Analysis of footwork diagrams from *Libro de las grandezas de la espada*

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Abstract – The goal of this analysis is to search for a plausible explanation of the rules followed by Pacheco in *Libro de las grandezas de la espada* to construct the footwork theory explained in it. For this purpose, we are going to geometrically analyse the diagrams presented in the treatise, we are studying it in the order the concepts are explained in the treatise: a presentation of a rigid explanation of the footwork and an apparently low-consistent application of it through the footwork diagrams. Thus, we will compile the data presenting some hypotheses that appear along the way until we can rearrange it to see the pattern that gives us a plausible construction rule for the footwork diagrams. In order to obtain a rule consistent with later *Verdadera Destreza* treatises and theory, and therefore more plausible as all of them claimed to follow Pacheco's teachings, we will present a brief analysis of several treatises *Common Circle* descriptions to see how the conclusions reached match with them. Finally, we are proposing a rule set that Pacheco may have used and an application of it to reconstruct some diagrams of the treatise.

Keywords – Verdadera Destreza, HEMA, Footwork, Pacheco, Geometry, Rapier

I. INTRODUCTION

One of Pacheco's first treatise distinctive features is the abundant use of diagrams of lines and dots around two simply depicted swept hilt swords. Through these lines and dots and their relations, he explains the techniques to be developed by the *diestro* while he is fighting.

We are focusing on these diagrams as a representation of the techniques, paying close attention to the way they are constructed. This might give some insight into the physical and technical details needed to accurately reproduce the diagrams. Furthermore, it will help to understand the ideas Pacheco had to classify them in the treatise and ~~in~~ the further development of *Verdadera Destreza* theory and practice by him and his epigones.Firstly, Pacheco depicts footwork in his diagrams as segments and curves divided as a ruler, he explains the footwork path and length in folios 66 and 67.

Checking with a compass in both folios, we can determine that curved lines are constructed as a circumference arc with a radius equal to the length of the step. It is to be noted though, that taking the length of a Castilian foot[1] (CF from now on) as 28.8635 cm, a small error in the measurement appears when measuring and comparing the length in the diagram and the length proposed by the text. This error is around 0.2 cm in a measure representing 3 CF = 83.5905 cm which, being a relative error of 0.233%, might be regarded as an error given by the tool used for measuring.

This outcome gives us the hope that every piece of footwork shown in the treatise follows this rule and, ideally, checking the rule and translating it to the fencing practice should be an easy task. Two pitfalls are found though:[1]

- None of the footwork (not segments nor curves) is divided showing the distance covered as in folios 66 and 67.
- Through a general look, the doubt of the rule establishing that the circumference radius is equal to the step length not being followed in the diagrams easily appears.

The second pitfall needs a fine analysis of the diagrams and before giving any outcome of it, we are going to explain the method followed to perform.

I.1. Analysis methodology

To explain the method, we are using the diagram shown in folio 135 as an example (Fig.1).

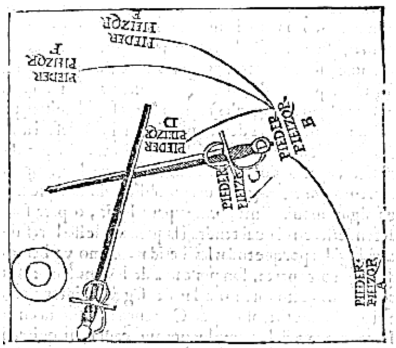

Figure 1. Libro de las Grandezas de la Espada, p.135.

First, we must acknowledge that the diagram size is not uniform in the treatise, Therefore, we cannot value whether the scale is rightly depicted and applied in the diagrams or not.–Consequently, it is impossible to perform any serious analysis comparing the actual sizes in the treatise diagrams. Thus, to perform the intended analysis, we assume that indeed diagram scale is correct and to apply it, we search for

[1] Almagro-Gorbea, *Antigüedades siglos.*

the common element, invariant in length and shown in every diagram to use it as a reference: the swords (more precisely and preferably the sword of the *diestro*). Furthermore, we must assume that the sword blade length Pacheco depicts is the one given by the law at the time, namely 3.75 CF (or five quarters of Castilian vara).[2]

Once we have established this first and important element, we obtain the distance of the segment AB (Fig.2).

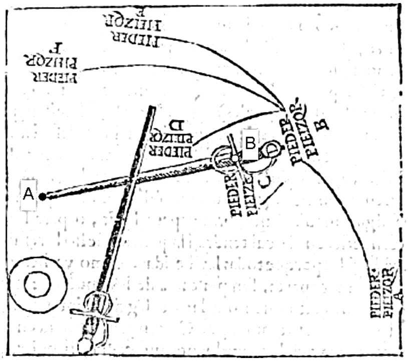

Figure 2: Libro de las Grandezas de la Espada p.135 diagram, edited adding points A,B

Next, we find the circumference containing three given points of the curve to test. From this construction we get some data (Fig.3):

1. If the curve matches a circumference arc.
2. The measurements needed to check the hypothesis about the relation between radius and length:

- The length covered by the arc, CE. To get this distance, two of the three points to use in the construction are the starting and ending points of the arc.
- The length of the radius, OD.

[2] Cortes, *Peticion* (various editions 1552-1558), see bibliography); Rada, *Nobleza de la espada* (1705); see also: del Valle and María, José, 'La espada ropera española en los siglos XVI y XVII'.

