Notes on Morphology of Typefaces

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Abstract

Designing a typeface implies the search for a visual coherence between a series of shapes with different structures. This coherence is the effect of different interdependent factors that can be described and measured.
The purpose of this analysis is to provide a detailed description of some of the main independent variables of the design of a typeface and their interactions. We will then present a study of the shape relationships between the glyphs of a typeface, we will identify some of the design variables of a typeface, we will give a description of these relations and use all these notions as a design and teaching tool. This approach is inspired by the work of Donald Knuth and therefore has its roots in digital typeface design and can lead to a parametric approach to drawing.
Isolating the independent variables allows us to control the design choices and potentially to experimentally verify their effects. A detailed description also allows us to control through the study of functions the interpolations between shapes – a widespread practice since the 1990s to draw intermediate variants of typefaces. In this manuscript we will consider the shape of the glyphs intended as silhouettes, even if described by the outlines; therefore we will consider the impact of the perceptual interaction between black and white on the basic design variables. From an educational point of view, elaborating and verifying the effects of a variable and checking an interpolation, in addition to providing specific knowledge for the typography field, can be placed among the configuration exercises in the context of basic design. This method has been used at some courses of design in some Italian universities.

Keywords: typeface design, parametric typography, font classification.

Introduction

The design of a typeface presents a complex interaction between geometric aspects and perceptual aspects.
Attempts at a geometric systematization of the design of the font have been made in various eras. A notable example in typography is the work of the commission led by Jaugeon for the *Romain du Roi* in the 17th century [Kinross, 2005, pp. 24-27].
Two more recent systematizations are particularly accomplished: the one described by Noordzij in *The Stroke* [Noordzij 2005] and that of Donald Knuth [Knuth, 1979], which led to *Metafont* (font definition language and rendering system).
In both cases these are analyses formulated in a relatively isolated way from the world of contemporary design, but both have had a very strong impact on the design of the typefaces.
Knuth had an impact from a more technical point of view, with the introduction of parametric curves, for Noordzij from a more aesthetic point of view, with the explosion of "broad nib" typefaces in the 1990s Dutch graphic design.
Although both Knuth and Noordzij had a strong impact on the project, they developed their models in relative isolation from their contemporary designers.
Donald Knuth in particular is one of the most important computer scientists, and was introduced to the world of typeface design mainly from a collaborative relationship with Hermann Zapf and only later with Charles Bigelow [McCarthy 2020].

For this paper the important aspects of these two models are related to the identification of parameters or design variables that allow generation of a wide combinatorial of shapes. Both identify calligraphy in the generating principle of forms and both models are based on the concept that the shapes of the letters can be generated by a calligraphic process in which a shape runs along a path and defines the shape of the letters. As fascinating as this hypothesis is, the drawing of a glyph is a silhouette only vaguely attributable to an essential, but distant calligraphic origin.
In fact, the traditional punch cutting method has shaped the Latin alphabet since the fifteenth century, progressively moving the shapes away from their calligraphic origin. This detachment was completed during the nineteenth century, when the process of engraving wood types made for advertising purposes was added.
The shapes of the letters, although indebted to a calligraphic tradition, emerge from a process of reworking the shapes with different techniques and therefore have assumed proportions and shapes specific to press and punch cutting. An example is the evolution of the shape of the serifs, which has mixed calligraphic elements with elements related to stone carving and punchcutting.
Furthermore, although a "calligraphic" approach to typeface design re-emerged during the twentieth century, the spread of font editors based on parametric cubic splines that define the outlines, sanctioned the fact that the design of a typeface was emancipated from its calligraphic origin.
A more recent model is the one proposed by Riccardo Olocco [Olocco 2019] for the analysis of historical typefaces; this model has been adapted and used in the design of revival typefaces again by Olocco with Michele Patanè [Olocco, Patanè 2022]. The effectiveness and interest of this approach are linked to the fact that the typefaces are considered for their silhouette on the page, rather than on their abstraction or idealization.
The systematic study of variables in typefaces is related to the fact that a typeface is a coherent system: a core of relatively few formal choices has a decisive impact on the design of almost any glyph. If the bow of the *b* joins to the stem at a certain height, with a certain thickness and at a certain angle, this will have consequences not only in *q*, *d*, *p*, but also in *n*, *m* etc. and on *6* and *9* or on *G*, although the shapes are not exactly the same in all glyphs [fig. 1].
This close connection between glyphs is what makes the Latin script very homogeneous and compact in its appearance. At the same time it makes it difficult to discern on

Fig. 1. The figure shows some recurring details in typefaces (graphic elaboration by the author).

