NSS

Neutrosophic Sets and Systems, Vol. 80, 2025

University of New Mexico

Neutrosophic Analysis of the Cultural Impact of the Pinkullo in Llata: Integrating ChatGPT and fsQCA

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Abstract

This study explores the cultural impact of the Pinkullo, a traditional Andean aerophone, on the community of Llata, Peru, through an innovative approach that integrates neutrosophic set theory with computational methods. By employing fuzzy-set Qualitative Comparative Analysis (fsQCA) and a novel application of ChatGPT for neutrosophic sentiment analysis, the research investigates the complex interplay between the Pinkullo and various aspects of community life, including cultural participation, social impact, and cultural preservation. Textual data collected from surveys was analyzed using the "ChatGPT Constructor" add-on in Orange Data Mining to generate neutrosophic scores, representing the truth, indeterminacy, and falsity of expressed sentiments towards the Pinkullo. These scores were then fuzzified and incorporated into the fsQCA to identify the key configurations of factors that contribute to a high degree of cultural participation. The findings reveal that a positive sentiment towards the Pinkullo, combined with its perceived social impact and role in cultural preservation, constitutes a crucial pathway for fostering cultural engagement. This research not only provides valuable insights into the enduring significance of the Pinkullo in Llata but also demonstrates the potential of integrating large language models and neutrosophic logic to analyze complex cultural phenomena, paving the way for new interdisciplinary approaches in the study of cultural heritage..

Keywords: Pinkullo, Neutrosophic Analysis. Cultural Impact, ChatGPT, fsQCA

1. Introduction

Traditional music serves as a powerful expression of cultural identity, with indigenous musical instruments playing a crucial role in preserving this heritage. Among these, the Pinkullo, an Andean aerophone characteristic of Peru's mountainous regions, stands as more than just an instrument; it embodies a profound spiritual, social, and cultural connection [1]. Particularly in the district of Llata, the Pinkullo holds a central position in festivities, rituals, and community practices. However, its multifaceted influence and deeper meaning have yet to be thoroughly explored from a rigorous scientific perspective. This study proposes to analyze Pinkullo's cultural and social impact in Llata using an innovative approach based on neutrosophic set theory, thereby bridging the gap between traditional cultural studies and quantitative analysis.

In recent years, there's been a growing interest in documenting and understanding traditional instruments, driven by a need to comprehend cultural dynamics in an increasingly globalized world that often threatens to homogenize local expressions [2]. While the Pinkullo has traditionally been studied from ethnographic and musicological perspectives [3], the application of mathematical and theoretical models to its analysis remains largely unexplored. This research seeks to fill that void by integrating qualitative and quantitative approaches to capture the complexity of Pinkullo's influence on the community of Llata.

The central challenge guiding this research is the lack of adequate methodologies to analyze complex cultural phenomena that involve multiple dimensions of meaning and perception, such as the impact of the Pinkullo.

A key question driving this study is: How can the influence of the Pinkullo on a community be assessed using tools that effectively handle the inherent ambiguity, uncertainty, and subjectivity of cultural systems? This challenge demands an approach that transcends conventional methods. In the existing literature, dominant approaches to the analysis of traditional music tend to be descriptive and lack models that integrate indeterminacy and subjectivity [5]. Recent studies on Andean instruments like the Pinkullo have highlighted the need to consider not only their musical dimension but also their role as catalysts for social cohesion and community resilience [6]. This work responds to these limitations by adopting neutrosophic set theory, a mathematical model capable of representing and analyzing phenomena involving uncertainty, contradiction, and subjectivity [7, 8], as its core analytical framework.

To achieve this, qualitative data collection techniques, including interviews and participatory observations, were combined with quantitative tools incorporating fuzzy variables, all within the framework of neutrosophic set theory. This methodological approach provides a more comprehensive and rigorous view of Pinkullo's impact in Llata [9, 10]. The primary objective of this study is to analyze the influence of the Pinkullo on the cultural and social dynamics of the Llata district using this innovative method. Furthermore, this research aims to generate a replicable methodological framework applicable to the analysis of other complex cultural phenomena.