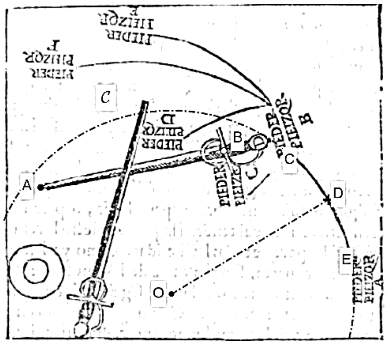

Figure 3. Libro de las Grandezas de la Espada p.135 diagram, edited adding points A,B,C,D and circumference C

Next, we study the different elements we have by the above-explained construction (Fig.4):

1. Expanding the image, we can check if the curve matches the circumference. In our example we can appreciate a quite precise match between them, as shown below by the white dotted line:

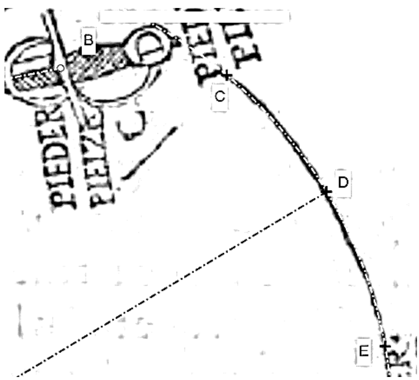

Figure 4. Libro de las Grandezas de la Espada folio p.135 diagram, detail of edited diagram.

2. We check the relations between AB, CE, OD (Note that the given distances are referred without any metric unit as it is not needed for the relations as long as the diagrams are not deformed when printed or digitally reproduced):

- $CE = 1.46, OD = 2.16$ thus $CE \neq OD$.
- $AB = 2.18, \acute{O}D = 2.16.$ Note that the difference between the segments is of 0.02 which as $AB = 3.75CF = 104.48cm$ translates into a difference of 0.03439 CF=0.9584 cm. This is a relative error of 0.917%. This kind of error might be very well due to the inaccuracy of the diagram printing method or the choice of A, B, C and E. So, we can take this error as a depreciable one and say that $AB = OD$.

This gave us two facts about the diagram:

- The proposed rule about radius and length is not followed.
- The length of the radius in the diagram equals the length of the sword blade.

We can, therefore, summarize the method as follows:

1. Measure the blade to determine the scale.
2. Construct a circumference from three given points in the arc: starting point, ending point and any middle point.
- Getting the length of the radius.
- Getting the length of the arc.
3. Test the relations between the circumference and the lengths giving the next categories:
- Related: verifying the rule *radius = arc length*.
- Nonrelated: not verifying the rule *radius = arc length*.
- No match (NM): Those diagrams where the curve line does not match a circumference arc.

II. FULL ANALYSIS BY SECTION

Now we are going to show and explain the data we obtain by studying the diagrams Pacheco uses to describe the techniques.

We are studying them according to the sections in which the treatise is divided. We do so to analyze in context the footwork length and therefore understand how it relates with later *Verdadera Destreza* techniques, descriptions, and the theory around them. It is to be noted that we have only covered curved lines.

In order to show the data, we are using Castilian foot and as a unit of measure in the following format: (Footwork length; Radius of the circumference)

II.1. Against *Destreza Vulgar*

This first section covers the folios 88 to 133 where Pacheco shows us the techniques taught by *Destreza Vulgar* and explains how to confront them by the principles of *Verdadera Destreza*. It is easy to see as it is stated in the text, that most of the footwork is done assuming the *diestro* had rightly chosen the Mean of Proportion and, therefore, the fighters are diametrically opposed within the Common Circle. But this Common Circle is not shown explicitly. Thus, we have no exact reference to the footwork relation to it (namely, if they match the Circle, get inside it, get out of it or are tangent to it). This is a good example of how establishing certain properties like the proposed rule might enlightened those relations and ease the study of such footwork.

Following the order of appearance in the treatise the data is:

(1.59;3.75), (2.74;NM), (1.82;3.75), (1.12;1.12), (4.6;3.75), (3;3), (3.28;3.28), (3.56;3.56), (2.85;2.85), (2.53;2.53), (3.84;3.84), (4.03;NM), (1.74;1.74), (4.65;4.65), (1.82;1.82), (1.87;3.75), (4.125;4.125), (1.78;3.75), (3.84;NM), (1.5;3.75), (2.9;3.75)

Whose classification is shown in Table 1:

Related	Nonrelated	No match
11	7	3
52.33%	33.33%	14.33%

Table 1

Leaving aside the non-matching footwork as a possible printing error, we observe:

- The biggest percentage of footwork follows the proposed rule.
- The 7 nonrelated lines are all done with a radius of 3.75 CF, quite close to the typically assumed Common Circle radius of 4 CF based on the later *Verdadera Destreza* authors. 5 of them are done from the Mean of Proportion and the path in the diagram reminds of the place where the Common Circle would be depicted.

This analysis establishes the following new hypothesis: Pacheco might be using the initial hypothetical rule when the footwork moves inside the Common Circle and uses the Common Circle or a circumference very close to it as a guide to much of the other footwork.

II.2. Verdadera Destreza own attacks

This section covers the folios 134 to 242, here we found similar issues with the study of the footwork to the ones in the first section of the treatise. There are four subsections dividing the techniques according to the intention of the techniques and its particular use.

II.2.1. Second intention attacks

This subsection covers the folios 135 to 207. Here we found the techniques later classified as *Tretas Generales*[3] or of second dignity and the different variations of them according to the fight evolution.