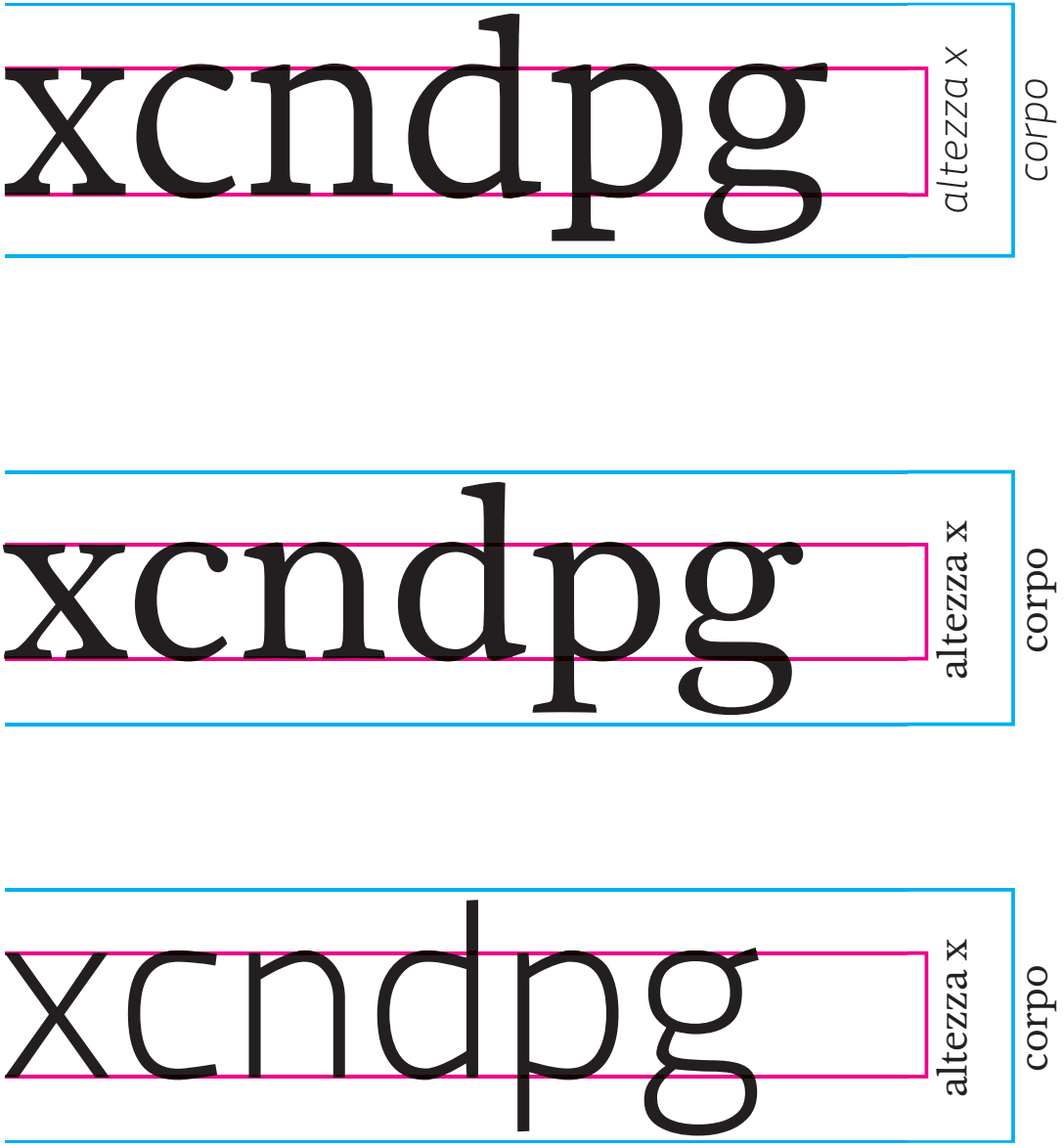


Fig. 2. The figure shows the relationship between x height and body in a typeface (graphic elaboration by the author).