Ultimately, this work seeks to illuminate the intricate relationship between music, culture, and community, demonstrating how an ancient instrument like the Pinkullo continues to resonate and shape social dynamics in the present day. By employing this innovative approach, the research not only aims to quantify the multifaceted impact of the Pinkullo on cultural participation but also to offer a methodological framework adaptable to other complex cultural phenomena. The findings are anticipated to contribute significantly to the understanding and appreciation of Andean cultural heritage, providing valuable tools for its preservation in an increasingly interconnected world [11]. Moreover, this study bridges the analytical and the humanistic, demonstrating that the intersection between these perspectives can generate deep and transformative knowledge, enriching the field of cultural studies and showcasing the power of integrating mathematical models into traditionally qualitative disciplines.

2. Preliminaries

2.1Complexity theory and causality and neutrosophic sets.

Relationships Understanding the relationships between variables is rarely straightforward. Complexity theory, which emphasizes non-linear interactions, provides a robust framework for such analysis. It posits that the same cause can yield vastly different outcomes depending on the context, highlighting principles like conjunction, equifinality, and causal asymmetry. Neutrosophy enhances this perspective by explicitly incorporating indeterminacy and uncertainty, elements often inherent in social phenomena[12, 13].

- Conjunction: Outcomes result from the interaction of multiple antecedent conditions, not from isolated factors. For example, a restaurant's success depends not solely on food quality but also on its location, service, and ambiance. A combination of average food, excellent service, and a prime location can be as successful as outstanding cuisine alone.

- Equifinality: A system can achieve the same outcome through different initial conditions and pathways. Multiple strategies, considering various combinations of factors, can lead to restaurant success. This applies broadly across social, political, and economic contexts.

- Causal Asymmetry: The factors leading to an outcome's presence are not necessarily the opposite of those leading to its absence. A successful restaurant might thrive due to high-quality food, but the absence of high-quality food doesn't automatically doom a different restaurant. This challenges deterministic approaches.

Neutrosophy offers a more nuanced approach by acknowledging inherent ambiguity and incomplete information. It utilizes neutrosophic sets to represent each variable with three components[14, 15]:

T: Truth (degree of membership)

I: Indeterminacy (degree of uncertainty)

F: Falsity (degree of non-membership)

This framework acknowledges that uncertainty is not a system flaw but an intrinsic characteristic of complex phenomena.

To assess the validity of neutrosophic configurations, we use consistency and coverage [16, 17].

Consistency measures the reliability of the set of causal conditions in producing the outcome:

$$Consistency\ (Y_i \leq\ X_i) = \frac{\sum \min\ (X_i, Y_i)}{\sum Y_i} \quad (1)$$

Coverage indicates the extent to which the causal conditions explain the outcome:

$$Coverage\ (Y_i \leq\ X_i) = \frac{\sum min\ (X_i, Y_i)}{\sum X_i} \quad (2)$$

Where:
$X_i$is the membership value of case i in the set of causal conditions.
$Y_i$is the membership value of case i in the result set.

Values greater than 0.8 for both measures generally signify a strong relationship uncertainty [18].

2.2. Neutrosophic Liker scales

Surveys using neutrosophic Likert scales [19, 20] effectively measure the diversity of opinions and their influence on public policies and social discourse, capturing areas of consensus, disagreement, and ambivalence.

Below we present the fundamental definitions and concepts related to neutrosophic sets and single-valued neutrosophic sets.

Definition 1 ([21]). Let U be a discurse universe. N ={ (x , T (x), I (x), F (x)): $x \in U$ } is a neutrosophic set, denoted by a truth membership function, $T : U \rightarrow]0-, 1+[$; an indeterminacy membership function, $I : U \rightarrow]0-, 1+[$; and a falsity membership function, $F : U \rightarrow]0-, 1+[$.

