Andreia Malucelli[I]

Altair von Stein Junior[II]

Laudelino Bastos[III]

Deborah Carvalho[IV]

Marcia Regina Cubas[V]

Emerson Cabrera Paraíso[I]

Classification of risk micro-areas using data mining

ABSTRACT

OBJECTIVE: To identify, with the assistance of computational techniques, rules concerning the conditions of the physical environment for the classification of risk micro-areas.

METHODS: Exploratory research carried out in Curitiba, Southern Brazil, in 2007. It was divided into three phases: the identification of attributes to classify a micro-area; the construction of a database; and the process of discovering knowledge in a database through the use of data mining. The set of attributes included the conditions of infrastructure; hydrography; soil; recreation area; community characteristics; and existence of vectors. The database was constructed with data obtained in interviews by community health workers using questionnaires with closed-ended questions, developed with the essential attributes selected by specialists.

RESULTS: There were 49 attributes identified, 41 of which were essential and eight irrelevant. There were 68 rules obtained in the data mining, which were analyzed through the perspectives of performance and quality and divided into two sets: the inconsistent rules and the rules that confirm the knowledge of experts. The comparison between the groups showed that the rules that confirm the knowledge, despite having lower computational performance, were considered more interesting.

CONCLUSIONS: The data mining provided a set of useful and understandable rules capable of characterizing risk areas based on the characteristics of the physical environment. The use of the proposed rules allows a faster and less subjective area classification, maintaining a standard between the health teams and overcoming the influence of individual perception by each team member.

DESCRIPTORS: Databases as Topic. Databases, Factual. Knowledge Bases. Artificial intelligence. Environmental Indicators. Environmental Risks. Risk Map.

[I] Programa de Pós-Graduação em Informática. Pontifícia Universidade Católica do Paraná (PUC-PR). Curitiba, PR, Brasil

[II] Secretaria Estadual de Saúde do Paraná. Curitiba, PR, Brasil

[III] Programa de Pós-Graduação em Computação Aplicada. Universidade Tecnológica Federal do Paraná. Curitiba, PR, Brasil

[IV] Instituto Paranaense de Desenvolvimento Econômico. Curitiba, PR, Brasil

[V] Programa de Pós-Graduação em Tecnologia em Saúde. PUC-PR. Curitiba, PR, Brasil

Correspondence:
Andreia Malucelli
A/C PPGIa
R. Imaculada Conceição, 1155
Prado Velho
80215-901 Curitiba, PR, Brasil
E-mail: malu@ppgia.pucpr.br

INTRODUCTION

Decentralization, as a principle for the construction of the National Healthcare System, includes strategies for changing the model of care, among them, approaching health from a territorial perspective. In this sense, territory is understood not only as geographical space, but as a territorial process, a social space in which people with personal characteristics associate with other people in social movements of transforming their territory.[6]

In order to begin carrying out the actions, the health teams performed a process of data appropriation and analysis regarding the community's conditions in their territory of activity, denominated territorialization. This process consists of the systematic collection of demographic, socioeconomic, political-cultural, epidemiological and health data, used to construct basic or thematic maps. Besides initializing or strengthening the ties between the health team and the community, this process identifies the delimitation of small asymmetrically shaped spaces called micro-areas.[8,10]

The micro-areas are defined as a subdivision of small extent within the territory of the Basic Health Unit. Its inhabitants have a homogeneous quality of life that can determine health risks.[6]

The risks of a micro-area can be classified in different levels depending on the characteristics that expose the residents to risks or that determine the development of worsened health.

The recognition of the risk micro-areas is fundamental for establishing priorities to be worked on by health teams, as well as for planning adequate actions for the actual problems of the community.[6] To do this, primary data sources are used, which can be the product of interviews with key informants, who live in the region, and secondary data sources are used from diverse databases of the city departments' information systems or from other governmental or non-governmental organizations.[9]

A technique recommended for the collection of data that identifies risk micro-areas is rapid assessment, which proposes stages of information gathering; preparing questionnaires; understanding of the territory; the formulation of hypotheses for the sub-division of the territory into micro-areas; and the identification of key informants from the community to validate the collected information.[6]

The effective result of the process of delimitating the micro-areas is the product of the subjective analysis of the combination of data. Currently, the risk micro-areas are delineated by health teams supported by community health agents (CHA), who know the local problems, since they experience them through being residents of the region.