Fig. 3. The figure shows the list of the variables described by the authors at this moment (graphic elaboration by the author).

which parts of a glyph it is acceptable to introduce formal "acceptable" inventions and within what limits.

Method

In the present analysis we have specifically taken into consideration Roman lowercase text typefaces, as the variables are different in relation to each writing style (see for example italics, formal scripts).
The taxonomy of the variables is the result of a research, carried out mainly by the authors at the Isia in Urbino and used in an educational key [Perondi, Arista, D'Ellena 2012] and research [Perondi et al. 2017].
This research had its starting point in the typeface design course by Giovanni Lussu at the Politecnico di Milano in the years 2006 and 2007 and from the discussions that emerged from the people involved in the course at the time (Michele Patanè, Giorgio Caviglia, Paolo Mazzetti).
The description of the variables is focused in particular on the measurement of the proportions of the letters, which allows us to study the interaction between the variables in the existing typefaces and the possible parametric generation of new typefaces. In this article, we will focus in particular on the general definitions and the problem of irregularity in digital typefaces.
All the measurements have been traced back to ratios, since the very functioning of a digital font is based on the scalability of elements in constant proportions [Southall 1991, pp. 93-98; Southall 2005, pp. 169-171].
The *x*-height is considered more representative of the body to indicate the apparent dimensions of a typeface [Law & Bigelow, 2011] and thus has been taken as a fundamental measure to which the others are compared, to the point that now even the legislation refers to that [Regulation (EU) No 1169/2011].
Basing the measurement on the *x*-height alone does not allow an optimal normalization of the apparent size of the typeface, as it is also influenced by other variables such as the expansion [Wallace et al. 2022, pp. 12-14], despite this, the height of the *x* is a better descriptor of the apparent size of a typeface than the size of the body.
As for the choice of the letter *x* to measure the font size, in order to carry out the measurement, we identified "representative" letters for each variable.
It would be possible to obtain measures for each single glyph and balance them according to the occurrence in a language, considering that the variables are systematic in a given typeface, but they are not necessarily applicable to all letters. For example, the degree of expansion is not applicable to letters such as *l* or *i*.
This operation is quite complex, and it would not be justified if the measurement of representative letters was a good predictor of the forms of the whole typeface [fig. 2].
We have distinguished the independent variables from the dependent ones. The independent variables which are the choices that are made in the design process, the dependent variables that are –in the most common conditions– the necessary consequences of the design choices. In fact, there is the possibility of untying the dependent variables and developing original proportions, but the result can lead to bizarre typefaces, hardly considered suitable for the composition of running texts.
Over time, rules and fashions have developed which are nothing more than the reiteration of combinations of variables or the introduction of new variables, gradually accepted.

Outline of independent variable descriptions

Definition
It is a description of the criteria adopted for measuring the proportions of the letters. All values are ratios, so they are independent of the physical size at which a typeface is rendered.
Cases
We mean a discussion on the measurements and on the critical issues in the measurements.
Nominal Value
We mean the arbitrary reference value for measurement of the variable. This value is an ideal starting point in which the interaction with the other variables is arbitrarily set equal to zero.
Examples
We mean the presentation of specific Examples whose measurements are known in detail.

The variables

We have identified 10 groups of variables grouped by type, each of which collects a series of variables. Each variable can be measured and potentially collect a set of attributes (tags) referring to the variable itself [fig. 3].

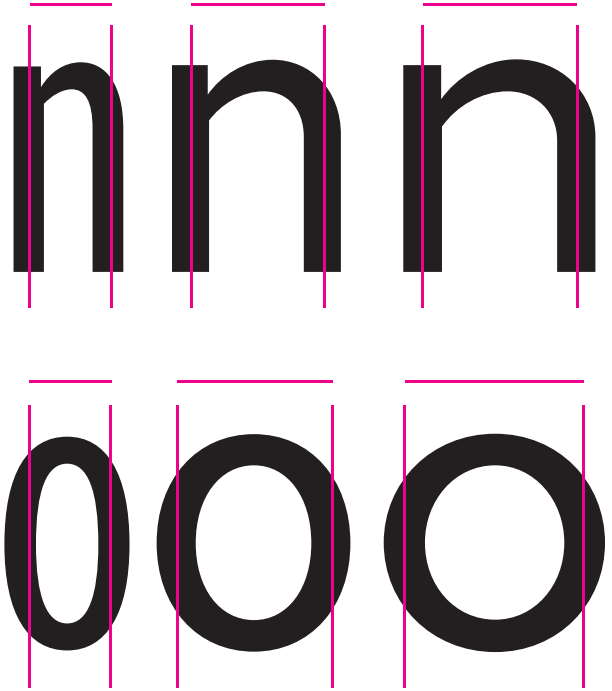


Fig. 4. The figure shows the average expansion of lowercase letters (graphic elaboration by the author).