Single-valued neutrosophic sets provide a way to represent and analyze possible elements in the universe of discourse U

Definition 2 ([22]). Let U be a universe of discourse. A single-valued neutrosophic set is defined as N ={ (x , T (x), I (x), F (x)): $x \in U$ }, which is identified by a truth membership function, $TN : U \rightarrow [0, 1]$; indeterminacy membership function, $IN : U \rightarrow [0, 1]$; and falsity membership function, $FN : U \rightarrow [0, 1]$, with $0 \leq TN\ (x) + IN\ (x) + FN\ (x) \leq 3$

Using neutrosophic scales with single-valued neutrosophic sets, responses are classified according to the total of the True, Indeterminate, and False components as follows[23]:

- T+I+F<1: Incomplete
- T+I+F=1: Complete
- T+I+F>1: Contradictory

These values are obtained because, in many cases, the opinions are incomplete or contradictory. This classification is one of the advantages of using neutrosophic methods, as it allows a more nuanced understanding of the different degrees of truth, indeterminacy, and falsity in the responses.

3. Material and Methods

This study investigated the influence of the Pinkullo, a traditional musical instrument, on the cultural fabric of Llata, Peru. The research employed a mixed-methods approach, combining quantitative data analysis using fuzzy-set Qualitative Comparative Analysis (fsQCA)[24] with qualitative sentiment analysis.

Participants:

A purposive sample of 20 inhabitants of Llata was surveyed. Participants included artisans, musicians, and community leaders recognized for their extensive knowledge of the Pinkullo cultural tradition.

Variables:

The study also considered the following variables:

Cultural Participation (CP): Measured by the frequency and quality of participation in events featuring the Pinkullo, such as traditional festivals and ceremonies.

Social Impact (SI): Assessed the role of the Pinkullo in fostering community interaction and strengthening social ties among Llata's inhabitants.

Cultural Preservation (CP): Evaluated the contribution of the Pinkullo to preserving ancestral traditions and knowledge. Note this is the same acronym as Cultural Participation but they represent different factors. Consider changing to avoid confusion.

Perceived Sentiment towards Pinkullo (PSP): Captured the emotions and attitudes evoked by the Pinkullo within the community, categorized as positive, neutral, or negative. This variable was derived from open-ended textual responses using sentiment analysis.

Data Collection:

Data on PI, CP, SI, and Cultural Preservation were collected through a survey employing Likert scales. Textual data for PSP was gathered via an open-ended question in the same survey.

Sentiment Analysis:

Textual responses related to PSP were processed using a sentiment analysis pipeline implemented in Orange Data Mining software, as illustrated in Figure 1 [25].