In this regard, the use of strategies to analyze the health situation in areas with similar living conditions can help in the identification and prioritization of health problems. Likewise, it can contribute to the adoption of intersectoral intervention strategies, capable of modifying the living conditions and contributing to actions related to health care.[7]

Within this context and because of the importance of the information resulting from analyzing the data of a territory, this is an area in which the field of computing can provide support through techniques and tools for data management, including the process known as Knowledge Discovery in Databases (KDD).

KDD is a process that seeks to identify patterns, associations, models or relevant information that remain hidden in databases, repositories and other forms of storing data. It allows for the identification of significant, new, potentially useful and understandable patterns and involves various scientific disciplines such as the study of machines, databases, statistics, pattern recognition and visualization, among others.[2]

Currently, KDD is applied in diverse fields such as administration, marketing analysis and medicine.[3] Nonetheless, in order for the identified patterns to be a source for generating new knowledge capable of supporting decisions, it is important that the patterns are interesting, useful and understandable to the potential administrators.

KDD consists of the following steps: pre-processing, data-mining and post-processing. The pre-processing phase is considered very important and has the objective of preparing the databases to extract patterns. After the pre-processing step, the data-mining step begins, which is considered the central step in the discovery of knowledge and involves the choosing and application of the tool and the algorithm to be used. Rule induction and genetic algorithms are among the possible algorithms to be used in this step.[4] The post-processing occurs last, when the obtained results are analyzed and interpreted. In this phase the patterns found are evaluated to verify if they satisfy the criteria to be considered an important element for supporting decision-making.

Considering that analysis to classify risk micro-areas is a subjective process of data manipulation and that the field of informatics has techniques that can make this manipulation objective, the aim of the present study was to identify, through the use of computational techniques, rules about the conditions of the physical environment that are capable of contributing to the classification of risk micro-areas.

Table 1. Set of attributes for classifying a micro-area in relation to the physical environment.

Attribute
Social resources
1. Public schools
2. Public day-care center
3. Public projects for children
4. Church (any religion)
5. Policing
6. Health unit
7. Hospital
Commerce
8. Pharmacy
9. Market
10. Supermarket
11. Grocery
12. Bar
Hydrography
13. Rivers
14. Ditches
15. Streams
16. Dams
Land
17. Sloped land
18. Low land
19. Constantly moist land
20. Dry land
21. Flat land
22. Landfill area
23. Irregular land
24. Occasionally moist land

To be continued

Table 1 continuation

Attribute
Infrastructure
25. Distribution of electricity
26. Public lighting
27. Provisioning of water
28. Sewage system
29. Trash collection
30. Road network
31. Barriers to access for the community
32. Transportation
Community
33. Spacing of houses
34. Types of housing
35. Construction area of the houses
36. Micro-area is considered violent
37. Existence of industrial pollutants
38. Urban open spaces
39. Agriculture
40. Climate
Vectors
41. Cows
42. Cats
43. Dogs
44. Pigeons
45. Horses
Recreation areas
46. Parks
47. Sports fields
48. Town squares

METHODS

An exploratory study was carried out in three stages in the city of Curitiba, Southern Brazil, in 2007.

Stage 1 - identification of attributes for the classification of micro-areas. The initial list was obtained from a review of literature. The group of attributes was submitted to validation by eight specialists in the field of collective health, five being nurses and three doctors, who classified them into irrelevant, important or essential attributes. The criteria for the selection of the specialists were that they had to be public health professionals for at least two years, with an academic affiliation and at least a Masters degree.

