wheels mesh with those of the central whim wheel. One rarely sees this in Chinese technological illustration, at this time or earlier. Usually, close is close enough. Another version of this illustration (fig. 25),\textsuperscript{45} even better in at least one way, is found in the Siku quanshu edition of the Nongshu, dating from perhaps a few years earlier. It realistically shows what the individual wooden, cog-shaped gear teeth actually looked like, something rarely to be encountered elsewhere in Chinese technical illustration.

\textbf{Figure 24}

\textsuperscript{44} Nongshu 16.12a; Needham 1965, 196, fig. 451.

\textsuperscript{45} Wang 1981, 287.
These examples barely begin to do justice to the wide range of drawing techniques devised by one or another Chinese artist to lend comprehension, accuracy, or verisimilitude to his drawings. Further examples (though not in drawings of machines) show Chinese illustrators simultaneously using two views (front and rear, front and side, plan and elevation) to give a complete picture of an object. Occasionally, as in the architectural illustrations in the *Yingzao fashi* (Treatise on Architectural Methods) of ca. 1100, we see drawings of sufficient precision to have served as working or construction drawings. Occasionally, the illustrators even created scale drawings, a process that probably goes back to the problem of how to transfer designs from paper to walls as in the Buddhist grottoes at Dunhuang.

What then are we to make of the wide-ranging repertory of drawing techniques devised by Chinese illustrators? Perhaps the most important thing is that, curiously, it was not a repertory at all in the sense of a set of techniques widely known by practitioners of technological illustration who could draw on it in making their own illustrations. Rather, what happened time and again was that a new technique representing a true advance in what the illustrator could show appeared in a single work, but then had no further influence and, for all practical purposes,

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46 Liu 1991, figs. 3a, 3b, 3c; Liu, Hu, and Fan 1995, 2, fig. 1, left.
was forgotten. Even during the Song and Yuan, and certainly afterwards, there was little or no cumulative advance, no generally accepted standards for either what information was to be expected of technological illustrations or how to portray that information. A work like the remarkable Yingzao fashi had no worthy successors. The illustrations in the equally remarkable Tiangong kaiwu, in their technical content at least, could as easily have been drawn in the thirteenth century as in the seventeenth century, and might have been drawn better.\(^{49}\)

At the same time, we need to recognize that there were some cases where, with even the best available skills and techniques, the complexity of the technology could outrun the capacity of the illustrators to portray it. With the drawing techniques available, it is difficult to imagine, for example, a set of illustrations that could provide a sufficiently complete and accurate picture so as to serve as working drawings for something as complicated as constructing Su Song’s clock-tower, or building an advanced silk loom. This suggests that one of the reasons for the later stagnation of Chinese technological illustration was that the limited amount of complex technology around in pre-nineteenth century China offered few challenges to illustrators to improve their skills. But to this possibility, I would add another: the means used in China for producing and reproducing technological illustrations in many ways themselves inhibited the improvement of the skills of the illustrators. How might that have been the case?

## Tools and Techniques

The striking differences between writing instruments in the West and in China, including those used in illustrating, immediately raise the question of whether these tools themselves facilitated or hindered the development of technological representation. For example, better technological illustrations might have resulted had the illustrators done more sketching from life and less sketching from previous illustrations or paintings. Did the fact that the brush was virtually the sole tool for getting an illustration on paper discourage this kind of sketching (especially on the fly)? Also, did the brush’s unsurpassed capacity for aesthetic ex-

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\(^{49}\) In this view, I find myself quite at odds with Liu Keming and his colleagues (Liu 1991, 244–245; Liu, Hu, and Fan 1995, 3) who profess to see the emergence of considerable standardization of technical illustrations in the Song, though I must admit I am less than perfectly clear on what they mean by “standardization.” Sometimes it seems to refer to something as trivial as where the title of an illustration was placed (Liu 1991, 244), or as irrelevant (from a technical point of view) as the different qualities of line used (id., 245). Moreover, I am not at all convinced by the implication that standardization of drawing techniques necessarily would have represented an advance in Song conditions and would have been a positive force for further development of these techniques. It seems to me equally possible that certain kinds of standardization could as easily have choked off further innovation.
pression in any way inhibit or discourage its use for more precise and accurate drawing? Was a brush in certain ways inferior to, say, a quill, or a crayon, or a pencil for making technical drawings? These, unfortunately, are questions on which research seems hardly to have begun.

Turning to drawing instruments, the Chinese were well equipped from earliest times with at least the essential drawing instruments: straightedge/ruler, compass and square. In this area, the major hindrance to the development of technological illustration was not technical but aesthetic. Chinese painting theorists almost universally condemned paintings done with the help of drawing tools, especially the straightedge. Thus we have warnings such as: "Now if one makes use of the line-brush (jiebi 界筆) and ruler (zhichi 直尺), the result will be dead painting." Or even more crisply: "A ruled brush makes a dead drawing." Of course, such strictures undoubtedly had their greatest effect among the literati painters, very few of whom would ever deign to paint anything that could be construed as a technological representation. But even the legendary Tang painter Wu Daozi 吳道子 (d. 792) who lived long before the ideals of the literati had come to dominate what was regarded as the best in Chinese painting refused to use a straightedge and drew long straight lines freckhand. And insofar as those who in later centuries made technical drawings considered themselves as artists first (even if less prestigious professional or specialist artists) and craftsmen second, this kind of thinking almost certainly mitigated against doing drawings where the focus was on getting it right.

