Evolutionary Changes in Persian and Arabic Scripts to Accommodate the Printing Press, Typewriting, and Computerized Word Processing

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1. Introduction

I have been involved in Iran's computing scene for five decades, first as an engineering student and instructor for five years, then as a faculty member at Tehran's Sharif (formerly Arya-Mehr) University of Technology for 14 years (1974-1988), and finally, as an interested observer and occasional consultant since joining University of California, Santa Barbara, in 1988. Recently, I put together a personal history of efforts to adapt computer technology to the demands and peculiarities of the Persian language, in English [1] and Persian [2], in an effort to update my earlier surveys and histories [3-6] for posterity, archiving, and educational purposes.

In this paper, I focus on a subset of topics from the just-cited publications, that is, the three key transition periods in the interaction of Persian script with new technology. The three transitions pertain to the arrivals in Iran of printing presses, typewriters, and computer-based word processors. Specifically, I will discuss how the Persian script was adapted to, and in turn shaped, the three technologies. In each adaptation stage, changes were made to the script to make its production feasible within technological limitations. Each adaptation inherited features from the previous stage(s); for example, computer fonts evolved from typewriter fonts.

2. The Persian Script

Throughout this paper, my use of the term "Persian script" is a shorthand for scripts of a variety of Persian forms (Farsi/Parsi, Dari, Pashto, Urdu), as well of Arabic, which shares much of its alphabet with Persian. Work on adapting the Arabic script to modern technology has progressed in parallel with the work on Persian script, with little interaction between the two R&D communities, until fairly recently, thanks to the Internet.

The Persian language has a 2600-year history, but the current Persian script was adapted from Arabic some 1200 years ago [7]. For much of this period, texts were handwritten and books were copied manually, or reproduced via primitive printing techniques involving etching of the text on stone or wood, covering it with a layer of ink, and pressing paper or parchment against it.

Given the importance attached by Persians to aesthetics in writing, decorative scripts were developed by artists adorning monuments and other public spaces with scripts formed by painting or tilework (Fig. 1). Unlike in printing, typewriting, and computerized word processing, decorative writing is primarily focused on the proportions and interactions of textual elements and the color scheme, with script legibility being a secondary concern

Fig. 1. Calligraphic writing as art (left; credit: Farrokh Mahjoubi) and tile-based writing at Isfahan's Jāmeh Mosque, which is very similar to modern dot-matrix printing (uncredited photo).

Prior to the arrival of modern technology, Persian was commonly written in two primary scripts: Nastaliq and Naskh. Rules for the scripts were passed on by word of mouth from masters to students. Thus, there were many styles of writing, whose popularity rested on the reputation of the practicing master. Among the rules were proper ways of generating combinations of letter (much like the "fi" & "ffi" combinations in English calligraphy). Because the Naskh script is more readily adaptable to modern technology, including to computer printers and displays, it has become more popular and has pronged into many varieties in recent decades.

Nevertheless, Nastaliq holds a special place in the hearts and minds of Persian-speaking communities. The fanciest books of poetry are still produced in Nastaliq, and some printed flyers use Nastaliq for main headings to embellish and attract attention. Some progress has been made in producing the Nastaliq script automatically, and the results are encouraging. The Web site NastaliqOnline.ir allows its users to produce Nastaliq and a variety of other decorative scripts by entering their desired text within an input box. An image of the generated text can then be copy-pasted into other documents.

One final point about the Persian script, before entering the discussion of the three transition periods: On and off, over the past several centuries, reformation of the Persian script, to "fix" its perceived shortcomings in connection with modernity, has been the subject of heated debates. My personal view is that technology must be adapted to cultural, environmental, and linguistic needs, and not the other way around. Fortunately, success in producing high-quality print and display output has quelled sporadic attempts at reforming the Persian script or changing the alphabet [8], in a manner similar to what was done in Turkey, to save the society from "backwardness."

