

2⁴ Experimental Factorial Model Application in the Music Publishing Industry

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ABSTRACT

The purpose of this study was to carry out a technological investigation that applied a 2⁴-factorial design in the field of the music publishing industry of Daniel Alomía Robles National University (UNDAR). The main target has been to optimize time and effort required to create fingering diagrams for instruments such as Pinkullo Huanuqueño, Flute, Quena and Saxophone, all within the Latex environment with Musixtex. The study shows parameters that indicate when it is appropriate to use this approach and concludes that it is one of the most convenient methods when it is necessary to analyze the joint effects of multiple factors and the interactions that occur between them.

I. INTRODUCTION

Currently, a sector of the university music publishing industry uses flexible open source environments for the edition of music books with high print quality, capable of providing a set of tools for the editing of scores, diagrams, among others. Such is the case of the Latex environment with the specialized bookstore Musixtex.

For this reason, this work has been carried out with the aim of applying a factorial model of experimentation 2⁴ to improve the production process in the music publishing industry of UNDAR.

A process or system can be represented by means of a black box, where there are controllable factors, X_1, X_2, \dots, X_i ; uncontrollable factors, Z_1, Z_2, \dots, Z_i (although they may be controllable for purposes of the experiment); inputs and a system response or output [4].

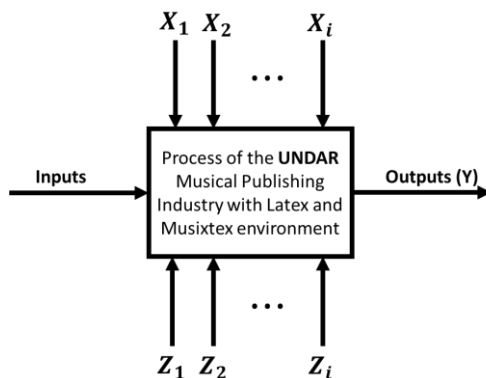


Figure 1: Diagram of a process in the music publishing industry.

Source: the authors.

This approach is fundamental in the research to determine the optimal configuration of the coverage of the own library for the generation of fingering diagrams of the Pinkullo Huanuqueño, the Recorder, the Quena and the Saxophone, since it allows to exhaustively evaluate the impact of multiple factors on a variable of interest, providing valuable information for decision-making and the understanding of music editing scenarios.

II. DESCRIPTION OF TECHNOLOGICAL RESEARCH

Identification of the problem: There is evidence of the need to improve the efficiency and speed of the process of generating the fingering diagrams of the musical notes for the instruments of the Pinkullo Huanuqueño, the Recorder, the Quena and the Saxophone, in the environment of Latex with Musixtex for the music publishing industry of the UNDAR. Currently in the Latex Package Repository (<https://www.ctan.org>) there is no custom library that allows you to make these typing diagrams automatically, so the manual procedure takes time and effort to learn. In this context, the formulation of the experimental problem arises: How to optimize the operation in the music publishing industry of Latex with Musixtex that allows obtaining in less time and effort the fingering diagrams of musical notes for the Pinkullo Huanuqueño, Recorder, Quena and Saxophone?

General objective: To optimize the operation of Latex with Musixtex by means of a library that allows to obtain in less time and effort the fingering diagrams of musical notes for Pinkullo Huanuqueño, Recorder, Quena and Saxophone

Specific objectives:

Development of a customized library in Latex with Musixtex that allows to obtain in less time and effort the fingering diagrams of musical notes for the Pinkullo Huanuqueño, Recorder, Quena and Saxophone.

Application of the factorial model of experimentation 2^4 in the music publishing industry of the UNDAR for the optimization of the time and effort of the musical note fingering diagrams of the Pinkullo Huanuqueño, Recorder, Quena and Saxophone.

State of the art:

Development of Custom Latex Library with Musixtex: In the field of music notation and score editing, Latex with Musixtex has been widely used [1]. However, so far, there is no specific library that focuses on the efficient generation of fingering diagrams for the aforementioned instruments [6]. Previous research has explored the potential of Latex in music notation, but there is still a gap in terms of a specialized solution for these instruments.