Stage 2 - construction of the database. From the attributes that the specialists considered essential, a questionnaire for data collection was designed for implementation by the CHA of the municipal health network. The only CHA excluded were the ones on vacation, on leave or missing from their activities during the period of data collection. The data was organized in an electronic folder creating a database with 531 entries about the physical environment of the micro-areas, representing a sample of 46.2% of the total micro-areas in Curitiba.

Stage 3 - applying the KDD process. This stage followed the stages of pre-processing and consisted of data cleaning, selection and transformation. For the data-mining stage the *Waikato Environment for Knowledge Analysis* (WEKA) tool was utilized.[a]

Table 2. Measures for performance evaluation of the set of rules obtained in the data mining stage. City of Curitiba, Southern Brazil, 2007.

Performance evaluation	Mean (SD)		Minimum	Maximum	Interval
Amount of associations per rule	5.74	(2.11)	2	12	10
Coverage	7.84	(15.00)	1	111	110
Success rate	91.6%	(14.00)	33.3%	100%	66.7%

Because this was a classification problem, algorithm J48 was used, which presents the results in the form of a decision tree, able to be transformed into a set of rules in the format: "IF...THEN...".

The evaluation during the post-processing stage was done through the perspective of computational performance and of the quality of the set of rules. To evaluate computational performance, the measures coverage and success were considered, and these measures were understood as:

coverage: indicates the number of examples covered by the association rules. High coverage with a high success rate can indicate a common sense rule.

success rate: presents the percentage of correctly classified cases in relation to coverage, indicating the credibility of the rule, and it was calculated using the following expression:

$$\text{Success rate} = \frac{(coverage - error)}{coverage} * 100$$

In this expression, the error is provided by the cases incorrectly classified by the algorithm.

To evaluate quality, the rules were analyzed in terms of how understandable and interesting they were for scientists, who were not involved in stage one. To evaluate understandability, the size of the rule, or in other words, the number of conditions per rule, was considered.

To evaluate how interesting the rules are, these were analyzed by three specialists in the field of collective health, who were selected according to the following criteria: public health workers (involved in service provision) for more than two years and at least a professional specialty in collective health or family health. The specialists attributed one of three possible scores to each rule: irrelevant (incompatible with reality); confirms their knowledge (confirms what they already know); and interesting (shows patterns that agree with reality, but were unknown until then). The estimate for "how interesting the rule was" was elaborated based on the value given by the specialists, such that the larger the mean, the more interesting the rule.

The study was approved by the Research Ethics Committee of the *Pontifícia Universidade Católica do Paraná* and by the Research Ethics Committee of the *Secretaria Municipal de Saúde de Curitiba*.

RESULTS

From a list of 49 attributes (Table 1) the specialists, who were included in the stage of identifying the attributes, classified 41 attributes as essential and eight as irrelevant. The set of attributes involves the conditions of infrastructure, hydrography, soil, recreational areas, community characteristics and vectors. The following attributes were considered irrelevant: supermarket, grocery, bar, town squares, irregular land, climate, occasionally moist land and hospital.

The database was composed of the information collected by the questionnaire, accounting for 46.2% of the total 1,148 CHA in Curitiba. In some questionnaires, several values were assigned to one attribute, making the correct classification of a micro-area more difficult.

To improve the performance of the data-mining process, the values of some attributes had to be transformed. For example, the attribute "distribution of electricity" could be assigned both "regular" and "clandestine"; therefore, the attribute became named "regular distribution of electricity", with the options "yes", "no" and "partially".

This transformation allowed for an increased success rate of the classifier, from 87.5% to 88.7%; decreased the number of rules generated, from 130 to 79; decreased the number of rules not covered by the examples in the database, from 57 to 10; and presented more easily understood rules due to a more objective value for the attribute that anteceded the rule.

The 68 rules obtained were expressed in the following format:

Antecedent: → IF <condition>

Consequence: THEN <conclusion>

The statistical results for coverage, success rates and the amount of conditions per rule, are presented in Table 2. The results show the performance and quality measures used to evaluate the set of 68 rules.