3. The Transition to Printing Press

The printing press arrived in Iran some 400 years ago (see the timeline in Fig. 2). Shah Abbas I was introduced to Persian and Arabic fonts and decided that he wanted them for his country [9]. A printing press and associated fonts were sent to Isfahan in 1629, but there is no evidence that they were ever put to use. Over the following decades, printing was limited mostly to a few religious tomes.

Broader use of printing technology dates back to 300 years ago. The invention of Stanhope hand-press in 1800 revolutionized the printing industry, because it was relatively small and easy to use. This device was brought to Tabriz, by those who traveled to Europe and Russia, around 1816 [10] and to Isfahan and Tehran a few years later, leading to a flurry of activities in publishing a large variety of books.

A key challenge in Persian printing was the making of the blocks that held the letters and other symbols (Fig. 3). English, with its comparably sized letters and the space between them, was much easier for printing than Persian, which features letters of widely different widths/heights, connectivity of adjacent letters, minor variations in letter shapes involving small dots (imagine having the letter "i," with 1, 2, or 3 dots), and more curvy letters.

Year	Events Affecting the Development of Persian Script
1600	
-	Printing press arrives in Iran; little/no use early on
-	Armenian press established in Jolfa, Isfahan
-	
-	
1700	
-	|
-	| Limited print runs; mostly on poetry and religion
-	|
-	Persian books published in Calcutta
1800	
-	First Stanhope hand-press arrives; printing spreads
-	Presses open in multiple cities; use of lithography
-	Technical books appear; newspapers flourish
-	
1900	First typewriter arrives in Iran
-	
-	Typewriters begin to be used widely
-	Electric typewriters, Linotype, and computers arrive
-	Standards for information code and keyboard layout
2000	Use of personal computers broadens
-	Computer-software and mobile-app industries thrive

Fig. 2. Rough timeline of key events and transitions in the history of adapting the Persian script to modern technology [9].

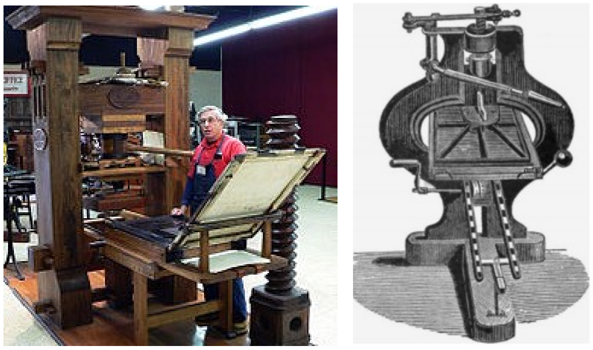

Fig. 3. Re-creation of Gutenberg's press at the International Printing Museum in Carson, California, USA (image: Wikipedia) and the Stanhope hand-press, introduced in 1800 [10].

The first order of business was to make the Persian script horizontally partitionable into letters that could then be juxtaposed to form the desired text. Pre-printing-press Persian script was not horizontally decomposable, as letters tended to mount each other vertically and overlap horizontally (bottom of Fig. 4). The modified form required some compromises in aesthetics, according to the prevailing tastes at the time (top-right of Fig. 4), which proved rather insignificant in retrospect.

Once conceptual changes were made, typographers got busy producing letters, letter combinations, and symbols for Persian printing (Fig. 5). We are now so used to the print-friendly Persian script that the pre-printing-press variants may look quaint to us!

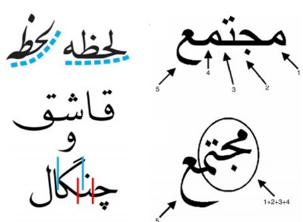

Fig. 4. For printing with movable type, the Persian script had to be made horizontally decomposable (uncredited Web images).

Fig. 5. Early Persian or Arabic metal fonts in the compartments of a typesetter's tray (uncredited Web image)

Fig. 6. Features of Persian script that make its printing difficult also create challenges in automatic text recognition [11].

