

APPENDIX

A. Review of Study Plans

For the analysis of the problem, the following

- 1) The means obtained in each article are calculated (M_x).
- 2) The CVC is calculated for each element.
- 3) The difference of each sum-total per item is calculated according to the maximum possible value per item (V_{Max}).
- 4) Then the error assigned to each item is calculated (P_{ei}).
- 5) Finally, the CVC is calculated by applying $CVC = CVC_i - P_{ei}$.

$$CVC_i = \frac{M_x}{V_{Max}} \quad (1)$$

$$P_{ei} = \frac{1^i}{i} \quad (2)$$

documents available in the web portals of the universities and thesis repositories were evaluated:

- Public educational objectives: Universities with ICAIT or ABET accreditation had educational objectives as part of the general documentation of the professional School.
- Specific social competencies: which in turn consisted of reviewing its mission, vision, specific lines of social responsibility, study plans, course summaries, and syllabus models. Each of the theses was only evaluated if social responsibility was mentioned, from a humanistic approach or social sustainability.
- Number of theses published from 2016 02/28/2021, extracted from repositories.
- The average number of citations of published theses: in this case, we considered those authors of theses who had the highest thesis production. This metric comes from Google Scholar. The detail of this scale can be seen in Table IV.
- Evidence of support for social relevance: in this case, we selected those documents that explained in detail why the responsibility topics and social objectives were chosen; all accredited schools had such evidence.

Table III shows the results of the evaluation of these items. The number of publications in 5 years is low, in some universities less than in others. On the other hand, the average number of citations reached a maximum of 4.46%, demonstrating the low relevance of the topics highlighted by the undergraduate theses for the systems science and engineering community. Another indicator is the percentage of use per search page. This means that when people look forward to reading a thesis, only 20%, in the case of the National University of the Altiplano, stay

to read, at least, its abstract. In addition, the evidence on the documents that sentence the decision of the lines of relevance or social responsibility, and social protection only exists in accredited universities.

B. Instrument Validation

For the validation of instruments, an expert judgment was carried out, from which the results of Tables V and VI have been obtained, through the Content Validity Coefficient (CVC); which allows assessing the degree of agreement of the experts regarding each of the items of the instrument.

After applying the equations 1 and 2, we concluded that both the checklist to measure the social and scientific relevancies were approved, except for improvements and indications corrected upon delivery of this project.

C. NCube Topics

The ten research topics in the next 25 years.

- ER approaches (engineering requirements) to define the behavioral needs of the appearance of Systems of Systems (SoS).
- SoS security requirements
- Engineering frameworks
- ER approaches to define and develop requirements of the SoS architecture
- SoS requirements evaluation metrics
- Characterization and description of SoS requirements
- Theoretical foundations for requirements engineering SoS.
- Multilevel modeling techniques for SoS requirements, requirements metrics
- Virtual requirements engineering environments
- Tools for requirement compensation decisions in SoS sites

D. Word2Vec Process

For social relevance dimensions, the measure of cosine similarity was ensured, which indicates how similar one set of words is to another. In this sense, a thematic dictionary is used, for example $D = \{\text{dog, cat, rabbit}\}$, to define the set of domestic animals, also we have followed observations: $Ob1 = \text{zebra}$, $Ob2 = \text{dog}$, $Ob3 = \text{dogy}$.

According to the cosine similarity between the dictionary terms and the observations is shown in the Table.

TABLE V. EXAMPLE OF COSINE SIMILARITY BETWEEN A DICTIONARY AND WORDS TAKEN AS OBSERVATIONS OR RECORDS

Observations	Similarity
Ob1=zebra	0
Ob2=dog	1
Ob3=dogy	0.7

$$\text{soft_cosine}(a, b) = \frac{\sum_{i,j}^N s_{ij} a_i b_j}{\sqrt{\sum_{i,j}^N s_{ij} a_i^2} \sqrt{\sum_{i,j}^N s_{ij} b_i^2}} \quad (3)$$

However, the semantic similarity of the words (that is, with similar meanings or related from the meaning), broadens the spectrum of possibilities when we compare similar documents, but that use different words.