Given the creativity Chinese artists displayed in devising a considerable range of drawing techniques to make technical illustration more informative, accurate and precise, it seems safe to posit a link between the amount of technical drawing being done and the likelihood that these techniques would be further developed and new techniques would be devised. Here I would like to propose a hypothesis that I can only inadequately support at present, namely, that with woodblock printing, the means for reproducing drawings over and over again, even after long intervals, were so efficient and economical that they consistently tended to promote reproduction of old drawings rather than the making of new ones. It is, of course, extremely difficult even to guess the extent to which this diminished the demand for new technical drawings and thus how important an influence this

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50 In the words of William Acker, "this most perfect line instrument ever devised by man." Acker 1954-1974, 1: xiii.
51 They may have originally been developed by carpenters (Maeda 1975, 123) and then borrowed, probably with some modification, for use in drawing. If, or how much, protractors were used in drawing is still obscure. The same is true for any instrument derived from or resembling calipers, of which at least five Han examples survived into the twentieth century; Wu Jiming 1988, 9.
53 Soper 1951, 122, n. 130.
54 Lust 1996, 253.
was for the stagnation of technological illustration in China. At this moment, I am not inclined to rate it among the most important reasons. At the same time, I doubt that the effect was negligible.

Long before woodblock printing was available, the copying of both texts and illustrations was relatively widespread in China. In a society where the written word played such an important role, there was a great desire among those who were literate to obtain copies of important texts. Moreover, China had a great advantage over all other societies in the first seven or eight centuries of the common era in its possession of paper, a relatively inexpensive medium on which texts and illustrations could be copied.

In early times, copying meant free hand copying. The result was that copies tended to be rare, expensive and often inaccurate. Copying of illustrations was particularly susceptible to inaccuracies because there were fewer built-in checks on it (texts, after all, had to remain readable) and inaccuracies were less likely to be noticed by eyes and minds accustomed to focusing mainly on texts.\(^{55}\)

Over time, other copying techniques emerged that led to more exact copies. (Of course, only woodblock printing would bring a significant breakthrough in the area of cost.) One of these methods, especially effective for illustrations, was pounce or stencil copying which was used as early as the second century BC.\(^{56}\) James Cahill describes it as follows: "pricks are made in the original at many points on the lines that make up the design, and a powder bag is patted onto the paper beneath to make a dotted outline which serves as a guide to the copyst."\(^{57}\)

Much more common, and equally practical for reproducing either text or illustration, was tracing, often using waxed paper.\(^{58}\) Regular paper was soaked with fluid wax to make it transparent. The waxed paper could then be placed on top of an original and one could make an exact copy. (Presumably, the wax would also make the paper impermeable so that ink would not leak through to the original.) Such copies were apparently made in considerable number to judge from a statement in the *Lidai minghua ji* 歷代名畫記 or *Notes on Famous Painters of all the Dynasties* of Zhang Yanyuan 張彦遠, which was completed in 847: "The amateur should lay in a hundred sheets of Xuan 宣 [-cheng xian 城縣] paper and wax them by (the usual) method preparatory to making tracings."\(^{59}\)

\(^{55}\) One is reminded of monks in medieval Europe copying out the Bible and also that it was Buddhism that greatly stimulated reproduction of texts and, important for our purposes, religious pictures in China. With its religious discipline, systematic transmission, and iconographic symbolism, Buddhism may have encouraged a greater sophistication in the copying of earlier works of art. See Tseng 1972, 325. Improved copying techniques, applied first to religious works, inevitably came to be used in the reproduction of secular works as well.

\(^{56}\) Tsien 1985, 145-146.

\(^{57}\) Cahill 1994, 91.

\(^{58}\) On this technique, see Tseng 1972, 314; Acker 1954-1974, 1: 191-192.

Finally, another method combined the concepts of tracing and stenciling. It consisted of tracing the original in chalk, then flipping the paper to apply the chalk pattern to another surface.\(^60\) However, this was presumably limited to the copying of large images.

The availability of such techniques for making single copies together with the rapid development in the late Tang and early Song of woodblock printing for producing multiple copies worked powerfully to encourage the preservation and re-use of existing technological drawings.

It is something of a mystery why a technology that held such importance especially for the literate book-writing elite in China as woodblock printing has, in the words of Qian Cunxun (Tsien Tsuen-hsüin), “scarcely been documented in Chinese literature.”\(^61\) We are thus not at all well informed about the details of the technology. For our purposes, however, it is clear that woodblock printing had a number of characteristics that encouraged the reproduction of the same or very similar illustrations over long periods of time.