The variable sizes and spacings of Persian letters also created manufacturing headaches for the font and difficulties for typesetters, who needed to handle blocks of widely different sizes. Interestingly, the features that make typesetting of Persian texts difficult are the same ones that make their automatic recognition challenging (Fig. 6). These include connectivity (a), error-causing minor differences (b), significant width variations (c), horizontal overlaps (d), and vertical overlaps (e).

Eventually, font designers succeeded in rendering the Persian alphabet with four shapes for each letter, in lieu of the nearly unlimited variations in calligraphic writing, where letters morph in shape, depending on the preceding and following letters (and sometimes, according to an even broader context). Still, with 4 variations for each letter, the number of different blocks needed was more than twice that of Latin-based scripts, the latter requiring a total of only 52 lowercase/uppercase letters. This made the utilization of typeface variations (boldface, italics, and the like) a lot more challenging.

Linotype, a hot-metal typesetting system invented by Ottmar Mergenthaler for casting an entire line of text via keyboard data entry, arrived in Iran in the 1950s, transforming and somewhat easing the typesetting problem for daily newspapers [12]. Contemporary Persian print output is now vastly improved (Fig. 7).

Fig. 7. Contemporary Persian newspaper print scripts. (Credit: *The Atlantic* Web site; Atta Kenare / Getty Images).

4. The Transition to Typewriting

Typewriters arrived in Iran around 120 years ago (Fig. 8), but much like the printing press, their use did not catch on right away. By the 1950s, many Western office-machine companies had entered Iran’s market. Again, peculiarities of the Persian script created adaptation challenges.

Direct adoption of print fonts was impossible, given that with 32 letters, each of which having four variants, too many keys would be required. For most Persian letters, however, the initial and middle forms, and the solo and end forms, are sufficiently similar to allow combining, with no great harm to the resulting script’s readability and aesthetic quality. Of course, early typewriters all using fixed-width symbols, were ill-suited to the Persian script, with its highly-variable letter widths. It would be many years before variable-width symbols improved the Persian typewritten script quality substantially.

For example, the letters “meem” (م) and “beh” (ب) aren’t too damaged by having two forms in lieu of four (Fig. 9). The same holds for “heh” (ه), at the left edge of Fig. 9, with slightly more distortion. The letters “ein” (ع) and “ghein” (غ) are the only exceptions needing all four variations (see the top-left of Fig. 9).

One of the highest-quality fonts for typewriters was offered by IBM in its Selectric line, which used a golf-ball print mechanism (right panels of Figs. 8 and 9). The golf-ball was easily removable for replacement with another golf-ball bearing a different font or alphabet (italic, symbol, etc.), making is easy to compose technical manuscripts involving multiple typefaces and equations. Even multiple languages could be easily incorporated in the same document. I used such a typewriter to produce my first textbook, *Computer Appreciation* [13], sample pages of which appear in Fig. 10.

Fig. 8. Mozaffar al-Din Shah’s custom-made typewriter, ca. 1900 (Golestan Palace Museum, Tehran) and a later-model IBM Selectric with golf-ball printing mechanism, ca. 1975 (IBM).

Fig. 9. The four shapes of Persian letters and their reduction to two shapes in most cases (left; uncredited Web image) and IBM’s Persian golf-ball print mechanism (personal photo).

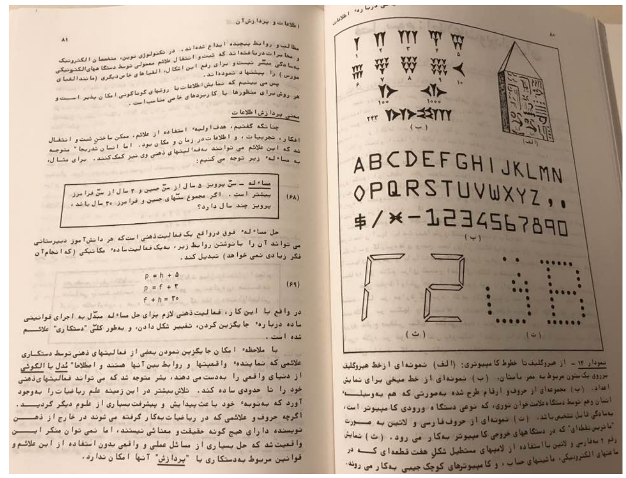

Fig. 10. Pages of the author’s book *Computer Appreciation* [13] which he personally created on an IBM Selectric (Fig. 8, right) with a Persian golf-ball print mechanism (Fig. 9, right).