Vertical Sizes – *Dimensioni verticali*
Horizontal Sizes – *Dimensioni orizzontali*
Weight – *Peso*
Squaring/Axis – *Squadratura/asse*
Path – *Ductus*
Joint – *Innesti*
Aperture – *Apertura*
Endings – *Terminazioni*
Serifs – *Grazie*
Irregularities – *Irregolarità*

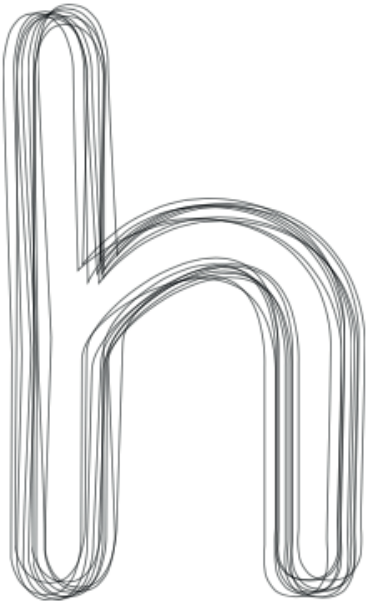
Here are some of the definitions we produced.

Vertical Sizes – x-height/body ratio – Rapporto x-height/corpo
Definition
We define the *x*-height/body ratio as the ratio between the distance between the bottom and the top side of the glyph *x* and the top side of the same glyph and the font body size.
Cases
The value returns the size of the lowercase in relation to the body.
The value of this variable is approximately between 0.4 and 0.52, i.e. the size of the lower case can be just under or about half the body. This is too wide an interval to see a correlation between the body size of a font and its *x*-height.
Sans serif fonts tend to have a higher value than serifs, with a large number of exceptions.
This value could show a correlation with the length of the ascenders and descenders.
Nominal Value
In our description all variables are ratios and most of them are expressed just as relations between a physical measure and the measure of the *x*-height. For this reason, we did not consider it necessary to define a nominal reference value.
Examples
The values of *Times* and *Arial* are 0.447 and 0.519 respectively. This means that if body size is equal, the apparent size of the lowercase letters of the two fonts is quite different.

Horizontal Sizes – Lowercase average expansion - Espansione media delle minuscole
Definition
We define expansion of a glyph as the ratio between the maximum distance on the *x* axis between the midpoints

Fig. 5. The figure shows the n-o expansion ratio (graphic elaboration by the author).