Following the order of appearance in the treatise the data is:

(2.53;3.75), (3.26;3.75), (1.59;3.75), (2.43,2.43), (3.51;3.75), (1.74;3.75), (2.09;3.75), (1.82;3.75), (3.28;NM), (4.59;NM), (1.64;3.75), (2.34;NM), (2.49;3.75), (3.56;3.56), (3.98;3.98), (3.15;5.7), (3.75;3.75), (1.24;3.75), (1.24;3.75), (1.92;3.75), (4.21;4.21), (5.24;5.34), (1.55;3.75), (3.84;NM), (2.53;2.9), (3.7;3.75), (3.3;4.42), (1.91;3.75),

[3] In *Nueva Ciencia y filosofía de la destreza de las armas, su teórica, y practica,* page 442, Pacheco states that the four *Tretas Generales* are the already described in its first treatise techniques: *Línea en Cruz, Estrechar ,Flaqueza debajo la fuerza y Flaqueza encima la fuerza.*

(1.99;3.75), (1.27;3.75), (1.04;3.75), (0.64;3.75), (1.98;1.98), (3.75;3.75), (3.75;3.75), (3.86;3.75), (3.47;NM), (0.84;3.75), (1.85;3.75), (1.67;3.75), (3.75;3.75), (2.85;3.75), (2.09;NC), (1.66;3.75), (2.96;2.96), (3.49;3.75), (2.01;8.21), (2.07;3.75), (3.65;3.75), (3.5;4.99), (1.83;3.75), (4.46;4.92), (3.1;3.75), (3.1;3.75), (4.66;4.47), (1.35;3.75)

Whose classification is shown in Table 2:

Related	Nonrelated	No match
10	40	6
17.85%	71.43%	10.72%

Table 2

It is to be noted that, although the ratios in this classification are very off of the first hypothesis (the rule relating footwork length with circumference radius), the second hypothesis (regarding the proximity to the Common Circle) seems to be reinforced as 36 of the 40 non-related curved lines have a radius of 3.75 CF. We will analyze this fact further once all the data is gathered.

II.2.2. First intention attacks

This subsection covers the folios 208 to 213, here we found a brief assortment of thrusts.

Following the order of appearance in the treatise the data is:

(1;1; 1;1); (0;93; 1;64); (1;82; 2;02); (2;15; 2;81)

Whose classification is shown in Table 3:

Related	Nonrelated	No match
1	3	0
25%	75%	0%

Table 3

Two observations must be made:

- The second pair of measurement does not match the text as it 2 CF must be covered, and we have got 0.93 CF.
- This kind of circular footwork will be replaced in later *Verdadera Destreza* treatises by straight motions. Even though there is no evidence of it being the reason for the ratios related to the first hypothesis in this subsection, we think it should be noticed.

II.2.3. Circular attacks

This subsection covers the folios 214 to 235, here we found different ways to perform *tajo* and *revés.*[4]

Following the order of appearance in the treatise the data is:

(2.73;1.38), (3.14;1.75), (2.91;1.86), (3.46;1.8), (1.18;1.18), (2.11;1.87), (3;1.51), (3.09;1.55), (3.2;1.65), (3.16;1.65), (3.41;1.71), (2.83;1.41), (3.88;2.06), (3.6;1.85)

Whose classification is shown in Table 4:

Related	Nonrelated	No match
1	10	3
7.14%	85.71%	7.14%

Table 4

It noticeable that all the circular footwork in this subsection is performed following a straight movement and all the non-related ones cover over half of the circumference used in their construction. This is clearly an exception to the usual footwork construction in the treatise and the physical meaning of such an extreme movement, which only seems appropriate to reinforce the technical implementation of both *tajos* and *reveses.*

II.2.4. Against the Turk treatise

This section covers the folio 236 to 242, here we found the way Pacheco considers optimal to, according to *Verdadera Destreza* principles, fence against a turkish cutlass.

Following the order of appearance in the treatise the data is:

(1.51;3.75), (2.04;3.83), (3.72,3.81), (1.4;3), (2.79;4.34)

Whose classification is shown in Table 5:

Related	Nonrelated	No match
0	5	0
0%	100%	0%

Table 5

The footwork analyzed in this subsection does not match any of our two hypotheses. The (obvious) exceptional nature of this subsection (confronting two very different weapons: the rapier and the cutlass) does not fade away the doubts such different data throws over our hypotheses. In the conclusions, it is going to be observed that the difference between the weapons seems to be the reason why this subsection is so off of

[4] In folio 91 Pacheco states how to perform *revés* as a wide cut, starting with the sword moving towards the *diestro*'s right leg to then cut from above the *diestro*'s head with a circular motion. In folio 95 Pacheco states how to perform *tajo* as the wide cut done from the side contrary to the *revés*, namely moving the sword toward the left leg.

the rules we are trying to obtain. Nevertheless, it should not be disregarded as its particularities could be of importance if more data were to be added regarding Pacheco's early footwork.

III. CONSISTENCY AND COMMON CIRCLE

Before compiling and analyzing the meaning of all the data gathered from Pacheco's treatise, we are going to analyze briefly the measure of the Common Circle through several *Verdadera Destreza* treatises in order to be able to compare with that repeated length of 3.75 CF we have found to be the radius of a total of 41 out of 100 curved lines analyzed and that set in motion our second hypothesis as early as in the first section of the treatise.