A common approach to building a Persian keyboard was to take an existing Arabic keyboard and add to it the four Persian-specific letters at arbitrary spots, giving rise to a multiplicity of layouts and making it difficult for typists to move between different typewriters. A standard Persian typewriter keyboard layout was thus devised [14]. Years later, standardization was taken up in connection with computer keyboards, creating the “Zood-Gozar” (زود گذر) layout [15], so named because of the sequence of letters at the very bottom row of Fig. 11, similar to the naming of the QWERTY keyboard. However, neither the keyboard layout nor the accompanying data interchange code [16] was adopted, given the pre-/post-revolutionary chaos.

Fig. 11. Unified Persian keyboard layout, a proposed standard for computers, typewriters, and other data-entry systems [15].

Intelligent typewriters soon arrived on the scene. First came word-processors that could store a line of text, thus allowing back-spacing to correct errors by striking the printing hammer on a white ribbon that would overwrite what was previously printed in a given position. This easy erasure mechanism is what allowed a non-professional typist like me to consider self-producing an entire book; cut-and-paste was, of course, still necessary for making larger corrections or moving paragraphs around.

The ultimate in intelligent typewriters, dubbed "word processors," allowed the use of a single key for each letter, with a built-in algorithm deciding which variant of the letter to print. This required a one-symbol delay in printing, as the shape of each letter could depend on the letter that followed it. As an example, to print the word "kamtar" (کمتر), first the letter "kāf" (ك) would be entered. That letter would then be transformed from the solo/end variant to initial-middle form (ک), once the connectable letter "meem" (م) follows. This process continues, until a space or line-break is encountered.

Interestingly, I cannot enter on my Microsoft Word program the initial/middle variant of "kāf" in isolation, as it is automatically converted to the solo/end variant. Thus, in the preceding paragraph, I was forced to connect something to "kāf" and then change the color of that letter to white, in order to make it disappear!

5. The Transition to Computer Printing

True word-processing and desktop publishing arrived in Iran in the 1980s [17], a few years after the worldwide personal-computer revolution. Prior to that, we produced Persian-script output on bulky line-printers and other kinds of printer devices connected to giant mainframes running in air-conditioned rooms of our computer centers, and, in later years, to mini- and micro-computers in our departmental and personal research labs.

One of the earliest computer printer technologies was the drum printer (Fig. 12, left). The rotating drum had one band of letters and symbols for each of the (typically 132) print positions. With the drum rotating at high speed, every letter/symbol would eventually be aligned with the print position, at which time, a hammer would strike on the paper and print ribbon, causing an impression of the raised symbol to be formed on the paper. A complete line was printed after one full revolution of the drum.

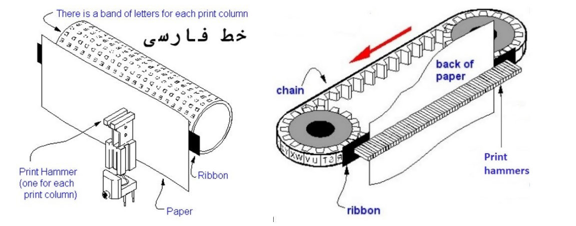

Fig. 12. Print mechanisms in early drum and chain printers (credit: *PC Magazine* Encyclopedia).

Drum printers were bulky and noisy, but, more importantly, were ill-suited to the production of legible Persian script. The separation of the bands of symbols on the drum and the spacing between adjacent hammers led to the appearance of white space between supposedly connected letters (Fig. 12, top-left). This space, combined with up- and down-shifting of symbols due to imprecision in the timing of hammer strikes, led to additional quality problems. The Latin script remains legible if adjacent letters are slightly up- or down-shifted, but the Persian script is much more sensitive to mis-alignment.