of the vertical strokes of a glyph with two vertical strokes (*n*, *h*, *o*, *p*, *q* etc.) and the *x*-height.
We define the lowercase average expansion of a typeface as the arithmetic mean of the expansion of the glyphs *n* and *o*.
Cases
The choice of midpoints is due to the attempt to represent the widths of the "skeletons" of the letters, excluding thicknesses as much as possible.
We have chosen as the reference value for the expansion of a typeface the average between the expansion of the letter *n* (Unicode: 006E) and the expansion of the letter *o* (Unicode: 006F) because, while the ratio between expansions of the letters *n* and *o* vary according to the style of the typeface, their average has much lower fluctuations (apparently independent of the style) and generally oscillates around the value of 0.75 ± 0.05, both for sans and for serifs.
With the commercial spread of super-families of typefaces, the expansion was introduced as a variable capable of differentiating different cuts available within the same coherent type family. An example of this is Adrian Frutiger's *Univers*, published in 1957.
The expansion can only be measured on letters that have only two vertical strokes (the presence of a single or of a third stroke drastically affects the expansion of a glyph). We think this measurement is sufficient to provide a precise idea of the height-to-width ratios of lowercase letters. In the case of open letters, such as the lowercase *c* (Unicode: 0063), the expansion is strongly influenced by the Aperture (in particular by the "degree of aperture") and therefore is a variable dependent both on overall 'expansion' and on the aforementioned set of variables Aperture.
Nominal Value
The nominal value of the expansion was set at 0.75, a value around which the typefaces are considered 'roman' (this value is in most of the fonts between 0.70 and 0.82), i.e. neither condensed nor extended, stand. Some fonts of more compact proportions, such as *Proforma* (serif) and *Officina* (sans), are not called "condensed", but have lower expansion values than the common "romans".
Examples
Gill Sans (*o*=0.86, *n*=0.64, med=0.76), *Frutiger* (*o*=0.82, *n*=0.7, med=0.76), *Garamond Premier Pro* (*o*=0.85, *n*=0.68, med=0.76), *Bodoni Twelve* (*o*=0.78, *n*=0.63, med=0.7), *Adobe Caslon* (*o*=0.82, *n*=0.6, med=0.76) [fig. 4].



```
#RANDOM VIBRAZIONE, SPOSTAMENTO ASTA VERTI
rnd_vbr_67_78h=random.uniform(-20,10)
#RANDOM VIBRAZIONE, SPOSTAMENTO ASTA VERTI
rnd_vbr_67_78hy=random.uniform(-30,0)
#RANDOM VIBRAZIONE, SPOSTAMENTO asta destr
1,2,3,4,13,14)
rnd_vbr_123_413_14h=random.uniform(-30,0)
#RANDOM VIBRAZIONE, SPOSTAMENTO BASE ASTA
(9,10,11)
rnd_vbr_910_11h=random.uniform(-10,10)
#spostamtento verticale della curva punti
rnd_vbr_34_13h=random.uniform(-25,0)
#spostamtento verticale dell'innesto punti
rnd_vbr_45_13h=random.uniform(-20,0)
```

Fig. 6. Some examples of irregularity of the letters in a project by two students of Isia Urbino (graphic elaboration by Mauro Tosarelli and Beatrice Bianchet).

n-o expansions ratio (Lower case proportions) – Rapporto di espansione n-o (Proporzioni del minuscolo)
Definition
We define the expansion ratio *n-o* as the quotient of the division of the degrees of expansion of *n* (Unicode: 006E) and *o* (Unicode: 006F). From this ratio we hypothesize it is possible to derive the expansion ratios of the single letters of the Latin lowercase.
Cases
Our hypothesis is that this ratio is fundamental to define the style of a typeface.
Usually a "roman" typeface commonly considered to have a "humanistic" structure has values between 0.7 and 0.8, a "roman" typeface with a "modern" or "grotesque" structure generally has higher values (between 0.8 and 0.9), although there are exceptions.
The n/o ratio is strongly influenced by the "degree of squaring" and the "expansion".
A correlation seems to emerge between these values. In particular the typefaces with "humanistic" structure, but with a high "degree of squaring", have relatively high values for this variable (this means that *n* and *o* degree of expansion is similar).
Nominal Value
The nominal value of the lowercase *o* (Unicode: 006F) was set to 0.79, while that of the lowercase *n* (Unicode: 006E) to 0.65, therefore the *n-o* ratio is set at 0.82.
Examples
Gill Sans (*n/o* = 0.74), *Frutiger* (*n/o* = 0.85), *Adobe Garamond Premier Pro* (*n/o* = 0.7), *Sabon* (*n/o* = 0.76), *Didot* (*n/o* = 0.88), *Fedra Serif* (*n/o* = 0.92) [fig. 5].
Irregularities
Digital fonts may have irregularities in their design (in their outlines or skeleton, for example). This solution can be adopted to reduce the effect of excessive precision and regularity given by the digital medium.
The degree of irregularity generally has two measures: the maximum span between two extreme measures and the distribution of the single measures (a good indicator could be the kurtosis index).
The degree of irregularity can be applied to some of the variables already described and is a deviation from homogeneous values; therefore, these variables cannot be approximated by measuring them on a single letter.
We have introduced this group of variables, despite the reduced use in typography, since a certain amount of irregularity is intrinsically produced in press (in particular in letterpress), and this can be considered a form of "machine memory".
This kind irregularity is easily tolerated by readers and some digital drawings have introduced a certain degree of irregularity. Beyond the irregularities related to printing, it is therefore possible to speak of "regular inconsistencies" typical of a typographic design, considering the combinatorial possibilities offered by digital.
We consider in particular two cases: the *Beowolf* by Letterror [Perondi 2016], in which the possibility of pseudorandomly arranging the positioning of the points was exploited; the second is the *Adobe Garamond Premier Pro* by Slimbach for Adobe in 2005, to which the author has given shapes that are more adherent to the irregularities present in the original models of Garamond and Granjon than the design of the 1989 *Adobe Garamond* that he himself executed, which is instead a modernized version, with perfectly regular curves and strokes.
These "regularities in inconsistency" therefore come not only to imitate printing or handwriting, but also to create controlled inconsistency effects even in contexts where a perfectly defined rendering of the original design would be possible.
In a context where the curves are necessarily quadratic (TTF) or cubic (Postscript), the degree of irregularity depends on the position of the control points of the curves with respect to an orthogonal and strongly coherent "neutral" position.
The degree of irregularity can also be controlled thanks to the fluctuation of the points in the same letter, since it is possible to have fonts that automatically and pseudorandomly use different variants for each typed character [fig. 6].