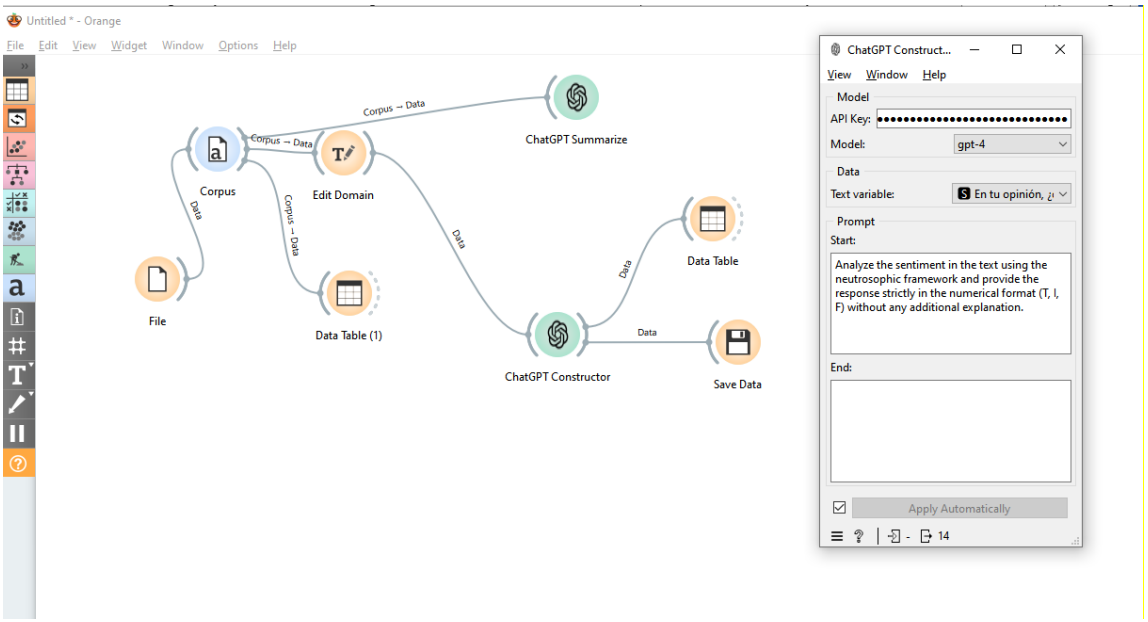

Figure 1: Orange Data Mining workflow for neutrosophic sentiment analysis using the "ChatGPT Constructor" widget.

A pivotal aspect of our methodology involved the innovative application of a Large Language Model, specifically ChatGPT [26, 27], for conducting neutrosophic sentiment analysis of the textual data gathered from the open-ended survey responses. This was achieved by leveraging the "ChatGPT Constructor" add-on within the Orange Data Mining software (see Figure 1), enabling seamless integration of the language model into our analytical workflow[28]. The prompt, "Analyze the sentiment in the text using the neutrosophic framework and provide the response strictly in the numerical format (T, I, F) without any additional explanation," was used to elicit neutrosophic scores—representing truth, indeterminacy, and falsity—directly from ChatGPT. These scores were subsequently transformed into fuzzy sets and served as input for the fuzzy-set Qualitative Comparative Analysis (fsQCA) [29, 30]. This novel integration of ChatGPT-powered, neutrosophic sentiment analysis [31] with fsQCA allowed for a nuanced exploration of the complex interplay between perceived sentiment towards the Pinkullo and the identified causal conditions influencing cultural participation. This approach represents a methodological advancement, demonstrating how AI-driven tools can be effectively combined with established social science methods to analyze qualitative data quantitatively.

Fuzzification:

The neutrosophic sets obtained are transformed into equivalent fuzzy sets, following the procedure described in [32]. This step is essential for the subsequent analysis, allowing to handle the uncertainty and ambiguity inherent in the collected data. $AN = \{x, (TA(x), IA(x), FA(x)) : x \in X\}$an NS. Its equivalent fuzzy membership set is defined as $AF = \{(x, \mu A(x)) : x \in X\}$,where $\mu A(x) = s\left((TA(x), IA(x), FA(x)), (1,0,0)\right)$. Then, using the similarity equation proposed in,

$$\mu A(x) = 1 - \frac{1}{2}[(1 - T_A(x)) + \max\{I_A(x), F_A(x)\}] \quad (3)$$

Since the range of the similarity measure function is the unit interval [0,1], μA (x) ∈ [0,1] for all x ∈ X. Therefore, the membership function of the derived fuzzy set belongs to [0, 1] and hence satisfies the property of a fuzzy set (FS) membership function.

Data Analysis:

Fuzzy-set Qualitative Comparative Analysis (fsQCA) was employed to identify combinations of conditions (CP, SI, Cultural Preservation, PSP) associated with varying degrees of the outcome (PI). Data processing was conducted using the fsQCA 4.0 software for Windows [33].

4. Results.

Cultural Participation (CP) will be selected as the outcome for the fsQCA analysis. This is because it represents the frequency and quality of participation in events where the Pinkullo is used, such as traditional festivals and ceremonies, making it a key indicator of cultural engagement.

The other variables, such as Social Impact (SI), Cultural Preservation (CP), and Perceived Sentiment towards Pinkullo (PSP), will be treated as causal conditions that influence the level of cultural participation.

A survey was conducted with a group of 20 inhabitants of Llata, including artisans, musicians, and community leaders with extensive knowledge of the Pinkullo cultural tradition (see Table 1).