We are going to analyze different authors using different methods or measures for the Common Circle always giving measures to compare with the gathered data. It should be noted that some authors do not give any specific distance, not even implicitly embedded in other mathematical data described in the treatise regarding the footwork.

III.1. Luis Pacheco de Narváez

Due to his prolific publications, we are going to use the measures in their first and last treatises, which also are the most extensive works.

III.1.1. Libro de las grandezas de la espada

Though the very closely related Mean of Proportion and Common Circle concepts have a central position in Pacheco's theory there are only two implicit references to the second's radius length:

> […] to know the opponent's sword, through the mean of proportion (as it is the goal of this proof) which its length is perceived, being aware, that in no way the sword shall surpass your hilt.[5]

- It is supported by the length of the human arm and legal sword length of the time. The legal sword length is 3.75 CF and most of *Verdadera Destreza* authors give the human ideal arm a length of 2 CF. If Pacheco included the hand in those 2 CF or not is not decidable. As other authors do not consider the hand included in the arm (and give a total length for the arm of 2.25 CF) we are going to give both possible distances. Thus, we get to plausible radius for the Common Circle:

$$r_1 = \frac{3.75 + 2.25 \times 2}{2} CF = 4.125CF$$

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[5] *reconocer la efpada contraria, mediante el medio de proporcion (que es el fentido defta demoftracion) el qual confidera la largura della, procurando, que de ninguna fuerte paffe la efpada contraria de la guarnición de la vueftra.* Pacheco de Narvaez, *Nueva ciencia, y filosofía de la destreza de las armas*, fol. 51.

$$r_2 = \frac{3.75 + 2 \times 2}{2} CF = 3.875CF$$

- The second reference appears on folio 57 referring to the image in folio 56. It is based on the geometric elements described in the text. There Pacheco refers to the points A and T, placed on the circumference and being a fourth part of the perimeter away from each other, namely marking the vertex of a right triangle with the centre of the circumference. And as Pacheco states this distance is 5 CF: 'You must walk by the circumference side from point A to reach the small circle in point T with only a geometrical step.'[6]
  We can apply Pythagoras Theorem to an isosceles right triangle with hypotenuse 5 CF and the Common Circle radius as the other sides. Therefore:

$$r_3^2 + r_3^2 = 5^2 \Rightarrow r_3 = 3.535CF$$

We find then that in fact, the Common Circle is not consistently defined in Pacheco's first treatise as we can obtain 3 different radii lengths.

III.1.2. Nueva Ciencia y Filosofía

On folio 243 Pacheco states, in a similar way as he does on *Libro de las grandezas de la espada* folio 51, that the sword point should be near to the opponent hand and gives a measure of 2.5 CF for the human arm. Therefore, he provides a new measure for the Common Circle radius:

$$r_4 = \frac{3.75 + 2.5 \times 2}{2} CF = 4.375CF$$

III.2. Octavio Ferrara

The treatise written by Octavio Ferrara, *Compendio y Philosophia y destreza de las Armas*, should be considered of certain importance for our topic as Ferrara was a direct disciple of Pacheco. Thus, it might be a good reflection of Pacheco's teachings. In this treatise we have two descriptions of the Common Circle:

- On folio 8 there is a textual description matching Pacheco's one on folio 51: It is to measure the swords, not exceeding the sword point from the hilt pommel.[7]
  Here we have the same issue found in Pacheco's descriptions, the need to add the length of the arm. It is easy to see that the choices we can make will result in the same radii we have already obtained.

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[6] *habeys de caminar por el lado de la circunferencia de punto A. hasta llegar al circulo pequeño de punto T. con solo un paso Geométrico.* Octavio Ferrara, *Compendio y Philosophia y destreza de las Armas*, fol. 8.

[7] *Es medir las espadas, que no pasen las puntas de los pomos de las guarniciones.* Ibid.

- In the diagram named as *Demostracion de los compases universales para todos los ejercicios de las armas* Ferrara gives us explicit measures for the different circles depicted, among them, the Common Circle for which we have a pair of circumferences:
- The shortest one, with the toe over it and a diameter of 7.5 CF, resulting in a radius of 3.75 CF.
- The longest one, with the middle of the foot over it and a diameter of 8.5 CF, resulting in a radius of 4.25 CF.

III.3. Luis Diaz de Viedma

Luis Diaz de Viedma in the treatise *Metodo de enseñanza de maestros en la ciencia filosófica de la veradera destreza matemática de las armas* shows two geometrical ways to obtain a radius length:

- The first one on folio 11 where he states: This has to be seen as having the diameter line eight foot from point A to point A.[8] From where we trivially obtain a radius of 4 CF.
- The second one is too on folio 11, as he also states:

> […] this circle has to be of twenty-four foot in perimeter: all of it divided in three-foot steps, making eight steps all around the circumference.[9]

We find a mismatch between the different descriptions when we compute the given lengths, both within the consistency of this second reference and with the first one.
If we assume that the perimeter has 24 CF we easily get, by the circumference formula that:

$$P_C = 2\pi r \Rightarrow r = \frac{P_C}{2\pi} \overset{\Rightarrow}{P_{C=24CF}} r = 3.819CF$$

If we assume that the length of the inscribed octagon side is

$$l_8 = 3CF$$

And knowing the central angle covering such side is of 45º, applying trigonometry
66

$$sin\frac{45^o}{2} = \frac{l_8}{2r} \Rightarrow r = 3.919CF$$

Both radii are quite close to each other in length and are not very far from the first one proposed of 4 CF.