The problem with the bulk of drum printers was mitigated with chain (Fig. 12, right) and daisy-wheel printers, but print quality did not improve much, if at all. All three mechanisms suffered from smudging due to high-speed hammer strikes. Thus, letters appeared to be fuzzy, which, ironically, helped with filling the undesirable inter-symbol gaps, but it created additional legibility problems for similar-looking Persian letters.

Several other printing technologies came and went, until improvements in dot-matrix printing made all other methods obsolete. Early dot-matrix printers had a column of 7 pins that made contact with a ribbon to form small black dots on paper (Fig. 13, left). Then, either the needles moved to the next print column or the paper moved in the reverse direction, thereby forming symbols via printing 5 or more columns and continuing on until a complete line of text was formed.

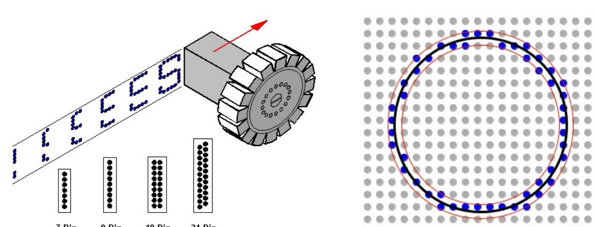

Fig. 13. Early dot-matrix print mechanism with a column of pins (left; credit: *PC Magazine* Encyclopedia) and the versatility of dot-matrix printing for producing images, in addition to text.

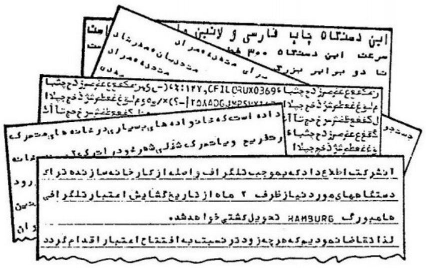

Fig. 14. Examples of Persian scripts produced by line printers and very early dot-matrix printers in the 1970s. [13]

Early dot-matrix printers, though convenient and economical, did not improve the quality of computer-generated Persian scripts, due to the matrix used being too small. In fact, there was a noticeable drop in print quality at first (Fig. 14). As matrix sizes grew and the dots were placed closer and closer to each other, the quality grew accordingly. We faced two categories of R&D problems in those days. First, given a dot-matrix size, how should the Persian letters and digits be formed for an optimal combination of legibility and aesthetic quality? Second, for a desirable level of legibility and aesthetics, what is the minimum required dot-matrix size?

To answer the first question, we would fill out matrices with letter designs and assemble them into lines (at first manually and later using a computer program) to check the script quality (Fig. 15, left). We then repeated the process with different matrix sizes to see the trade-offs. From these studies, we drew two key conclusions in connection with the second question.

First, for low-cost applications in which we cannot afford to use large dot-matrices, a lower bound of 9-by-9/2 dot-matrix size was established, below which legibility and quality become unacceptable. The simulation results for fonts in 7-by-5, 7-by-9/2, and 9-by-9/2 are depicted in Fig. 15, right. A matrix dimension $m/2$ implies the presence of m rows/columns of dots in skewed format, so that the physical dimension of the matrix is roughly $m/2$, despite the fact that there are m elements. This kind of skewed arrangement helps with generating fonts of higher quality, when the letters have curved or slanted strokes.

Second, we used the results from a Persian printed-text automatic recognition study to conclude that a "pen-width" of 4 is adequate for a legible and aesthetically pleasing script output (Fig. 16, left), although, of course, greater resolution can only help (Fig. 16, right).