Table 1. Survey data for the 20 participants

Participant	PC	IS	CP	SP
1	(0.9, 0.8, 0.1)	(0.6, 1.0, 0.6)	(0.3, 0.7, 0.3)	(0.8, 0.6, 0.1)
2	(0.6, 0.6, 0.6)	(1.0, 1.0, 1.0)	(0.6, 0.1, 0.6)	(0.6, 0.6, 0.2)
3	(0.8, 0.7, 0.4)	(0.7, 0.9, 0.6)	(0.8, 0.6, 0.6)	(0.8, 0.6, 0.3)
4	(1.0, 1.0, 0.0)	(0.8, 0.8, 0.0)	(1.0, 0.9, 0.3)	(0.7, 1.0, 0.4)
5	(1.0, 0.6, 0.0)	(1.0, 0.6, 1.0)	(1.0, 0.6, 0.1)	(0.9, 0.6, 0.1)
6	(0.9, 0.9, 0.9)	(0.9, 0.9, 0.9)	(0.9, 0.9, 0.2)	(0.9, 0.9, 0.1)
7	(0.1, 0.6, 0.8)	(1.0, 0.0, 0.0)	(0.6, 0.6, 0.6)	(0.8, 0.6, 0.1)
8	(1.0, 0.9, 0.1)	(0.9, 0.9, 0.1)	(0.9, 0.9, 0.1)	(0.9, 0.9, 0.1)
9	(1.0, 1.0, 0.0)	(0.8, 0.8, 0.0)	(1.0, 0.0, 0.0)	(0.9, 0.0, 0.0)
10	(0.7, 1.0, 0.1)	(0.9, 0.4, 0.0)	(0.6, 0.9, 0.1)	(1.0, 0.0, 0.0)
11	(0.4, 0.7, 0.1)	(0.3, 0.9, 0.4)	(0.8, 0.4, 0.6)	(0.4, 0.8, 0.3)
12	(0.6, 1.0, 0.6)	(0.6, 0.6, 0.1)	(0.1, 0.6, 0.7)	(1.0, 0.1, 1.0)
13	(0.7, 0.8, 0.4)	(0.8, 1.0, 0.5)	(0.7, 0.5, 0.4)	(0.7, 0.7, 0.5)
14	(0.5, 0.7, 0.2)	(0.6, 0.8, 0.6)	(0.5, 0.6, 0.5)	(0.6, 0.6, 0.4)
15	(0.9, 0.7, 0.3)	(0.7, 1.0, 0.4)	(0.6, 0.8, 0.4)	(0.8, 0.7, 0.3)
16	(0.8, 0.6, 0.5)	(0.9, 0.7, 0.3)	(0.7, 0.5, 0.6)	(0.8, 0.6, 0.4)
17	(0.6, 0.8, 0.4)	(0.7, 0.8, 0.2)	(0.5, 0.7, 0.5)	(0.7, 0.8, 0.3)
18	(0.7, 0.9, 0.3)	(0.6, 0.9, 0.2)	(0.7, 0.6, 0.6)	(0.8, 0.7, 0.3)
19	(0.6, 0.8, 0.5)	(0.8, 1.0, 0.3)	(0.6, 0.7, 0.4)	(0.7, 0.8, 0.4)
20	(0.8, 0.7, 0.4)	(0.9, 0.8, 0.2)	(0.7, 0.6, 0.5)	(0.8, 0.7, 0.4)

The fuzzification process is developed using the equation (3)

Table 2: Fuzzy values .

Participant	PC	IS	CP	SP
1	0,55	0,3	0,3	0,6
2	0,5	0,5	0,5	0,5
3	0,55	0,4	0,6	0,6
4	0,5	0,5	0,55	0,35
5	0,7	0,5	0,7	0,65
6	0,5	0,5	0,5	0,5
7	0,15	1	0,5	0,6
8	0,55	0,5	0,5	0,5

9	0,5	0,5	1	0,95
10	0,35	0,75	0,35	1
11	0,35	0,2	0,6	0,3
12	0,3	0,5	0,2	0,5
13	0,45	0,4	0,6	0,5
14	0,4	0,4	0,45	0,5
15	0,6	0,35	0,4	0,55
16	0,6	0,6	0,55	0,6
17	0,4	0,45	0,4	0,45
18	0,4	0,35	0,55	0,55
19	0,4	0,4	0,45	0,45
20	0,55	0,55	0,55	0,55

Figure 2 illustrates the relationship between Cultural Participation (CP) and Perceived Sentiment towards Pinkullo (PSP). The data points reveal a moderate positive association, indicating that higher levels of cultural participation tend to align with more favorable perceptions of Pinkullo. The consistency values—0.799 for $X \leq Y$ and 0.962 for $X \geq Y$—suggest a strong alignment between the two variables, with minor deviations observed in specific cases. This relationship underscores the importance of positive sentiment in fostering active cultural engagement.