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[8] *este se ha de entender que tiene la linia del diámetro ocho pies de punto A. a punto A.* Luis Diaz de Viedma, *Metodo de enseñanza de maestros en la ciencia filosófica de la verdadera deſtreza matemática de las armas*, fol. 11.

[9] *este circulo debe ser de veinte y cuatro pies de circuito: todo el cual dividido en compases de a tres pies, hace ocho compases en toda su circunferencia*. Ibid.

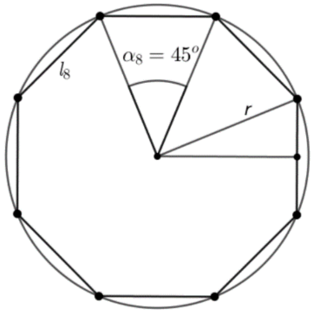

Figure 5: Octogon inscribed in circle (Viedma). Author's diagram

It is fair enough to assume that the computation error made by Viedma is an acceptable one to represent a radius of 4 CF and give an approximation of how the different lengths covered by the footwork were according to his practice and theoretical approach. Nevertheless, it is worth mentioning how close the shortest radio we get from Viedma falls next to the 3.75 CF repeatedly obtained in Pacheco's first treatise.

III.4. Francisco Lorenz de Rada

The treatise *Nobleza de la Espada* is divided in three volumes where we find several references to the Common Circle. All of them result on the same length and we are giving here two of them:

- In the volume *Arte de la espada* Rada states: 'whose centre is point A. and the circumference the sword point makes, moving around the pommel placed in A. this shall be a mysterious circle in Destreza, as it stablishes the distance that has to be between the two combatants, being from point D. to point B. of eight geometric foot and this Circle shall be called *Circulo Comun* (common circle).'[10]
  We obviously obtain a radius of 4 CF
- In the volumen *Experiencia de la espada* Rada states: 'And the other common circle to both combatants, and it is in the middle of both of them when armed and in the mean of proportion whose semidiameter is of four foot, which is the sword length, from pommel to point.'[11]

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[10] *cuyo centro es el punto A. y la circunferencia que se describe con la punta de la Espada, moviendose alrededor del pomo que esta en punto A. este sera un circulo muy misterioso en la Destreza, porque determina la distancia que ha de haber entre los dos combatientes, que es desde el punto D. al punto B. de ocho pies Geometricos y este Circulo se llamara Circulo común.* Rada, *Nobleza de la espada.*

[11] *Y el otro circulo comun a ambos combatientes, y esta en medio de los dos cuando estan armados en el medio de proporcion, cuyo semidiametro es de cuatro pies, que es la longitud de la espada, desde el pomo hasta la punta.* Ibid.

Here states the radius explicitly as 4 CF.

It is to be noted that Rada gives us some insight to the issue with the radius length in Pacheco's texts coming back from the late XVIIth century. We found it in the folios 45 to 49 from the volume *Experiencia de la espada,* he gives a diameter length for Pacheco's Common Circle of 8.5 CF, a radius of 4.25 CF. This radius is not very off from the 4.375 CF we get from Pacheco and seems an acceptable variation due to the inaccuracy of Pacheco's description when studied in detail. It shows that some current issues with the study of *Verdadera Destreza* are not actually new at all.

III.5. Summary of radius lengths

In the following lines we summarize the obtained radius lengths and comparing them to see what we can state from this brief research.

- Pacheco's radii: We have got the next collection of possible lengths:
$$r_1 = 4.125CF; r_2 = 3.875CF; r_3 = 4.375CF; r_4 = 3.535CF$$
- Ferrara radii: We have got two lengths:
$$r_5 = 3.75CF; r_6 = 4.25CF$$
- Viedma's radii: We have got three lengths:
$$r_7 = 4.919CF; r_8 = 3.819CF; r_9 = 4CF$$
- Rada radius: We got just one radius:
$$r_{10} = 4CF$$

We can observe two groups of radii, gathering around two lengths from which they do not differ too much: 4 CF and 3.75 CF (respectively the usual length given to the Common Circle radius and the one we have found in the analysis of *Grandezas de la Espada* footwork diagrams). To group them we have use the lesser difference to both lengths to choose where to place them. Therefore, r_2 is in both groups as the difference with both lengths is the same.

- 4 CF group: Around this length we obtained the radii $r_1, r_2, r_3, r_6, r_7, r_9, r_{10}$. They vary between [-0.125 CF, 0.375 CF] from the given distance, which translates to [-3.607 cm, 10.44 cm]. It is to be noted that the greater difference is given when we use the arm length including the hand as 2.5 CF. This ~~a~~ measure is criticized by Rada and only used by Pacheco. If we remove it, we obtain an upper bound of 7.21 cm (given also by Ferrara's exterior Common Circle).
- 3.75 CF group: Around this length we got the radii r_2, r_4, r_5, r_8. They vary between [-0.215 CF, 0.069 CF] from the given distance, which translates to [-5.99 cm, 3.607 cm]. Though they are less they got a narrower error range than the other group.

It is interesting that the shorter lengths are spawned through a shortest error segment than the longer ones, almost reflecting the fact that the closest a fencer is to the opposing fencer, the more dangerous the mistakes become. Ferrara's depiction of his two Common Circles, differing only where they are placed in the front foot (which differs from Rada's approach depicting his exterior Common Circle, placed under the rear foot and thus of no real use for the present analysis), matches our finding from *Grandezas de la Espada* actually placing one of each radii in one of our groups.