Optimization in the Music Publishing Industry: The application of the factorial model of experimentation 2^4 in the music publishing industry is a novel approach. Factorial experimentation techniques have been shown to be effective in identifying the optimal combination of variables in complex processes [4,5]. However, its specific application in the field of music publishing production, especially in relation to the optimization of learning time and effort, is an area that requires further research.

Recent Contributions in Music Technology: The current landscape of technology applied to music shows significant advances in music notation software and tools [1,2]. However, most of these solutions are generic and do not address the idiosyncrasies of the aforementioned instruments. Current research seeks to fill this gap by developing a specialized library that integrates with existing tools and addresses the specific needs of the music publishing industry.

Components of the project: The process of musical editing in Latex with Musixtex is detailed in Figure 2, in which the factorial model of experimentation 2^4 was applied, in order to optimize the time and effort in the generation of musical note fingering diagrams for the Pinkullo Huanuqueño, Recorder, Quena and Saxophone.

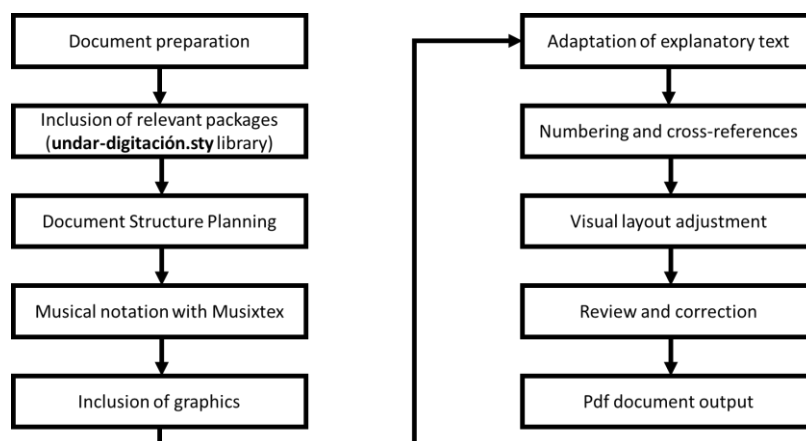


Figure 2: Diagram of the Latex music editing process with Musixtex.

Source: the authors.

This production system of the UNDAR publishing industry is designed online, whose sub-processes are detailed below:

The process of publishing a music book on LaTeX involves several key steps to ensure an accurate and aesthetically pleasing presentation. The general process is described below:

Document Preparation: The goal of this stage is to create a new LaTeX file using the appropriate document class for books or sheet music. This specifies the paper size, page layout, and other basic settings.

Inclusion of relevant packages: At this stage, relevant packages are included, such as "musixtex" for musical notation, the customized package "undar-fingering" for the generation of the musical note fingering diagrams of the Pinkullo Huanuqueño, Recorder, Quena and Saxophone, among others.

Planning the structure of the document: At this stage, the book is divided into chapters or sections according to the planned structure. LaTeX commands are used to create titles, subtitles, and other structural elements.

Music Notation with Musixtex: At this stage, the Musixtex "music" environment will be used to incorporate scores. Notes, durations, and other elements of musical notation are specified using commands provided by Musixtex.

Inclusion of Graphics: At this stage, images or graphics of existing scores are inserted using or scores in pdf format are attached. It adjusts the size and position of images for optimal presentation.

Explanatory Text Adequacy: At this stage, musical content is interspersed with explanatory or descriptive text using standard LaTeX text commands. Introductory sections, explanations of musical techniques, or any other informative content are added.

Numbering and cross-referencing: At this stage, pages, chapters, and sections are properly numbered. Cross-reference commands are used to reference specific parts of the book, such as musical figures or sections.

Visual layout adjustment: This stage adjusts the visual layout of the document, such as line spacing, line spacing, and paragraph spacing. The design will be customized according to editorial preferences or project requirements.

Revision and correction: At this stage, exhaustive reviews of the content are carried out, verifying the accuracy of the musical notation and the coherence of the text. Typographical, grammatical, and musical errors are corrected as needed.