Once they had been carved, woodblocks could theoretically be stored over years, decades or, in rare cases, even centuries, ready to be used for a new printing whenever desired. To be sure, in addition to the problem of amount of storage space blocks required, they were also subject to the kinds of deterioration that threatened anything made of wood: flood, wood-eating insects, etc. Fire, of course, could destroy them completely. But the most common cause of the deterioration of woodblocks was in all likelihood simply the normal wear that occurred as the blocks were used. We see this in the title pages from two different editions of the *Sanguozhi pinghua* 三國志平話 (Stories from the Romance of the Three Kingdoms). The first (fig. 26) dates from the period 1321-1323, while the second (fig. 27) is from about thirty years later.\(^62\) The earlier title page has clearly been very much worn by repeated use, so that much of the detail is lost. By contrast, the later illustration, on the right, presumably a recutting based on a good original, shows detail with far greater clarity. Thus a drawing, once made and printed, tended to have a long life-span. Even when the original block became too worn for further use, it was a relatively easy process to use one or another tracing method to recreate the original design and use it for cutting a new block.

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\(^{60}\) See Wen Fong’s comments to Tseng 1972, 328.

\(^{61}\) Tsien 1985, 194.

\(^{62}\) For both figures, see Twitchett 1983, 56-57, plate xxi.
Woodblocks that had not yet reached the stage of wear that dictated their replacement could be partially repaired, modified or corrected quite easily. To return to our two editions of the Sanguozhi pinghua: at the top of each page is information on who did the printing and, in the central column in the lower half of the pages, is the date of printing. If one wanted to change just these two items, as has happened here, but retain all the other information on the page, that could be done quite easily by cutting out the unwanted information and inserting a plug on which the new information could then be carved.

Original designs for woodblocks could be modified just as easily. Here one equivalent of using a plug in a woodblock correction was simply to paste a correction over the appropriate area of the original drawing. The repaired drawing then could serve as the pattern for a new or repaired woodblock. As in the case of modified woodblocks, such changes are usually not detectable in the final product. Only in rare cases (especially where the job was done rather crudely) does the evidence for the procedure shows up in the prints made from the modified block. We have two examples in the many drawings from Su Song’s Xin yixiang fayao. The first is a drawing of the armillary sphere as it appears in a printing from 1922 (fig. 28). Someone apparently attempted to add the equatorial gear

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ring that caused the celestial globe to rotate by pasting on a curved slip of paper
with serrations on one edge to represent the gear teeth. John Combridge specu-
lates that the reason the lower half of the gear ring is missing may be “because a
corresponding slip of paper became detached before th[is] assembly-drawing was
subsequently printed.” In a similar correcting of a drawing from the same work
shown above (fig. 18) someone has pasted a rectangular piece of paper over the
area portraying the celestial globe, presumably to substitute a picture of the globe
enclosed in a box for an earlier unenclosed globe.

Figure 28

These, then, are some of the ways that the very techniques for producing and
reproducing illustrations reduced the need to produce new, original drawings.
This in turn may well have hindered the appearance of improved illustration
techniques that one could reasonably have expected to emerge had more illustra-
tors been producing greater numbers of original drawings. When considered
along with other characteristics of technical illustration from the Song on, includ-

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64 Combridge 1975, 291.

65 Combridge 1975, 291. Combridge believes that a similar pasting (?) alteration
must have been made to the general view of the clocktower. If so, it was done sufficiently
skillfully as to be undetectable.
ing changes in the aesthetic values governing drawing and painting, the background and motivations of those who did the illustrating, as well as just what was expected from a technological illustration, production and reproduction techniques will surely provide us with part of a necessarily many-sided explanation for the truncated development of technical illustration in late imperial China.

References

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Song (960-1279)

Wujing zongyao 武經總要 (Collected Essentials of the Military Classics), by Zeng Gongliang 曾公亮 et al. 1044. 40 ch.

Xin yixiang fajao 新儀象法要 (New Armillary Sphere and Celestial Globe Essentials), by Su Song 蘇頌. 1094. 3 ch.

Yingzao fashi 營造法式 (Treatise on Architectural Methods), by Li Jie 李誥. 1097. 1+34 ch.

Gengzhi tu 耕織圖 (Illustrations of Agriculture and Sericulture), by Lou Shou 樓壽. 1145.

Yuan (1279-1368)

Nongshu 農書 (Treatise on Agriculture), by Wang Zhen 王禎. 1313.

Aobo tu 熬波圖 (Illustrated Boiling of Sea Water), by Qu Shouyi 瞿守義, completed by Chen Chun 陳椿. Ca. 1335.

Ming (1368-1644)

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Qiqi tushuo 奇器圖說 (Diagrams and Explanations of Wonderful Machines), by Deng Yuhan 鄧玉函 (Johann Schreck) and Wang Zheng 王徵. 1627. 3 ch.

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2. Studies