Weight Irregularity – Irregularity of stroke thicknesses – Irregolarità degli spessori
We present for illustrative purposes and for synthesis only one variable of the group Irregularities.
Definition
We define the thicknesses of a typeface as irregular, if the thickness of the straight vertical strokes of *l*, *n*, *p*, *q*, *i*, *b*, *q*, *h*, *d*, *f*, *j*, *k*, *u* is not constant.
We define the 'degree of irregularity of the thicknesses' as the maximum deviation value between two thicknesses of the vertical rod within the character.
We define "variance of thicknesses" as the value of the variance $\sigma 2$ with respect to the mean value.
We define "kurtosis of the irregularity of thickness" as the value of the distance from a normal distribution of the irregularities ($\gamma 2$).

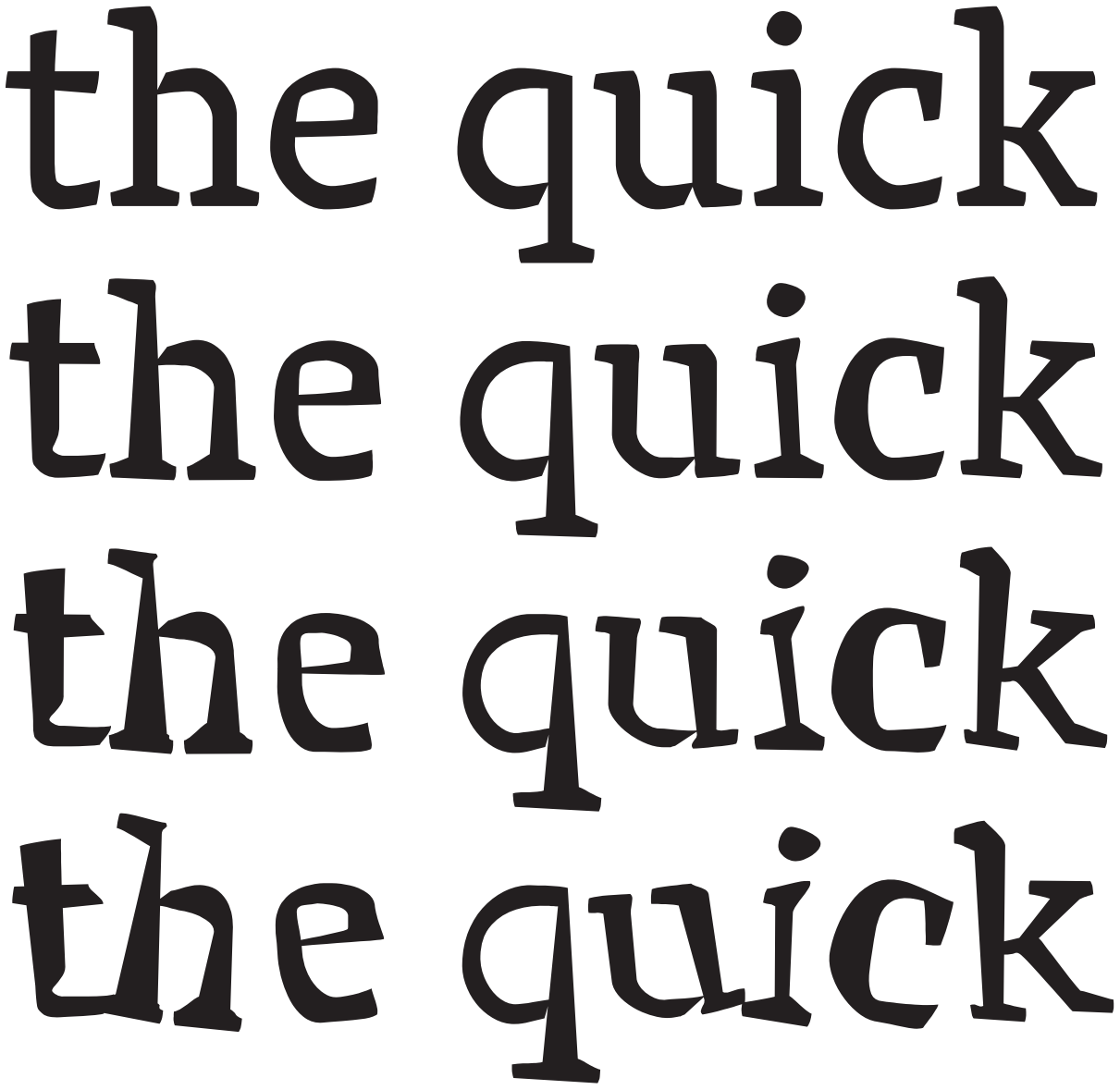


Fig. 7. The figure illustrates the irregularity of the thicknesses (graphic elaboration by the author).

Cases
The irregularity of the thicknesses can only be measured on vertical straight sections: the other elements (curves, heels, horizontal sections, etc.) have irregularities depending on the specificity shape.
As an alternative to the variance, the standard deviation σ can be used, which makes the idea of the amplitude of the dispersion of values more intuitive.
Nominal Value
The nominal value of the degree of irregularity, the variance and the kurtosis are equal to zero and indicate the case in which the design adheres to an ideal orthogonal and perfectly regular model. In some cases this model is given and the degree of irregularity is controllable and easily measurable, because it is obtained through algorithms (see for example *Beowolf* by Letterror, *Arlt Lanzallamas* by Alejandro Lo Celso, *Valnera* by Riccardo De Franceschi).
Examples
Valnera Regular (maximum weight irregularity=0,15) [fig. 7].

Discussion

The systematization of the variables allows a description of the typefaces useful for different purposes, first of all it allows us to describe the typefaces and insert them in a classification by attributes and not by facets, which would allow easier identification and choice in a catalogue of fonts. This systematic description can favour the development of automation and presumably Machine Learning processes. Since it is based on the outline drawing