Generation of the pdf document: In this last stage, the LaTeX document is compiled to generate the final pdf file. The appearance of the book is checked, making sure that all scores and textual content are presented correctly.

This comprehensive music editorial editing process in LaTeX ensures the creation of a well-formatted and professional music book.

Activities carried out:

During the experiment, the optimal value of the inputs (four instruments) was determined to influence the output of the process of generating musical note fingering diagrams so that a desired value is reached, to identify the most influential variables (time and effort) in the output of the process, to minimize the variability of the output by adjusting the inputs, and to reduce the effects of uncontrollable factors by determining the best value of the inputs that affect the output in the generation of the fingering diagrams of the Pinkullo Huanuqueño, Recorder, Quena and Saxophone.

III. MATERIALS AND METHODS

The type of research is technological [3], with a level of experimental research.

General hypothesis: If, in the music publishing industry of Latex with Musixtex, a personalized library is used, then the fingering diagrams of the Pinkullo Huanuqueño, Recorder, Quena and Saxophone will be obtained in less time and effort.

Specific hypotheses:

If, in the music publishing industry, a personalized library (undar-digitacion.sty) of Latex is used with Musixtex, then the fingering diagrams of the Pinkullo Huanuqueño, Recorder, Quena and Saxophone will be obtained in less time and effort.

If, the factorial model of experimentation 2^4 is applied in the Latex music publishing industry with Musixtex, then the time and effort of the musical note fingering diagrams of the Pinkullo Huanuqueño, Recorder, Quena and Saxophone will be optimally analyzed.

Variables, Dimensions, and Indicators

Independent Variable: Custom Latex library with Musixtex.

Table 1: Independent Variable with Dimensions and Indicators

Independent Variable	Personalized Latex bookcase with Musixtex	
Conceptual Definition	Dimension	Indicator
The custom library undar-digitacion.sty is a set of predefined commands and definitions that allow you to extend the capabilities and basic functionality of Latex to generate fingering diagrams of the Pinkullo Huanuqueño, Recorder, Quena and Saxophone.	Pinkullo Huanuqueño	Commands for Generating Fingering Diagrams for Pinkullo Huanuqueño
	Recorder	Commands for Generating Fingering Diagrams for Recorder
	Quena	Commands for Generating Fingering Diagrams for Quena
	Saxophone	Commands for Generating Fingering Diagrams for Saxophone
Source: the authors.		

Dependent Variable: Fingering diagrams of the Pinkullo Huanuqueño, Recorder, Quena and Saxophone.

Table 2: Dependent Variable with Dimensions and Indicators

Dependent variable	Fingering diagrams of the Pinkullo Huanuqueño, Recorder, Quena and Saxophone	
Conceptual Definition	Dimension	Indicator
Fingering diagrams are visual representations that show the exact positions of fingers in the holes or holes of a musical instrument. Each hole or hole in these instruments represents a specific musical note.	Time to elaborate the fingering diagrams of the Pinkullo Huanuqueño, Recorder, Quena and Saxophone.	Time to prepare the fingering diagrams in minutes (min) for each instrument.

Fingering diagrams provide a graphical reference of which fingers need to be placed in each hole to play a particular note.	Effort to elaborate the fingering diagrams of the Pinkullo Huanaqueño, Recorder, Quena and Saxophone.	
Source: the authors.		

Methodology:

Table 3: Methodological summary

Problem	How to optimize the operation in the music publishing industry of Latex with Musixtex that allows obtaining in less time and effort the fingering diagrams of the Pinkullo Huanaqueño, Recorder, Quena and Saxophone?				
Hypothesis	If, in the music publishing industry of Latex with Musixtex a personalized library is used, then the fingering diagrams of the Pinkullo Huanaqueño, Recorder, Quena and Saxophone will be obtained in less time and effort.				
Type of Research	Technological research				
Object of Research	Fingering diagrams of the Pinkullo Huanaqueño, Recorder, Quena and Saxophone for the music publishing industry of UN DAR.				
Variables	Independent		Dependent		
	Personalized Latex bookcase with Musixtex		Fingering diagrams of the Pinkullo Huanaqueño, Recorder, Quena and Saxophone		
Measuring Scales	Commands for Generating Fingering Diagrams for Pinkullo Huanaqueño		Fingering diagram preparation time in minutes (min) for each instrument		
	Commands for Generating Fingering Diagrams for Recorder				
	Commands for Generating Fingering Diagrams for Quena				
	Commands for Generating Fingering Diagrams for Saxophone				
Research Design	Factorial design $24 = 2 \times 2 \times 2 \times 2$, completely random:				
	(A) P i n	(B) R e c	(C) Q u e	(D) S a x	Treatment (combination of dimensions)
	A1	B1	C1	D1	A1 B1 C1 D1
			C2	D2	A1 B1 C2 D1
		B2	C1	D1	A1 B2 C1 D1
			C2	D1	A1 B2 C2 D1
	A2	B1	C1	D1	A2 B1 C1 D1
			C2	D1	A2 B1 C2 D1
		B2	C1	D1	A2 B2 C1 D1
			C2	D1	A2 B2 C2 D1
			D2	A2 B2 C2 D2	

Data collection techniques	<p>(A) Time to prepare the fingering diagrams for Pinkullo Huanuqueño in minutes: two treatments (manual and with personalized library)</p> <p>(B) Time to prepare the fingering diagrams for Recorder in minutes: two treatments (manual and with personalized library)</p> <p>(C) Time to prepare the fingering diagrams for Quena in minutes: two treatments (manual and with personalized library)</p> <p>(D) Time to prepare fingering diagrams for saxophone in minutes: two treatments (manual and with personalized library)</p>
Data processing and analysis techniques	<p>Significance Test: Using the null hypothesis criterion and the tests:</p> <ul style="list-style-type: none"> • "F", to test the significant effect of the factors. • Significance level $\alpha = 0.05$. <p>H0: Factor A has no significant effect H1: Factor A has a significant effect</p> <p>H0: Factor B has no significant effect H1: Factor B has a significant effect</p> <p>H0: Factor C has no significant effect H1: Factor C has a significant effect</p> <p>H0: Factor D has no significant effect H1: Factor D has a significant effect</p>
Source: the authors.	

The target population includes professionals and entities involved in the creation, production, and distribution of music-related educational and publishing resources, as well as musicians, students, and educators who use these resources. The sample is for convenience and will be made to the team of researchers of the project who collaborate with the music publishing industry of the UNDAR.

IV. RESULTS

It should be noted that the results obtained from the experiment have been greatly influenced by the programmer's expertise in Latex with Musixtex. The following table shows the results obtained:

Table 4: Results of the experiment

Personalized Latex bookcase with Musixtex					Fingering diagram preparation time in minutes (min)			
(A) Pinkullo Huanuqueño	(B) Recorder	(C) Quena	(D) Saxophone	Treatment (combination of dimensions)	To	B	C	D
A1	B1	C1	D1	A1 B1 C1 D1	60	58	63	59
			D2	A1 B1 C1 D2	60	58	60	27
	C2	D1	A1 B1 C2 D1	62	59	29	59	
		D2	A1 B1 C2 D2	62	57	27	33	
	C1	D1	A1 B2 C1 D1	63	27	58	62	

	B2	C2	D2	A1 B2 C1 D2	57	29	59	30	
			D1	A1 B2 C2 D1	60	31	28	63	
		D2	A1 B2 C2 D2	60	32	29	29		
	A2	B1	C1	D1	A2 B1 C1 D1	29	59	63	62
				D2	A2 B1 C1 D2	33	59	59	30
			C2	D1	A2 B1 C2 D1	29	62	31	61
D2		A2 B1 C2 D2		28	62	27	32		
B2		C1	D1	A2 B2 C1 D1	31	27	61	62	
			D2	A2 B2 C1 D2	30	33	59	28	
	C2	D1	A2 B2 C2 D1	30	29	28	62		
D2		A2 B2 C2 D2	30	31	27	28			

Source: the authors.