Considering the median value for the relevance of each rule, the rules were divided into two sets. Set A was composed of the 37 inconsistent rules and had a median value of one. Set B was composed of the 31 rules that confirmed the specialist knowledge and had a median

Table 3. Rules that confirm the knowledge of specialists (stage of identifying the attributes). City of Curitiba, Southern Brazil, 2007.

Identification	Description of the antecedent	Consequence
Rule 1	IF micro-area is considered violent = no AND Trash locations collected by city = yes AND Area of house building = legalized AND Constantly moist land = no AND Provisioning of water by public system = yes AND Stream =contaminated AND Flat land = yes AND Public projects for children = present	Low risk (7.0/2.0)
Rule 2	IF micro-area is considered violent = no AND Trash locations collected by city = yes AND Area of house building = legalized AND Constantly moist land = no AND Provisioning of water by public system = yes AND Stream =contaminated AND Flat land = yes AND Public projects for children = absent	Medium risk (9.0/1.0)
Rule 3	IF micro-area is considered violent = no AND Trash locations collected by city = yes AND Area of house building = legalized AND Constantly moist land = no AND Provisioning of water by public system = yes AND Stream =contaminated AND Flat land = no	Low risk (15.0/1.0)
Rule 4	IF micro-area is considered violent= no AND Trash locations collected by city = yes AND Area of house building = legalized AND Constantly moist land = no AND Provisioning of water by public system = yes AND Stream = not contaminated	Low risk (3.0/1.0)
Rule 5	IF micro-area is considered violent = no AND Trash locations collected by city = yes AND Area of house building = legalized AND Constantly moist land = no AND Provisioning of water by public system = yes AND Stream = absent	Low risk (111.0/17.0)
Rule 7	IF micro-area is considered violent= no AND Trash locations collected by city = yes AND Area of house building = legalized AND Constantly moist land = yes AND Stream = contaminated	Medium risk (6.0/2.0)
Rule 9	IF micro-area is considered violent= no AND Trash locations collected by city = yes AND Area of house building = not legalized AND Landfill area = no AND Industrial pollutants = present	Low risk (5.0/1.0)
Rule 10	IF micro-area is considered violent= no AND Trash locations collected by city = yes AND Area of house building = not legalized AND Landfill area = no AND Industrial pollutants = absent	Medium risk (11.0/2.0)
Rule 11	IF micro-area is considered violent= no AND Trash locations collected by city = yes AND Area of house building = not legalized AND Landfill area = yes	Low risk (5.0)
Rule 12	IF micro-area is considered violent= no AND Trash locations collected by city = yes AND Area of house building = under legalization process AND Sloped land = no	Low risk (3.0)
Rule 14	IF micro-area is considered violent= no AND Trash locations collected by city = partially AND barrier to access of health unit = no AND Regular distribution of electricity = yes AND Organized spacing of houses = yes AND Asphalt road network = yes	Low risk (8.0)
Rule 15	IF micro-area is considered violent= no AND Trash locations collected by city = partially AND barrier to access of health unit = no AND Regular distribution of electricity = yes AND Organized spacing of houses = yes AND Asphalt road network = partially	Medium risk (3.0/1.0)
Rule 18	IF micro-area is considered violent= no AND Trash locations collected by city = partially AND barrier to access of health unit = no AND Regular distribution of electricity = yes AND Organized spacing of houses = no	Medium risk (4.0)
Rule 23	IF micro-area is considered violent= reasonable AND Rats = yes AND Cava = absent AND Asphalt road network = yes AND Stream = contaminated	Medium risk (44.0/4.0)
Rule 25	IF micro-area is considered violent= reasonable AND Rats = yes AND Ditches = absent AND Asphalt road network = yes AND Stream = absent AND Church (any religion) =present AND Sports field = present	Medium risk (21.0/6.0)
Rule 29	IF micro-area is considered violent= reasonable AND Rats = yes AND Ditches = absent AND Asphalt road network = yes AND Stream = absent AND Church (any religion) =present AND Sports field = absent AND Trash locations collected by city = yes AND Flat land = yes AND Urban open spaces with the presence of trash= yes	Low risk (4.0)
Rule 34	IF micro-area is considered violent= reasonable AND Rats = yes AND Ditches = absent AND Asphalt road network = no	Medium risk (3.0/1.0)
Rule 36	IF micro-area is considered violent= reasonable AND Rats = yes AND Ditches = absent AND Asphalt road network = partially	Medium risk (42.0/6.0)
Rule 39	IF micro-area is considered violent= reasonable AND Rats = yes AND Ditches = absent AND Asphalt road network = partially AND Agriculture = without use of agrotoxins AND Urban open spaces with the presence of trash = yes	Medium risk (14.0/3.0)