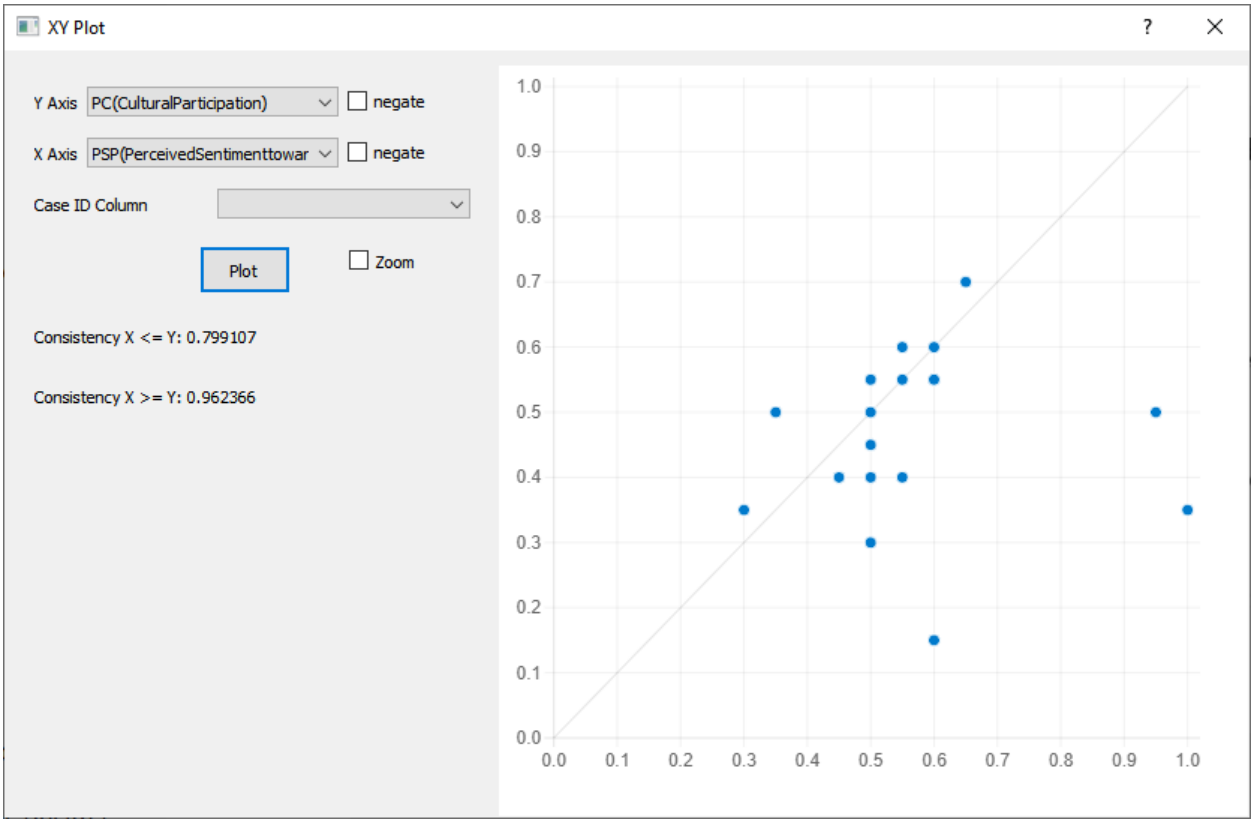

Figure 2. Relationship between Cultural Participation and Perceived Sentiment towards Pinkullo

. Figure 3 presents a subset/superset analysis exploring the relationships between key factors such as Social Impact (IS), Cultural Preservation (CP), and Perceived Sentiment towards Pinkullo (PSP). It provides three metrics for each term or combination of terms: consistency, indicating the degree to which the

condition supports the outcome; coverage, showing how much of the outcome is explained by the condition; and combined, a summary measure reflecting overall relevance. The highest consistency (0.957317) is observed in the combination of IS, CP, and PSP, emphasizing their collective influence on the cultural and social impact associated with Pinkullo.