The Latex library with Musixtex has been designed for the efficient generation of specific musical fingering diagrams of the Pinkullo Huanuqueño, Recorder, Quena and Saxophone; characterized by the fact that the command is made up of 6 parameters: two optional and four specific, the first optional parameter defines the tuning of the instrument, the second the vertical displacement, while the first specific parameter defines the musical note in American, English or Anglo-Saxon format, the second specific parameter defines the octave with respect to the piano tuned to 440 Hz, The third specific parameter defines the alteration if required (sharp or flat), and the fourth specific parameter defines the alternative positions. It comprises the following structure:

$$\backslash\text{tipo_instrumento}[op1][op2]\{\text{par1}\}\{\text{par2par3par4}\}$$

Where:

$\backslash\text{tipo_instrumento}$: Defines the instrument type

Table 5: Variants of the instrument type of the custom Latex library with Musixtex

$\backslash\text{flute}$	Double Hole Recorder	$\backslash\text{pinkullo}$	Pinkullo
$\backslash\text{fluteB}$	Single Hole Recorder	$\backslash\text{quena}$	Quena
$\backslash\text{Saxophone}$	Saxophone		

Source: the authors.

[op1]: Defines a specific tuning for the selected instrument

Table 6: Optional Parameter 1 of the Latex Custom Library with Musixtex

[spn]	Soprano recorder	[la]	Quena tuned in A
[spnn]	Sopranino Recorder	[]	Quena tuned in G
[la]	Pinkullo tuned in the	[fa]	Quena tuned in F
[sib]	Pinkullo tuned to Bb	[re]	Quena tuned in D
[si]	Pinkullo tuned in B	[]	Saxophone

Source: the authors.

[op2]: Defines an offset up if positive or down if negative

{par1}: Defines the musical note in American, English, or Anglo-Saxon format

Table 7: Specific Parameter 1 of the Latex Custom Library with Musixtex

{C}	Note do	{E}	Note mi	{G}	Nota sol	{B}	Note si
{D}	Note re	{F}	Note F	{A}	Note la		

Source: the authors.

{par2par3par4}: par2 defines the octave with respect to the piano tuned to 440 Hz, par3 defines the alteration if required, and par4 defines the alternate positions

Table 8: Specific parameters 2, 3 and 4 of the custom Latex library with Musixtex

{par2}	4, 5 or 6 for the Recorder	par3	, (empty) for natural note
{par2}	3, 4, 5 or 6 for the Pinkullo	par4	, (empty) standard position
{par2}	3, 4, 5 or 6 for the Quena	par4	2, 2nd alternate position in Quena
{par2}	3, 4, 5 or 6 for the Saxophone	par4	2, 2nd alternate position on Saxophone
par3	s, for sharp note	par4	3, 3rd Alternate Position on Saxophone
par3	b, for flat note	par4	4, 4th alternate position on Saxophone

Source: the authors.

Below are the commands of the custom Latex library with Musixtex for the generation of the fingering diagrams of the Pinkullo Huanuqueño, Recorder, Quena and Saxophone:

Table 9: Latex Custom Library Commands with Musixtex

Custom Command	Description
\flute[spnn]{F}{4}	Fingering of the F note Sopranino Recorder with double holes, from the note F in 4th octave
\flute[spn][12]{C}{4}	Fingering of the soprano recorder with double holes, of the note C in 4th octave, raised 12 vertical spaces
\fluteB[spnn]{F}{4}	Fingering of the F note Sopranino Recorder with Single Holes, in 4th octave
\fluteB[spn][12]{C}{4}	Soprano recorder fingering with single holes, of the note C in 4th octave, raised 12 vertical spaces
\pinkullo[si][12]{B}{3}	Fingering of the Pinkullo Huanuqueño in B tuning, of the note B in 3rd octave, raised 12 vertical spaces
\pinkullo[sib][12]{B}{3b}	Fingering of the Pinkullo Huanuqueño in B flat tuning, of the note B in 3rd octave, raised 12 vertical spaces
\pinkullo[la][12]{A}{3}	Fingering of the Pinkullo Huanuqueño in A tuning, of the note A in 3rd octave, raised 12 vertical spaces
\quena[re][12]{Ds}{3}	Fingering of the Quena in D tuning, of the note D sharp in 3rd octave, raised 12 vertical spaces
\quena[fa][12]{F}{3}	Fingering of the Quena in F tuning, of the note F in 3rd octave, raised 12 vertical spaces
\quena[so][12]{G}{3}	Fingering of the Quena in G tuning, of the note G in 3rd octave, raised 12 vertical spaces
\quena[la][12]{A}{3}	Fingering of the Quena in A tuning, of the note A in 3rd octave, raised 12 vertical spaces
\saxophone{B}{4b2}	Saxophone fingering of the note B flat in 4th octave with alternate second position, raised 12 vertical spaces

Source: the authors.

