

Models of decision making in clinical bioethics: notes for a computational approach

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Abstract

Bioethics has become over the recent decades a central question to clinical practice, due to the fact that it provides theoretical tools for decision making in health care. The issue that arises concerns how to know whether the decision made is the most appropriate, considering that a clinic decision – whether working in primary, secondary, or tertiary care – must be accurate from both the technical and the ethical point of views. As a result, different models for decision making in clinical bioethics have been presented in the literature. Based on these considerations, the objective of this article is to point important issues about (i) decision making in the field of clinical bioethics and (ii) the possibilities of computational approaches to assist such decisions.

Keywords: Bioethics. Computation. Medical informatics computing. Decision making. Decision support techniques. Management decision making.

Resumo

Modelos de tomada de decisão em bioética clínica: apontamentos para a abordagem computacional

A bioética tem se tornado, nas últimas décadas, um tema de importância central para a prática clínica, por fornecer ferramentas teóricas para a tomada de decisão do profissional de saúde. A questão que se propõe diz respeito a como saber se a decisão é a mais apropriada, já que uma decisão na esfera clínica – quer se esteja atuando na atenção primária, secundária ou terciária – deve, necessariamente, ser acertada tanto do ponto de vista técnico, quanto do ponto de vista ético. A literatura tem apresentado diferentes modelos para a tomada de decisão no campo de análise da bioética clínica. Com base nessas ponderações, objetiva-se, no presente ensaio, apresentar apontamentos sobre (i) a tomada de decisão na área de bioética clínica e (ii) as possibilidades de abordagem computacional das decisões bioéticas.

Palavras-chave: Bioética. Computação. Informática médica. Tomada de decisões. Técnicas de apoio para a decisão. Tomada de decisões gerenciais.

Resumen

Los modelos de toma de decisiones en bioética clínica: apuntes para un enfoque computacional

La bioética se ha convertido, en las últimas décadas, en un tema de gran importancia en la práctica clínica, proporcionando herramientas teóricas para la toma de decisiones de los profesionales de la salud. La pregunta que se plantea es cómo saber si la decisión es la más apropiada, puesto que una decisión en el ámbito clínico – si se está trabajando en la atención primaria, secundaria o terciaria – debe necesariamente ser correcta desde el punto de vista técnico, como el punto de vista ético. La literatura ha presentado diferentes modelos para la toma de decisiones en el ámbito del análisis de la bioética clínica. Sobre la base de estas consideraciones, el objetivo en el siguiente texto es presentar puntos sobre (i) la toma de decisiones en el ámbito de la bioética clínica y (ii) las posibilidades de un enfoque computacional de las decisiones bioéticas.

Palabras-clave: Bioética. Computación. Informática médica. Toma de decisiones. Técnicas de apoyo a la decisión. Toma de decisiones gerenciais.

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Declararam não haver conflitos de interesse.

The current experienced changes in the Brazilian society have made bioethics a central theme, providing theoretical basis for decision making in health care practices¹, among the different spheres that compound the clinical practice - diagnosis, treatment, prevention, rehabilitation, promotion and education. There are different concepts to *decision-making*, but the main settings come from the administration area, as the characterization of Chiavenato: *decision-making is the process of analysis and choice between several alternatives available in the course of action that the person must follow.*²

The question that arises - in the midst of this debate - is about how to know if the decision is the most adequate - the most correct for the patient -, considering that this adjustment is not just about a technical relevance, scientific, but also the promotion of the *best* benefit to the patient, whenever possible on the patient's own perspective. It is not proposed the simple transfer, for the patient, of responsibility for the decisions made, in a perceived attitude of respect for autonomy. It is, instead, about restructuring the professional-user relationship in the Unified Health System (SUS), rejecting the assumption that it is a moral obligation of the professional to act on behalf of their patients, rather than making the decision a shared process¹.

To that purpose, it have been presented in the literature different models for decision making in the field of analysis of clinical bioethics, which refers to the delimitation, appreciation and proposition of solving ethical problems emerged in the individual patient care. In addition, computer support methods have been proposed to improve this process. Based on these considerations, the scope of this article is to present a literature review, focusing on aspects relating to (i) decision-making in bioethics and (ii) the computational approach possibilities of the ethical decision making, with special focus on learning methods of machine supervised, that is, that depend on training data (containing examples for which we already know the answer) to build a learning model.

Methods

The article was written from a literature review, with defined search strategy. The first step included the selection of key words found in DeCS - Health Sciences Descriptors. The descriptors identified were: 1) "*Bioethics*"; 2) "*Ethics*"; 3) "*Medical Informatics*"; 4) "*Decision Support Techniques*

and; 5) "*Decision Trees*". The second step included the completion of the research, undertaken in the US National Library of Medicine National Institutes of Health (Pubmed) until the deadline of July 31st, 2014, using the descriptors combined, as shown in Table 1.