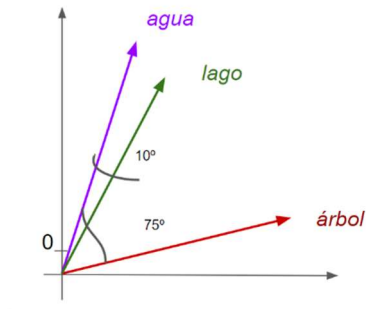


Fig 4: Cosine similarity of the words in Spanish 'lago' ('lake'), 'agua' ('water') and 'árbol' ('tree'), then of vectorization

For example, the word 'lago' ('lake') and the word 'agua' ('water') are completely different morphologically and their cosine similarity is 0 (zero) according to the

formula (3), in contrast to the word 'árbol' ('tree'). However, we can affirm that there is a relationship between 'lake' and 'water' but that their relationship is semantic and not morphological.

To perform a semantic analysis of words, paragraphs and documents, there is an artificial intelligence-based technique called Word2Vec. Word2vec is a natural language processing technique whose algorithm uses a neural network model to learn word associations from a corpus (set of documents) of text. This pre-trained model, detects and suggests synonyms or related words based on the similarity metric. Word2vec represents each distinct word with a particular list of numbers called a vector as shown in Figure 4, then the cosine similarity metric finds the distance between the vectors based on their angle of separation.

For this reason, the Word2vec technique is more suitable for the comparison of documents, in this case the theses and the relevant topics, because it is not possible to find or use identical words or clean cases, but rather terms that are related to each other.

TABLE III. ASSESSMENT OF THE CAUSES IN INDICATORS OF SOCIAL AND SCIENTIFIC RELEVANCE IN 6 UNIVERSITIES IN THE SOUTHERN OF PERU.

Universities	Shows educational goals	Specific Social competences	Publications quantity	Percentage of citation rate per publication	Shows social relevance documents social	Quantity of searches	Downloads rate
Technological University of the Andes	No shows	1	1	0%	No shows	1263	0
Catholic University of Santa Maria	Shows	3.5	155	0.64%	Shows	no data	no data
Andean University of Cusco	Shows	4	66	3.03%	Shows	6030	10%
Private University of Tacna	Shows	4	25	0%	Shows	492	0
Amazon National University of Madre de Dios	No shows	0	6	0%	No shows	no data	no data
National University of Moquegua	No shows	1	4	0%	No shows	c	0
National university of Altiplano	Shows	0.5	112	4.46%	No shows	8348	20%

TABLE IV. SCALE OF THE SOCIAL COMPETENCIES CONSIDERED ACCORDING TO THE LITERATURE REVIEW

Universities	Mention the SGD	Mention vision and mission	Social responsibility topics	Study plans	Total
Technological University of the Andes	0	0	1	0	1
Catholic University of Santa Maria	0	1	0.5	1	3.5
Andean University of Cusco	0	1	1	1	4
Private University of Tacna	0	1	1	1	4
Amazon National University of Madre de Dios	0	0	0	0	0
National University of Moquegua	0	0	0	1	1
National university of Altiplano	0	0	0	0.5	0.5

TABLE V. VALIDATION OG SOCIAL RELEVANCE CHECKLIST

	expert1	expert2	expert3	expert4	expert5	Sx1	Mx	CVC	Pe	CVCfin
item1	5	5	4	3	4	25	5	1	0	1
item2	5	4	5	4	4	25	5	1	0	1
item3	5	5	5	3	3	23	4.6	0.92	0	0.92
item4	5	4	5	5	5	22	4.4	0.88	0	0.88
item5	5	4	5	5	4	22	4.4	0.88	0	0.88
item6	5	4	5	5	4	22	4.4	0.88	0	0.88
item7	5	5	4	5	4	19	3.8	0.76	0	0.76
item8	5	4	4	5	4	23	4.6	0.92	0	0.92
item9	5	5	5	5	4	20	4	0.8	0	0.8
item10	5	4	4	5	4	25	5	1	0	1
									Total mean	0.904

TABLE VI. VALIDATION OF SCIENTIFIC RELEVANCE CHECKLIST

	expert1	expert2	expert3	expert4	expert5	Sx1	Mx	CVC	Pe	CVCfin
item1	5	5	5	3	4	25	5	1	0	1
item2	5	5	5	4	4	25	5	1	0	1
item3	5	4	5	3	5	23	4.6	0.92	0	0.92
item4	5	4	5	5	5	22	4.4	0.88	0	0.88
item5	5	4	4	5	4	22	4.4	0.88	0	0.88
item6	5	5	4	5	4	22	4.4	0.88	0	0.88
item7	5	5	4	5	4	19	3.8	0.76	0	0.76
item8	5	4	5	5	5	23	4.6	0.92	0	0.92
item9	5	5	5	5	5	20	4	0.8	0	0.8
item10	5	5	5	5	4	25	5	1	0	1
									Total mean	0.904