The following ANOVA table shows the results of the hypothesis tests for each factor in the experiment:

Table 10: Summary of ANOVA Analysis

	Sum of squares	Degrees of Freedom	Variance	Fisher statistician	P value
To	3721	1	3721	1302.35	3.23932E-15
Total A	3761	15			
Error A	40	14	2.86		
B	3451.5625	1	3451.5625	11.74836869	0.004082596

Total B	3509.9375	15			
Error B	4113.071038	14	293.79		
C	4096	1	4096	1194.666667	5.88966E-15
Total C	4135	15			
Error C	48	14	3.43		
D	4000.5625	1	4000.5625	1234.327893	4.69748E-15
Total D	4045.9375	15			
Error D	45.3752	14	3.24		

Source: the authors.

As the p value of factor A (3.23932E-15) is lower than the level of significance, we reject the null hypothesis, approve the alternative hypothesis and affirm that: "**Factor A has a significant effect**", that is, that the personalized library of **Pinkullo Huanuqueño** has a significant effect on the project.

Since the p value of factor B (0.004082596) is less than the significance level, we reject the null hypothesis, approve the alternative hypothesis and affirm that: "**Factor B has a significant effect**", i.e. that the personalized library of the **Recorder** has a significant effect on the project.

As the p value of factor C (5.88966E-15) is lower than the level of significance, we reject the null hypothesis, approve the alternative hypothesis and affirm that: "**Factor C has a significant effect**", that is, the Quena personalized library has a significant effect on the project.

As the p value of factor D (4.69748E-15) is less than the level of significance, we reject the null hypothesis, approve the alternative hypothesis and affirm that: "**Factor D has a significant effect**", i.e. that the personalized library of the **Saxophone** has a significant effect on the project.

V. IMPACT GENERATED

The evidence presented reveals a significant impact derived from the statistical evaluation of factors A, B, C, and D in the project. By rejecting the null hypotheses associated with each of these factors, we confirm the presence of significant effects for the personalized libraries of the Pinkullo Huanuqueño, the Recorder, the Quena and the Saxophone, respectively. This finding suggests that specific implementations of these libraries have a substantial impact on the project, validating the importance of their inclusion and supporting their significant contribution to the optimization of the process in question.

```

\begin{music}
\hspace=\linewidth
\resetlyrics
\font\A=phvb8t at 6pt% added for letter type.
\setlyrics{articulo}{A\text{\musSharp{}}$3$} G\text{\musSharp{}}$4$
A\text{\musSharp{}}$5$ G\text{\musSharp{}}$4$ A\text{\musSharp{}}$5$ B\text{\musFlat{}}$3$
F\text{\musSharp{}}$4$ C\text{\musSharp{}}$4$ A\text{\musSharp{}}$3$ E\text{\musFlat{}}$6$ D\text{\musFlat{}}$6$
C\text{\musSharp{}}$4$}}
\setsongraise1{-7mm}
\parindent0mm
\nobarnumbers
\startextract
\Aassignlyrics1{articulo}
\notes\saxofon{A}{3s}\wh{a}\hqsken
\notes\flauta{[sno][12]{G}{4s}\wh{g}\hqsken
\notes\flauta{[sno][12]{G}{4s}\wh{o}\hqsken
\notes\flautaB{[sno][12]{G}{4s}\wh{g}\hqsken
\notes\flautaB{[sno][12]{G}{4s}\wh{o}\hqsken
\notes\pinkullo{[la][12]{B}{3b}\wh{b}\hqsken
\notes\pinkullo{[sib][12]{F}{4}\wh{f}\hqsken
\notes\pinkullo{[si][12]{C}{4}\wh{c}\hqsken
\notes\quena{[la][12]{A}{3}\wh{a}\hqsken
\notes\quena{[E]{6b2}\wh{s}\hqsken
\notes\quena{[fa]{D}{6}\wh{r}\hqsken
\notes\quena{[re]{C}{4}\wh{c}\hqsken
\nolyn
\lyricsoff
\endextract
\end{music}

```

Figure 3: Fingering code of the Pinkullo Huanuqueño, Recorder, Quena and Saxophone.