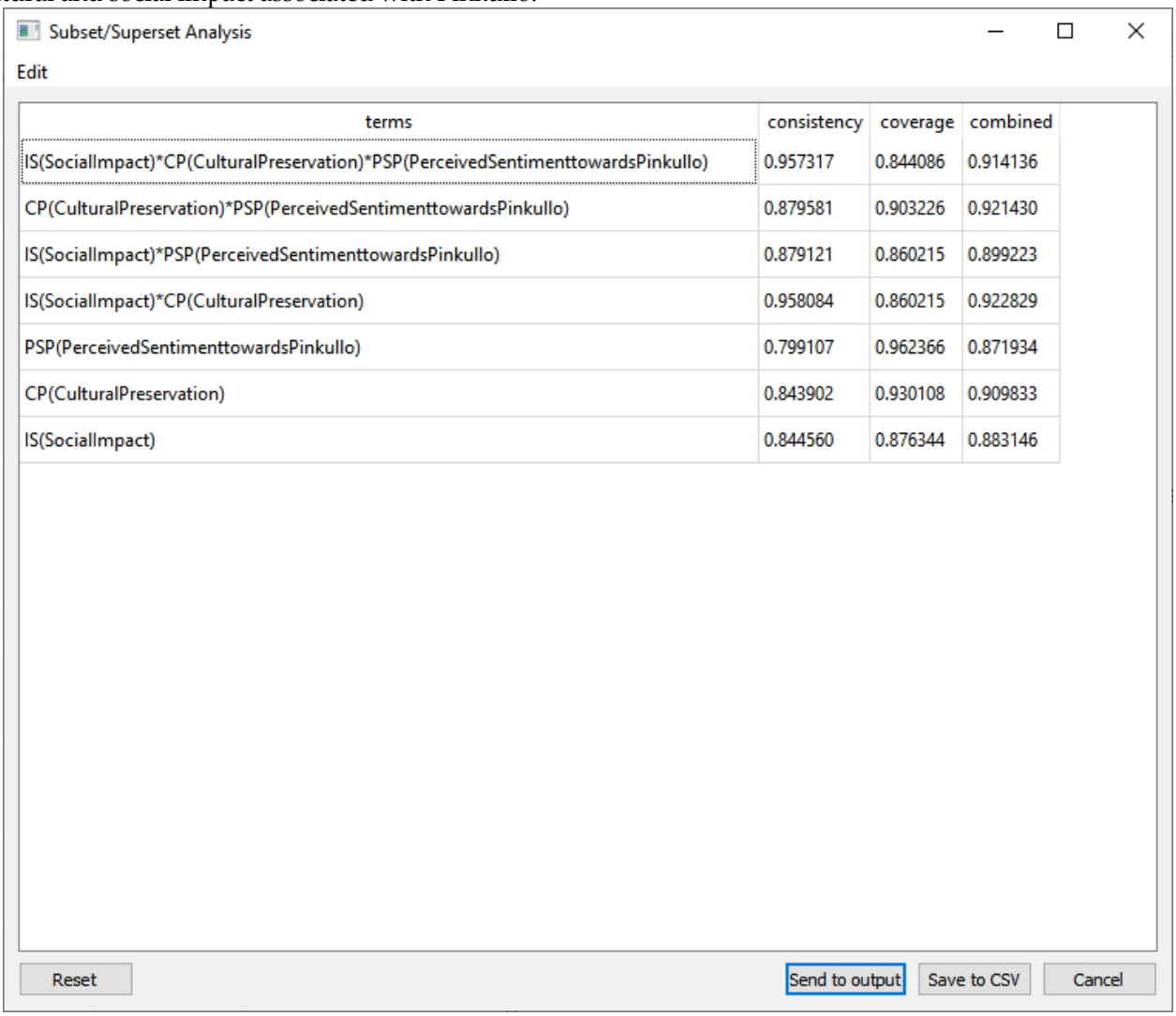

Figure 3. Subset/Superset Analysis of Cultural and Social Factors Related to Pinkullo