Table 1. Descriptors used, research strategies and number of citations obtained

Research strategy	Number of citations from PubMed [*]
<i>Bioethics + Decision Support Techniques</i>	114
<i>Ethics + Medical Informatics + Decision Trees</i>	15
TOTAL	169

* Query Date: to 07/31/2014.

The third - and final - step involved the selection of articles, chosen by systematic reading of the titles and abstracts, and as criteria the presence in the text of the driven approach to decision making in clinical bioethics, with emphasis on computational support. The texts chosen - a total of twelve articles, complemented by prior references of authors - were read and its discussions summarized in the following sections: (1) Decision making in clinical bioethics and (2) computational approach to decision making in clinic bioethics: machine learning algorithms.

Decision making in clinical bioethics: briefs

The clinical bioethics covers disparate orders of problems relevant to decision making, especially highlighting³⁻¹⁰: (1) *early life* - abortion, assisted reproductive technologies; (2) *end of life* - euthanasia, assisted suicide, order of no resuscitation, advance directives, palliative care, dysthanasia, therapeutic obstinacy, organ transplants (criterion of death, priority to access for the procedure); (3) diagnostic, therapeutic and prophylactic decisions in the event of patient or his legal guardian refusal; (4) confidentiality, privacy and confidentiality of information and; (5) allocation and management of scarce resources (or "*who goes to the respirator?*").

These are some of the situations - conflicting and, sometimes, "dilemmatic" - in which the conduct taken will depend on a detailed analysis and employment of the theoretical principles of bioethics to support the choice, in a *decision making process* that should be as clear as possible. The decision-making procedure - central problem of this text

– is understood by its extremely intricate areas, able to be investigated at different levels of complexity, from neurobiology to applied social sciences^{2,11}.

In terms of clinical bioethics, much has been discussed about the decision-making methods. Special emphasis has been given to *principialist* and *casuistic* models, often employed in ethics consultation committees¹². One approach to decision-making processes in bioethics was proposed by Schramm, in which is considered the initial need of clarification of rationality of argumentation, in the following terms: *a) to be clear about the descriptive approaches and understanding of conflicts; b) to make a deductive and inductive reasoning approach of seeking to legitimize a decision and; c) to make a pragmatic approach about the relationship between resources, purposes and the involved*¹³. Such procedures outlined by the author may be very useful to support decision making in clinical bioethics, which can benefit from the use of computational approach to support the decision-making process, as described below.

Computational approach to decision making in clinical bioethics: machine learning algorithms

The computational support for decision-making has diverse applications in the contemporary world, mentioning the areas of finance, agriculture, industry, trade and health, among others. Different methods can be used for this purpose, especially the use of artificial neural networks (ANN).

The ANN are computer systems - inspired by the functioning of human brain - which processing begins with a learning phase in which a data set (for which the answer is already known) is displayed, making that the strength of connections network are changed so as to generate a result that is as close as possible to that observed in the training data¹⁴. It is ulteriorly expected that the ANN acquires ability to generalize, that is, the ability to provide responses to future examples, for which information of interest is not known^{14,15}.

The application of ANN - or even other supervised machine learning methods (MLM) - in the medical practice represents a developing area, demonstrating vast potential of such approaches in solving problems in various biomedical systems^{15,16}. MLMx can be used in numerous situations where there is a relationship between variables - *inputs* - and predictive results - *outputs*¹⁴. Among the various applications, four areas are highlighted: modulation

(simulation of brain functions and neurosensory organs); processing bioelectric signals (filtration and evaluation); diagnosis (control and responses and interpretation of results) and; prognosis (retrospective analysis of stored information)¹⁷.

In the context of bioethics, however, the use of MLMx - and other computer support tools - is still limited, with few examples in literature. It is emphasized in this context the use of simulated clinical cases to train ethical decision making of nursing professionals - according to a research conducted in South Korea¹⁸ - and the development of computer simulation to support decision-making addressed to planning care actions to the diseased in the process of end of life¹⁹. In the latter case, through an interactive program using hypothetical clinical cases - (i) patient with hemorrhagic stroke intraoperative; (ii) patient with cerebral hemorrhage induced by trauma; (iii) patients with spinal cord trauma with subsequent paraplegia; (iv) patient with closed head injury with significant mental deficits; (v) patient with metastatic colon cancer, kidney failure and sepsis; and (vi) patients with Alzheimer's dementia, pneumonia and anorexia - a more effective computer support was possible for medical decision making in end-of-life situations¹⁹. The implied ethical aspects in studies involving virtual reality environments have also been described^{20,21}.

With regard to bioethical issues in the field of public health, it may be mentioned the research aiming at assessing the performance and applicability of the computer simulation model to examine the impact of two policies of resource allocation in organ transplantation programs²². The computer simulation tool used was useful to help the bioethics decision making in terms of allocation policies in transplants²².