To be continued

Table 3 continuation

Identification	Description of the antecedent	Consequence
Rule 40	IF micro-area is considered violent = reasonable AND Rats = yes AND Ditches = absent AND Asphalt road network = partially AND Agriculture = with use of agrotoxins	Medium risk (4.0)
Rule 44	IF micro-area is considered violent = reasonable AND Rats = yes AND Ditches =contaminated AND Pharmacy = absent AND Organized spacing of houses = partially	High risk (4.0)
Rule 45	IF micro-area is considered violent = reasonable AND Rats = yes AND Ditches = contaminated AND Pharmacy = absent, AND Organized spacing of houses = no	High risk (2.0)
Rule 49	IF micro-area is considered violent = yes AND Ditches = absent AND Sewage system = piped AND Landfill = no AND Rio = contaminated, AND barrier to access of health unit = no	Medium risk (21.0/1.0)
Rule 50	IF micro-area is considered violent = yes AND Ditches = absent AND Sewage system = piped AND Landfill = no AND River = contaminated AND barrier to access of health unit = yes AND Market = present	Medium risk (2.0)
Rule 51	IF micro-area is considered violent = yes AND Ditches = absent AND Sewage system = piped AND Landfill = no AND River = contaminated AND barrier to access of health unit = yes AND Market = absent	High risk (2.0)
Rule 61	IF micro-area is considered violent = yes AND Ditches = absent AND Sewage system = mixed AND Landfill = no AND Town square or park = absent AND Area of house building = not legalized AND Trash locations collected by city = yes	High risk (3.0)
Rule 63	IF micro-area is considered violent = yes AND Ditches = absent AND Sewage system = mixed AND Landfill = no AND Town square or park = absent AND Area of house building = under legalization process	High risk (8.0)
Rule 64	IF micro-area is considered violent= yes AND Ditches = absent AND Sewage network = mixed AND Landfill = yes	High risk (10.0)
Rule 66	IF micro-area is considered violent= yes AND Ditches = absent AND Sewage system = open sky	High risk (3.0/1.0)
Rule 67	IF micro-area is considered violent= yes AND Ditches = not contaminated	Medium risk (1.0)
Rule 68	IF micro-area is considered violent = yes AND Ditches = contaminated	High risk (9.0)

value of two (Table 3). Table 4 presents a comparison between Set A (rules considered inconsistent) and Set B (rules that confirmed the knowledge of specialists). Despite 12 being the maximum sample number for the quantity of conditions, Set A contained 66.7% of rules within the average of 5.89 (SD=2.4). On average, the quantity of conditions per rule in Set A is discretely greater than in relation to Set B.

In relation to the total set of rules, the average amount of conditions per rule (5.74; SD=2.11) remained close to the ideal of a practical rule, or in other words, 73.5% of rules were between four and seven associations. The success rate for the set of rules was 91.6% (SD=14.00), which is a satisfactory result for the set obtained.

The rules obtained were also utilized to identify the attributes that best differentiated the micro-areas into low, medium or high risk. In this way, the attributes positioned among the first five associations and with a greater frequency were considered as the most important (Table 5).

Table 4. Comparison between the performance of the sets of inconsistent rules and rules confirmed by specialists. City of Curitiba, Southern Brazil, 2007.