IV. ANALYSIS OUTPUT

First of all, we are taking a look to the compilation of all the data regarding whether their match to the rule about radii length equalling footwork length, as shown in Table 6:

Related	Nonrelated	No match
23	65	12
23%	65%	12%

Table 6

This first classification shows us clearly that the footwork does not follows the construction rule employed to draw the diagrams in folios 66 and 67. Thus we shall add the second hypothesis into the study to see if we can propose a set of rules that make sense and help us reconstruct the diagrams. To achieve that objective, we shall classify them with more detail dividing the non-related into three categories: those which seem~~s~~ to go close to the Common Circle, the ones used to perform circular attacks and the ones that do not fit in any of them. Proceeding this way, we obtain a new classification as shown in Table 7:

Related	Nonrelated			No match
-	Common circle	Circular attacks	No rule	-
23	41	10	14	12
23%	41%	10%	14%	12%

Table 7

Under this new light we can appreciate that there is a majority of footwork to which we can bound to a rule to make its construction. A total of 74% of the analysed diagrams are in this position and 12% of them are not able to be properly analysed, meaning that even a greater portion of them could follow a rule. But we shall refrain ourselves to point the 14% left with no rule as mistakes and be aware that this is Pacheco's first treatise and the possibility of not every technique and movement being described correctly following the theory he proposes.

Keeping in mind all the information summarized above and the analysis of the Common Circle we have performed we can state the following:

- The footwork following curve lines is constructed following circumference arcs. It is to be noted to, that the 12% left as errors are not far off circumference arcs.

- The footwork that goes from outside to inside the Common Circle and reversely seems to accurately follow the rule relating radius length as equal to footwork covered length.
- The footwork related to the techniques that evolved into the so-called *Tretas Generales* follows circumference arcs of 3.75 CF radius length, which matches a feasible approximation of the Common Circle as we have seen in section III. From this we got certain foothold to also think that Pacheco is depicting the path of the foot's tip.
- The footwork related to wide cuts is done reinforcing the sword motion by adding body inertia behind it.
- Some of the footwork following no rule is used to perform techniques which were later depicted using straight footwork, called *transversales*. This kind of footwork is not described in the treatise as were added to the theory in later Pacheco's works.

From this we can redraw the diagrams, reconstructing them using our conclusions as rules to follow and be consistent in the way we go from treatise to practice.

IV.1. Redrawing diagrams

As closure and as an example of how the analysis performed can improve our approach and study of *Grandezas de la espada* we are going to show the reconstruction of the diagrams Pacheco gives in it. We are going to show new draws of the first diagram for *estrechar*, *linea en cruz*, *flaqueza encima de la fuerza* and *flaqueza debajo de la fuerza* (the last two sharing the same diagram).

We are going to depict the Common Circle diagram in a similar way to what we see in Rada's treatise. Therefore, we are showing a 4 CF Common Circle to appreciate the difference with the 3.75 CF radius we have concluded Pacheco seems to use (if we do not specify otherwise this 3.75 CF is the radius length used in the construction). We are going to provide the original diagram, the redraw and a summary of the distance and techniques each point marks in the diagram.

The common elements depicted in our diagrams are the following (Fig.6):

- C_d, C_i: Right foot (C_d) and left foot (C_i) Common Circles.
- d: common diameter
- O_n : n-castillian foot orb. We are only depicting the 4, 5 and 6 CF orbs as they are the proportionate means for conclusion movement, cuts and thrust respectively and adding more will not add any relevant information.
- $O_{m,d}, O_{m,i}$: maximum orb for the right foot and the left foot.
- C_p, C'_p: Own circle of both fencers.

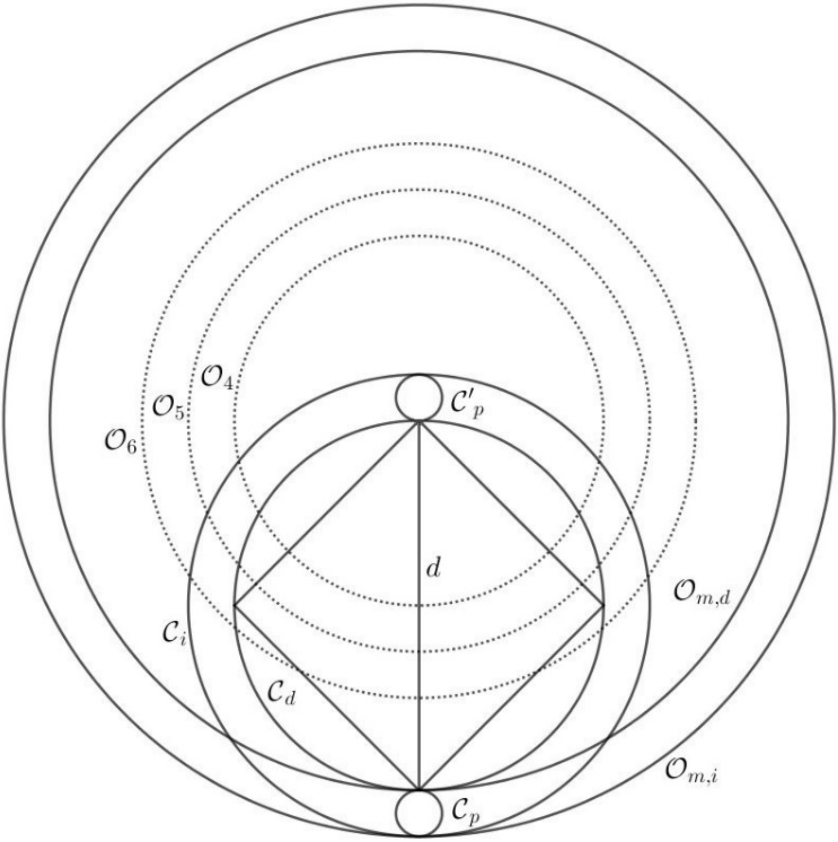

Figure 6: Reworked diagrams. Author'diagram.