Yet in a recent paper (published in the Journal of Intelligence in Medicine) of four authors of this text - in partnership with other colleagues - a set of MLM techniques is presented as a general procedure for construction of computational simulation systems applicable to any domain of interest, provided the appropriate data for training. These data should contain examples - or instances - of the past with their attributes that make sense in the context of interest and an attribute of conclusion - or class - for which one knows the correct answer of the past. Therefore, the idea - with applicability in the decision-making process in clinical bioethics - is that a supervised MLM relates the attributes with the class values, building a learning model in order to get a general concept that enables to correctly predict

class of future instances, for which the answer is not known yet. The authors present a procedure composed of the following steps:

- 1) Conversion of available data to an appropriate format: a necessary step for the data to be easily processed by computer tools, in particular, programs that implement algorithms of ML ²³.
- 2) Pre-processing of data: comprehends any manipulations necessary to perform ML algorithms. It should be mentioned in particular the reduction of dimensionality through the named attributes selection ²⁴, which is the process of selecting a subset of attributes of the instances in the set of data, in order to eliminate irrelevant and/or redundant attributes, leaving those who have strong relationship with the class. It is important the participation of experts so that we can unite knowledge and mathematical methods in order to extract the best attributes. Other changes such as sampling, discretization and binarization of data ^{23,24}, may also be useful at this stage.
- 3) Conducting experiments with various ML algorithms supervised: after the previous stages, the training set is ready, allowing these experiments to begin. Each execution creates a learning model ^{23,24}. With some statistical methods, one can measure the *performance* of the obtained models, based on, for example, the higher total success rate and in the accuracy rates of the true positives and true negatives (sensitivity and specificity, respectively) ^{23,24}. Thus, one or more algorithms can be selected for the creation of the final learning model.
- 4) Coding a program with graphical interface: the program should enable the creation of models with the ML algorithm(s) that was(were) selected in the previous phase and especially allow the easy change of attribute of simulated instances, so that for each change in value, the prediction of the class is provided in real time by the system, facilitating the hypothesis test and consequently the decision making. It is also important that the system includes mathematical methods of attribute ranking ^{23,24} in order to explain to the user the attributes that would cause greater impact in the class.

To validate the MLM procedure proposed, the authors used them in the preterm data from the in-

tensive care unit for newborns ²⁵. Using ANN to assemble the learning model, the authors made the simulation of many variables, observing the class value (probability of death) resulted for each combination. It was found that the obtained model had a high predictive power, as it provided fully compatible results with clinical information of the current literature that relates causes of preterm deaths with the key attributes mentioned above. This work with preterm shows that, provided there is adequate data for training, MLM methods can be extremely helpful in the decision making process as it enables the creation of highly efficient computer simulators.

Tools to support decision-making of physicians and parents of children admitted in the intensive care unit are also being developed, involving (i) assessment of the clinical environment, (ii) establishment of the project's criteria, (iii) development of the system's project, (iv) implementation of the system and (v) realization of usability testings. Usability results indicated the usefulness, effectiveness, acceptance and satisfaction tool ²⁶. Similarly, studies have been conducted in order to support decisions relating to nursing care for mothers and newborns ²⁷.

Such procedures are in consonance with the approach proposed by Schramm ¹³ - which assumes that the decision-making process in bioethics is deductive, inductive and pragmatic - defining a context in which the MLM methods are effectively applicable. Additionally, it should be noted that, for each scenario, you must have appropriate training sets, so that the resulting model is the most appropriate. Thus, in many situations, such as in different cultures of disparate values, an appropriate model should be built, in order to reflect the specific characteristics of that context. That is, there is no claim here to create a single model that can be used in any situation, but to only support human decision.

From this perspective, it is proposed the use of MLM algorithms for the development of computational support system in clinical bioethics decision making - involving aspects relating to the decision-making process (*Bio-Oracle = Organizer of the Rational Approach in Computational Learning Bioethics*) ²⁸ - which is aimed, in the first instance, the assessment of problems concerning primary health care ²⁹.

It should be emphasized the *support* to the decision, and not the transfer of decision-making to a computer system. It is important to realize, how-

ever, that these techniques are systems for decision support³⁰. The final word, obviously, will always be from the skilled professional, who will not have to give up from his exercise of ethical awareness. The investigation is ongoing, highlighting, at this time, the definition of the requirements for the development of the system. Later - after the development of *Bio-Oracle* - studies should be designed to evaluate the cross-cultural characteristic of the system, that is, its ability to support the decision, regardless of the culture in which it is inserted.

Final considerations

The decision making in bioethics can be an extremely difficult process for the healthcare professional. In this sense, the development of computer systems to support decision making in clinical bioethics - based MLM methods - may assist the moral choices of those involved, contributing to the improvement of educational processes and care practices in health.

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Participação dos autores

R. Siqueira-Batista e A. P. Gomes desenharam o presente artigo, tendo supervisionado P. Mendes Maia na redação da primeira versão. I. T. Costa, A. O. de Paiva e F. R. Cerqueira revisaram a versão final do artigo, trazendo contribuições decisivas para o âmbito (1) da tomada de decisão e (2) da aprendizagem de máquina.