Measure	Amount of associations per rule		Coverage		Success rate	
	A	B	A	B	A	B
Average	5.89	5.55	3.84	12.61	93.7%	88.9%
Standard deviation	2.40	1.71	2.65	21.23	14.4	13.2
Interval	10	8	11	110	66.7%	33.3%
Minimum	2	2	1	1	33.3%	66.7%
Maximum	12	10	12	111	100.0%	100.0%

A: Inconsistent rules
B: Rules confirmed by specialists

Table 5. Relation between the attribute and its position in the rule. City of Curitiba, Southern Brazil, 2007.

Attribute	Position in the condition of the rule
Micro-area is considered violent	1
Ditch	2
Trash locations collected by city	2
Rats	2
Construction area of the houses	3
Barrier to access of health unit	3
Sewage system	3
Regular distribution of electricity	4
Pharmacy	4
Road network	4
Landfill area	4
Low land	4
Constantly moist land	4
Industrial pollutants	4
Pigs	4
Sloped land	4
River	5
Provisioning of water by public system	5
Sports field	5
Horses	5
Stream	5
Organized spacing of houses	5
Church (any religion)	5
Town square or park	5
Agriculture	5

Of the attributes considered essential by specialists during the identification stage, six did not appear as associations in the rules, including: policing; cat; dog; pigeon; sufficient space in childcare; and public lighting. Therefore, these can be given less weight in the classification of micro-areas.

DISCUSSION

The identification of homogenous areas of risk helps in the prioritization of collective actions focused on disease prevention, directed to territorial spaces where inequities are greater, which results in a greater impact on the risk associations.[1]

Thus, some of the attributes identified as essential, including social resources and recreation areas, can be altered by public policies. Other attributes, such as the existence of vectors, are modified through intersectoral actions and with community participation. Therefore,

an information system that monitors the association of these attributes can assist in the planning of actions at the local, regional and central levels. It even allows for the identification of some conditions to be improved by incentivizing the community.

The fact that the amount of conditions per rule in Set A is discretely larger in relation to Set B can indicate that the complexity of the rules did not interfere when the specialists evaluated them. This discounts the hypothesis that the specialists experienced difficulty in interpreting the rules and in judging them as inconsistent.

Nonetheless, the average of coverage for Set B indicates that there is a greater probability of having rules considered as commonsensical. Despite being a set of rules that confirms the knowledge of specialists, the success rate did not surpass Set A.

The average of coverage for Set B was greater in relation to Set A. This relationship suggests that the rules contained in Set B tend to represent common sense, which was confirmed by the opinions of specialists when they described the rules as confirming their knowledge.

Thus, the rules of Set B (Table 3), despite having a lower computational performance according to evaluation by specialists, are the ones that better classify a micro-area in relation to the risk contained in the physical environment.

This unexpected divergence between specialist opinion and the statistical measures indicates that this set may contain some interesting rules. Nonetheless, in evaluating the rules, the specialists may have been resistant to accepting new patterns or to understanding new models that opposed to previous knowledge.

Detailing and collectively discussing the diversity, that originated from the different perceptions of the territory, help to close the gap between the problems identified and the possible solutions, which should be collectively prioritized.[5]

The data mining provided a combination of useful and understandable rules able to characterize micro-areas, classifying them in regards to the degree of risk, when considering the characteristics of the physical environment. Nonetheless, the physical environment does not constitute the only factor for classifying a micro-area, since an effective classification should also include information about the epidemiology of the region, the organization of the community and administrative facts.

The utilization of the proposed rules allows for the classification of a micro-area to be done in a faster, less subjective way that maintains a standard between the health teams, overcoming the influence of each individual perception.

The influence of subjectivity can be understood by the fact that different participants in the evaluation process have their own set of personal values, constructed based on their experience and interaction with different cultural, economic and social contexts. This greatly influences the importance given to certain attributes in detriment to other attributes. [11]

The classification of risk micro-areas is an important management and service tool because it involves the distribution of resources and services for the population of a given territory. Performing the classification in a way that converges the inherent subjectivity of the process with more objective analytical methods allows for the optimization of actions and resources.

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