IV.1.1. Estrechar

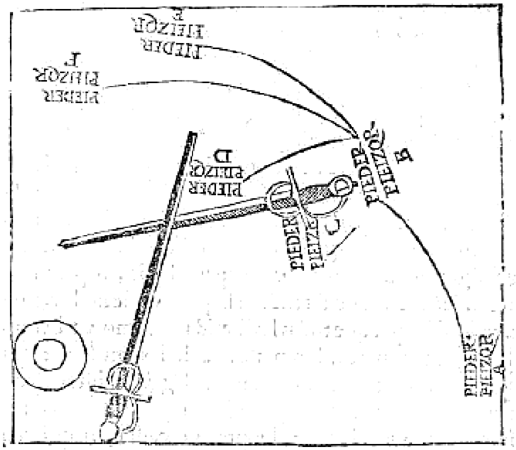

Figure 7. Libro de las Grandezas de la Espada p.135

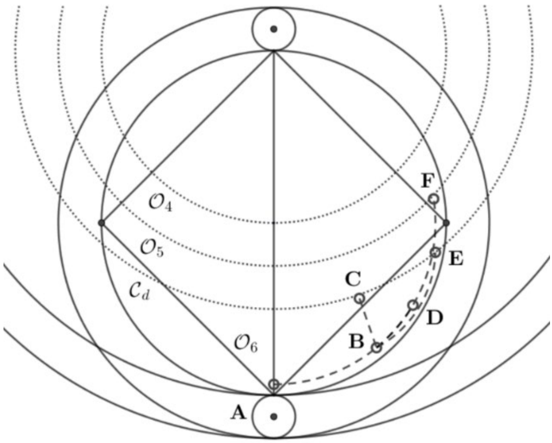

Figure 8. Estrechar diagram drawn following the presented conclusions

- **A:** Mean of proportion chosen by active *diestro*
- **B:** Step length of 2.75 CF. Here we are pressing the opponent and can thrust if needed according to the text. To perform the thrust there is a need to extend the reach 1.3 CF or one of the fencers to move to shorten this distance.
- **C:** Step length of 1.21 CF. Here we can thrust, but there is a need to extend the reach 0.09 CF.
- **D:** Step length of 1.3 CF. Here we can thrust but there is a need to extend the reach 0.73 CF.

- **E:** Step length of 2.6 CF with a radius of equal length. Here we can thrust.
- **F:** Step length of 3.7 CF. Here we can cut (precisely, perform a *tajo*) but there is a need to extend the reach 0.06 CF.

IV.1.2. Linea en cruz

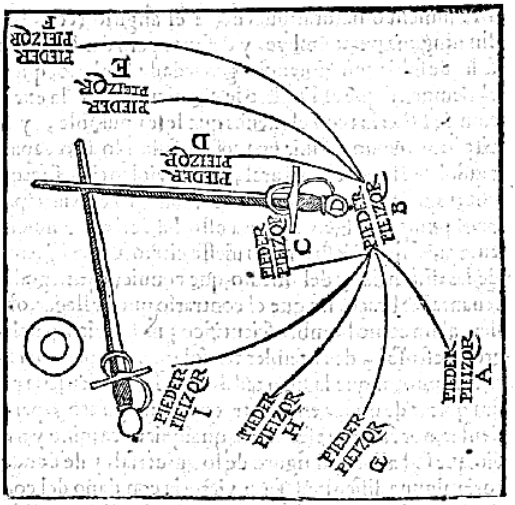

Figure 9. Libro de las Grandezas de la Espada, p. 144.

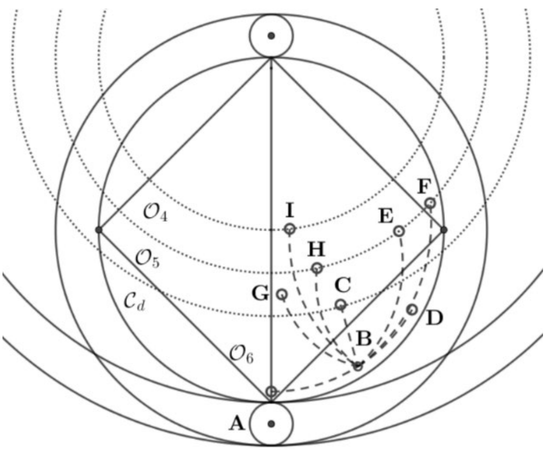

Figure 10. Linea en cruz diagram drawn following the presented conclusions.