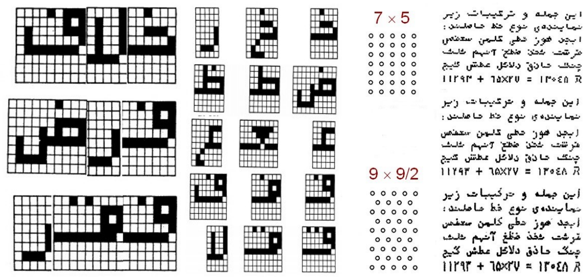

Fig. 15. Illustrating the design of dot-matrix fonts and juxtaposition of letters to check on the quality of the resulting script (left) and results of a study to establish a lower bound on the size of dot-matrix for producing Persian script [18].

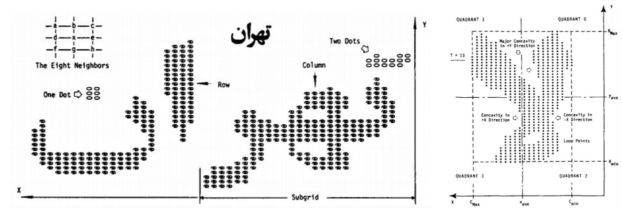

Fig. 16. Decomposition of connected Persian text into letters and recognizing the letters or composite forms [11].

In modern computer applications, a variety of Persian fonts are available to us. Legibility has improved significantly, but the aesthetic quality is still lacking in some cases. In order to make small point sizes feasible, certain features of Persian letters must be exaggerated, so that details are not lost when font sizes are adjusted downward or when images are resized (as in fitting a map on the small screen of a mobile device). Some examples based on the Arial font appear in Fig. 17.

For actual modern computer-generated Persian scripts, I have chosen samples from Microsoft Word (Fig. 18). The samples show both high legibility/quality and problem areas (such as inordinately small dots for Tahoma).

Fig. 17. Illustrating the quality of Persian script using the Arial font of different sizes (top) and the effects of font-size adjustment and image resizing on readability of the resulting text.

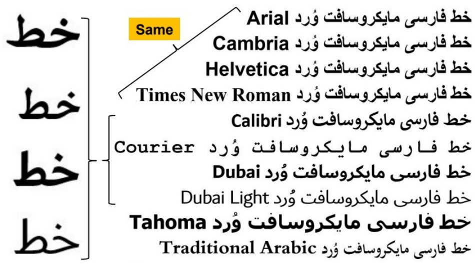

Fig. 18. Examples of modern Persian text output produced by Microsoft Word and the resulting script quality [1-2].

It appears that Calibri and Dubai fonts provide the best combination of legibility and aesthetic quality. The fixed-width Courier sample near the middle of Fig. 18 highlights the fact that fixed-width fonts produce even poorer-quality Persian text than is the case for Latin.

6. Digital Display Technologies

Displays used the dot-matrix approach much earlier than printers. CRT displays, in which an electron beam scans various "rows" on the screen, turning the beam on and off to produce a light or dark point on the screen's coating, constitute a form of dot-matrix scheme. Before modern LCD or LED displays made the use of dot-matrix method for display universal, stadium scoreboards and airport announcement boards used a primitive form of dot-matrix display formed by an array of light bulbs.

For completeness of this historical perspective, I present a brief account of efforts to build Persian line-segment displays for calculators and other low-cost devices. The designs and simulated outputs are depicted in Fig. 19. Peculiarities of the Persian script made the designs of such displays a major challenge. We established that 7 segments would be barely enough for displaying Persian digits and that a minimum of 18 segments would be required for a Persian script that is readable (with some effort). Such displays became obsolete before the project moved to the production stage.

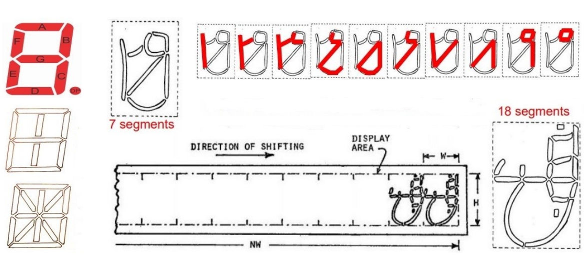

Fig. 19. Line-segment displays for Latin-based alphabets (left) and corresponding designs for Persian digits (top) and letters [1].