it is limited in the developments regarding the overall drawing of a typeface, but it is well suited to the curve editing software most in use today (*Glyphs*, *Fontlab*, *Robofont*). Since it is also derived from the analysis of existing typefaces, it should be less affected by a particular imprint linked to a design approach by a particular designer.

This description investigates specific variables related to the design of the typeface by individuating them with precision, a path followed by a line of research on reading [Beier, Oderkerk 2022]. This approach aims to reduce the problem of internal validity [Schulz 2016] in the experiments on reading and allows us to treat the problem of equalization of the typeface size in a more precise way [Wallace et al. 2022].
This description provide s a useful summary for students to understand the aspects related to the design of a typeface, in particular for a more informed use and choice of the typefaces themselves.
The description can provide more precise measurement criteria in the regulatory environment (for example in relation to medical packaging, road signs or food packaging).
The problems of this description are related to the reductionist nature of the model, which makes it difficult to deal with some more complex issues to be described such as the inclination of the axis [Bringhurst, 2004, pp. 12, 13], areas in which a mathematically more complex approach would be required, such as the one proposed based on Fourier transforms [Boschin, 2021], although it is not considered an adequate model of the human visual system [Majaj et al. 2002].
Furthermore, this type of approach led to the development of *Prototypo* (www.prototypo.io), which however was not commercially successful and was discontinued as a development. Such a detailed approach to the font can be useful in the design field, as demonstrated by the success of parametric tools on the market in 2022, but probably the market is not yet ready for such complexity in the choice of a font. It is possible that an ever greater growth in computer skills among graphic designers and a greater diffusion of variable fonts could push in this direction, but at present this model appears far from the practices of choosing and using typefaces.

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