- **A:** Mean of proportion chosen by active *diestro*

- **B:** Step length of 2.09 CF. Here we are pressing the opponent and we can thrust if needed according to the text. To perform the thrust there is a need to extend the reach 1.44 CF or one of the fencers to move to shorten this distance.
- **C:** Step length of 1.49 CF. Here we can thrust.
- **D:** Step length of 1.82 CF. Here we can thrust but there is a need to extend the reach 0.7 CF.
- **E:** Step length of 3.28 CF with a radius of equal length. Here we can cut (precisely, perform a *tajo).*
- **F:** Step length of 4.14 CF. Here we can cut (either a *tajo* or *medio revés*).
- **G:** Step length of 2.43 CF. Here we can cut (either a *tajo* or *medio revés*) but there is a need to extend the reach 0.5 CF
- **H:** Step length of 2.47 CF with a radius of equal length. Here we can cut (precisely, perform a *revés*) while grabbing the opponent's sword hilt with our left hand, but for being able of grabbing the hilt there is a need to extend the reach 1 CF.
- **I:** Step length of 3.56 CF with a radius of equal length. According to the text here the opponent should have moved toward us and therefore we will be able of place our left foot close to its right one and, grabbing his sword hilt perform any type of attack.

IV.1.3. Flaqueza encima de la fuerza and *flaqueza debajo de la fuerza*

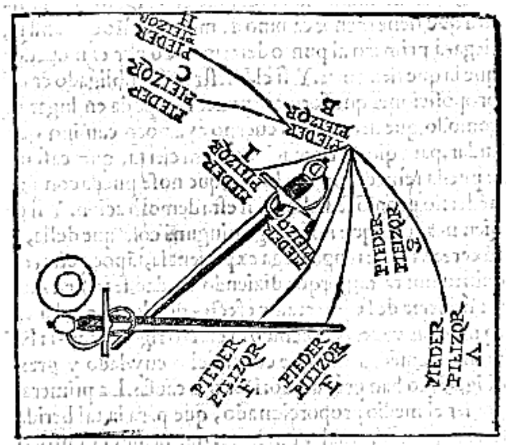

Figure 11. Libro de las Grandezas de la Espada, p. 202.

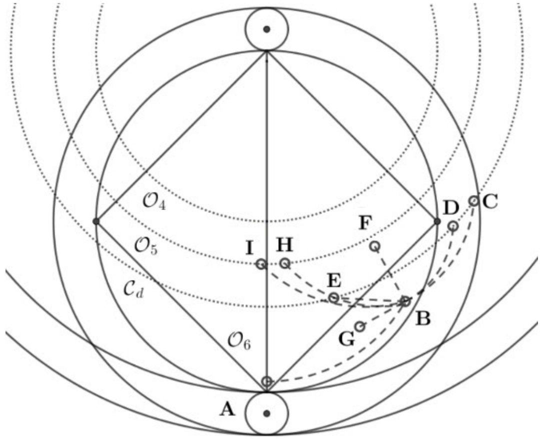

Figure 12. Flaquezas diagram drawn following the presented conclusions.

- **A:** Mean of proportion chosen by active *diestro*
- **B:** Step length of 3.75 CF. Here we are pressing the opponent and can thrust if needed according to the text. To perform the thrust there is a need to extend the reach 0.71 CF or one of the fencers to move to shorten this distance.
- **C:** Step length of 2.85 CF. Here we can thrust.
- **D:** Step length of 2.09 CF. Here we can thrust.
- **E:** Straight step length of 1.68 CF. Here we can thrust. According to the text this is a response to the opponent advancing while thrusting and thus we should be able to grab his sword hilt.
- **F:** Step length of 4.14 CF. Here we can cut (precisely, perform a *tajo*) but there is a need to extend the reach 0.23 CF. According to the text this is a response to the opponent advancing while thrusting and thus we should be able to grab his sword hilt.
- **G:** Straight step length of 1.22 CF. Here we can thrust but there is a need to extend the reach 0.82 CF. According to the text this is a response to the opponent advancing while thrusting and thus there might be no need to extend the reach.
- **H:** Step length of 2.96 CF with a radius of equal length. Here we can cut (precisely, perform a *revés*).
- **I:** Step length of 3.49 CF with a radius of equal length. Here we can cut (precisely, perform a *revés*). According to the text this is a response to the opponent advancing while thrusting and thus we should be able to grab his sword hilt.

To close this analysis of the diagrams, it is to be said that within *Verdadera Destreza* way of fencing there are ways of extending our reach while keeping the principles the authors proposed in their treatises. Therefore, those notes about the need to extend the reach are not necessarily fails neither in Pacheco's diagrams nor in the redrawing of those diagrams.

V. CONCLUSIONS

We have analysed the geometry of the footwork depicted in Pacheco's first treatise, for this purpose we have followed the next steps:

1. We have searched for a description of the elements the diagrams are based on. From it we have obtained some geometrical properties to search for and to work with in the diagrams. From this first set of data we have stablished a hypothesis for the footwork construction structure.
2. We have designed an analysis method that gives us data for every diagram and studied its possible deviation (seeing that it was within an acceptable magnitude).
3. We have applied the method designed to the diagrams and obtained a significant amount of data.
4. We have analysed the data, checked the hypothesis, and discarded it in favour of a set of statements that are backed by the data.

We think that there are several benefits that follows from this analysis:

- In the sight of the material used to perform this research we can state that there is a considerable level of consistency throughout *Verdadera Destreza* treatises regarding the common circle concept and its properties.
- We have given a method of study that allows to compare *Verdadera Destreza* first diagrams with the later ones and see how they, and the fencing techniques they represent, evolved.
- We have obtained some outputs that allow to accurately translate the techniques from *Libro de las grandezas de la espada* to practice, which is aligned with the main goal of the research and represents its principal benefit.

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