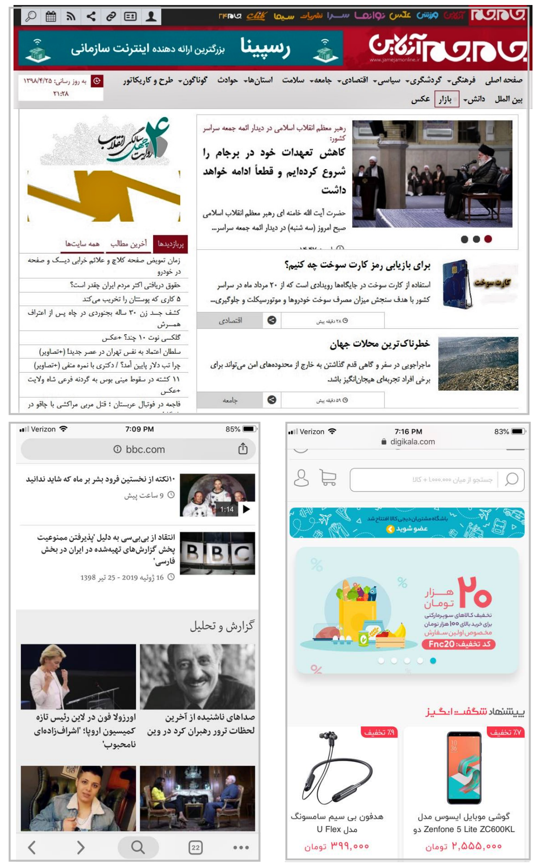

Fig. 20. Persian text displayed on Jam-e Jam news site of the government-run Islamic Republic of Iran Broadcasting system (top; laptop screen capture on July 16, 2019, 10:30 AM PDT) along with the BBC Persian news site and Digikala e-commerce site on a smartphone (bottom; captured the same afternoon).

Dot-matrix display methods are now producing Persian scripts that are comparable in quality to those of our best printers. The transition from CRTs to LCD, LED, and other modern display technologies has removed the flicker problem, the effect of low refresh rate which is particularly significant on CRT displays. Even though modern screens have a much larger number of dots, increases in processing rate and clock speed has made it less likely to have an inadequate refresh rate.

Examples of Persian scripts on modern displays, both spacious desktop/laptop screens and smaller screens of personal electronic devices, appear in Fig. 20. Web sites generally format their contents differently, depending on whether they are viewed on a big screen or a small screen, so that legibility does not become an issue even on the smallest device screens. It is however true that when such screens are viewed in bright environments, such as well-lit offices or outdoors, legibility may suffer.

7. Conclusion and Future Work

Today, technological tools for producing legible and aesthetically pleasing Persian script are widely available. So, whatever problems still remain are algorithmic and software-based in nature. Put another way, whereas until a couple of decades ago, computer typefaces had to be designed with an eye toward capabilities and limitations of printing and display devices, we can now return to typeface design by artists, with only aesthetics and readability in mind. Any typeface can now be mapped to suitably large dot-matrices to produce high-quality and easily-readable Persian script.

We now have reasonably good tools for generating and editing Persian texts. Among them are TeX systems for Arabic [19] and Persian [20], as well as many other text-processing systems based on Unicode [21]. Some popular programming languages also have built-in support for Persian text processing and I/O [22].

What remains to be done are systematic studies of trade-offs between Persian script legibility [23] and aesthetic quality and devising methods for taking care of formatting issues, particularly when bilingual text is involved. Use of crowdsourcing may help with solving the first problem. The second problem has persisted through many attempted solutions over several decades. It is still the case that when, for example, a Persian word is entered within an English text, or vice versa, the text may be garbled depending on the location of the alien word in the formatted line (close to a line break, e.g.). An integrated, easy-to-use bilingual keyboard and improved optical character recognition would be important first steps in solving the remaining text-input problem.

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