The results of the fuzzy-set Qualitative Comparative Analysis (fsQCA), with Cultural Participation (CP) as the outcome, highlight the complex interplay of factors contributing to engagement with the Pinkullo tradition in Llata. The moderate positive association observed between Cultural Participation (CP) and Perceived Sentiment towards Pinkullo (PSP), illustrated in Figure 2, suggests that a positive emotional connection to Pinkullo is a significant driver of participation in related cultural events. This is further supported by the high consistency values (0.799 for $X \leq Y$ and 0.962 for $X \geq Y$), indicating that positive sentiment is often a necessary, though perhaps not always sufficient, condition for active participation. These findings align with broader theories of cultural sociology, which emphasize the role of affect and emotion in motivating collective action and cultural preservation. The minor deviations observed in certain cases, where high participation occurs despite less positive sentiment, could be attributed to other factors like social obligation or a sense of duty towards preserving cultural heritage, suggesting avenues for further qualitative investigation.

Furthermore, the subset/superset analysis presented in Figure 3 provides crucial insights into the configurations of conditions that foster cultural engagement. The particularly high consistency value (0.957317) for the combined influence of Social Impact (SI), Cultural Preservation (CP), and Perceived Sentiment (PSP) underscores the synergistic effect of these factors. This suggests that Pinkullo's influence on cultural participation is maximized when it is perceived as having a positive social impact, contributing to the preservation of cultural heritage, and eliciting positive emotions. This configuration (SICPPSP) implies that initiatives aimed at promoting cultural participation should focus not only on showcasing Pinkullo's artistic value but also on emphasizing its role in strengthening social bonds and preserving cultural identity. This integrative approach, which considers the interplay of social, cultural, and emotional dimensions, offers a more holistic understanding of cultural participation than analyzing each factor in isolation. The relatively lower coverage values across the table suggest that while these factors are important, other unmeasured variables or alternative pathways may also contribute to cultural participation, highlighting the inherent complexity of cultural dynamics within the community.

5. Conclusions

This research investigated the influence of the Pinkullo on cultural participation in Llata, Peru, employing a novel approach that integrates fuzzy-set Qualitative Comparative Analysis (fsQCA) with neutrosophic sentiment analysis. A key innovation of this study was the use of a Large Language Model, specifically ChatGPT with the "ChatGPT Constructor" add-on in Orange Data Mining, to analyze open-ended textual responses and generate neutrosophic sentiment scores. This application of ChatGPT to derive structured neutrosophic data from qualitative text represents a pioneering methodological advancement in the field of cultural studies. To the best of our knowledge, this is the first study to utilize a Large Language Model for this specific purpose, demonstrating the potential of artificial intelligence to enhance the analysis of complex cultural phenomena.

The findings underscore the multifaceted relationship between the Pinkullo and cultural engagement. A positive emotional connection to the instrument quantified through neutrosophic sentiment analysis, was found to be a crucial driver of participation. The synergy between Social Impact (SI), Cultural Preservation (CP), and Perceived Sentiment (PSP) further highlighted the Pinkullo's significance, not just as a musical instrument, but as a cornerstone of social cohesion and cultural identity.

While the study acknowledges limitations, such as the potential influence of unmeasured factors suggested by the relatively low coverage values in the fsQCA, the adopted methodology incorporating neutrosophic logic and ChatGPT proved valuable in handling the ambiguity inherent in cultural data. This research contributes significantly to our understanding of Andean cultural heritage, specifically the enduring significance of the Pinkullo in Llata.

In conclusion, this study provides a novel methodological framework, leveraging the capabilities of a Large Language Model (ChatGPT) for neutrosophic sentiment analysis, to investigate the complex interplay between a traditional musical instrument and its community. The successful implementation of this approach paves the way for future research to explore other complex cultural phenomena using similar AI-enhanced methodologies, potentially revolutionizing the integration of quantitative analysis in traditionally qualitative disciplines.

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Received: Sep 27, 2024. Accepted: Jan 20, 2024