Source: the authors.

Figure 4 shows the result obtained from the coding of the fingering diagrams of the musical notes for the Pinkullo Huanuqueño, Recorder, Quena and Saxophone indicated in Figure 3.

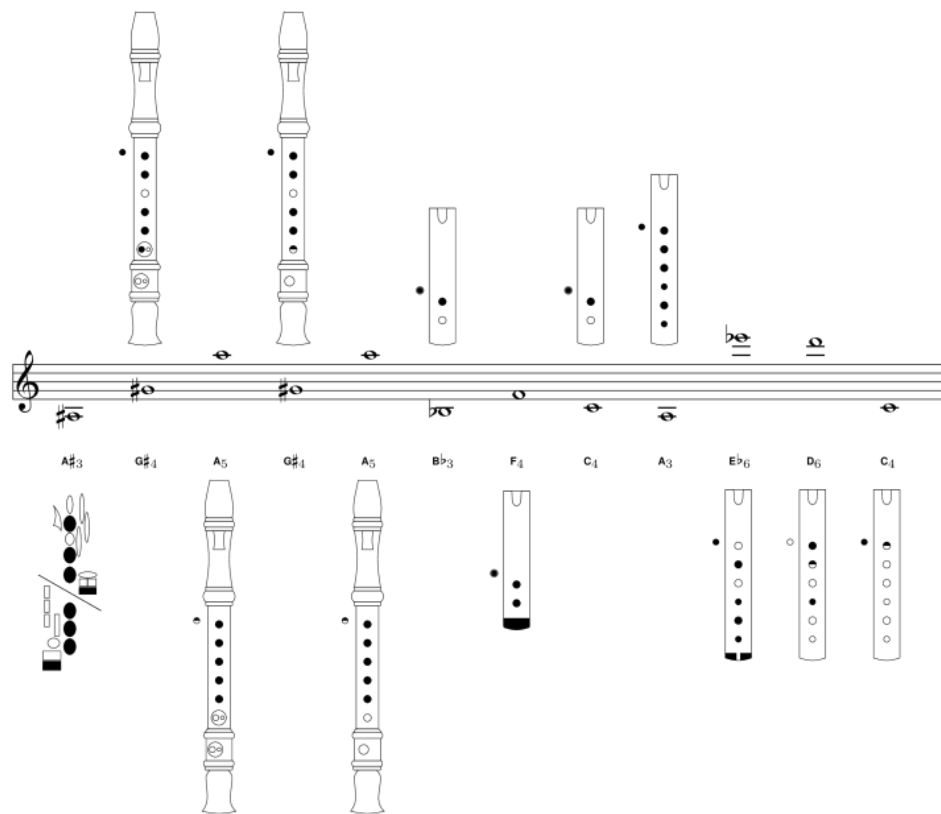


Figure 4: Fingering diagram of the Pinkullo Huanuqueño, Recorder, Quena and Saxophone.

Source: the authors.

Faced with the challenge of generating modern and specific technological tools in the music publishing industry to innovate in the teaching of the fingering of the Pinkullo Huanuqueño, Recorder, Quena and Saxophone at UN DAR, the development of the personalized library in Latex environment with Musixtex has been successfully achieved. This technological contribution will be useful for the elaboration of academic texts in both physical and digital format aimed at teaching the Pinkullo Huanuqueño, Recorder, Quena and Saxophone.

As of the date of publication of this article, the official version of the library has been published on the CTAN platform, located at the link: <https://ctan.org/pkg/undar-digitacion>.

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