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Design of a Fuzzy Logic Classification System for an Ocular Sun Protection Factor

Projeto de um sistema de classificação de lógica difusa para um fator de proteção solar ocular

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Abstract

There is no reliable and universal method to assess and compare protective properties of lenses, which is generally communicated to the purchasers by sunglasses categories based on lenses only, classifying the entire sun transmission spectrum (ultraviolet, infrared and visible), without accounting the geometry of the frame, nor the back reflection of the lenses, which is a serious problem. The present work develops a fuzzy classification system whose purpose is to create a reliable method to rate and compare sunglasses through their sun protective properties. This system treats the pre-acquired data relative to the lenses, i.e. ultraviolet transmittance and back reflection, in addition to the frame coverage data through the fuzzification interface, followed by the fuzzy inference process and later by the defuzzification interface. The output is an alphabetic rate of the protective eyewear to inform consumers, in a simple way to understand, regarding the sun protective properties of the sunglasses they purchase. Through the results it was possible to prove the effectiveness of choosing a fuzzy system for this classification system, as it was able to translate, in mathematical terms, the linguistic rules, classifying each of the various possible combinations of the inputs to one of the six factors stipulated for the ocular sun protection factor (OSPF) proposed in this work.

Keywords: Fuzzy Logic, Classification System, Ocular Sun Protection Factor, Sunglasses, Ultraviolet Radiation.

Resumo

Não existe um método confiável e universal para medir e comparar as propriedades protetivas dos óculos de sol, as quais são geralmente comunicadas aos consumidores por meio das categorias dos óculos de sol que são baseadas apenas nas características das lentes dos mesmos, classificando todo o espectro de transmissão do sol (ultravioleta, infravermelho e visível), sem levar em consideração a geometria da armação, nem a reflectância traseira das lentes dos óculos de sol, o que é um problema sério. Tendo como propósito criar um método confiável de se medir e comparar os óculos de sol através de suas capacidades protetivas frente à radiação solar, foi elaborado neste trabalho um fator de proteção ocular solar (FPOS) utilizando um sistema de classificação por lógica fuzzy. Este sistema utiliza dados pré-aquisicionados relativos às lentes, i.e. transmitância ultravioleta e reflectância traseira das lentes, e dados da capacidade de proteção da armação por meio da interface de fuzzificação, seguida do processo de inferência fuzzy e depois pela interface de defuzzificação. A saída do sistema é uma nota alfabética, voltada para informar os consumidores, de uma maneira simples de entender, com relação às capacidades protetivas solares dos óculos de sol que estes possuam ou venham a adquirir. Através dos resultados parciais foi possível comprovar a eficácia da escolha de um sistema fuzzy para este sistema de classificação, pois o mesmo foi capaz de traduzir, em termos matemáticos, as regras linguísticas propostas inicialmente, classificando cada uma das diversas combinações possíveis das entradas em um dos seis fatores estipulados inicialmente para o FPOS proposto neste trabalho.

***Palavras-chave**: Lógica Fuzzy, Sistema de Classificação, Fator de Proteção Ocular Solar, Óculos de sol, Radiação Ultravioleta.*

1. Introduction

Ultraviolet radiation (UVR) is commonly divided into three components: UVA (315 to 400 nm) radiation that causes tanning but is also thought to contribute to aging of the skin and skin cancer; UVB (280 to 315 nm) radiation that can cause sunburn and predispose to skin cancer; and, UVC (110 to 280 nm) radiation that is nearly completely absorbed by the ozone layer before reaching the Earth' s surface. UV radiation plays a role in the development of various ocular disorders including cataract, pterygium, cancer of the skin around the eye, photokeratitis and corneal degenerative changes, and may contribute to age-related macular degeneration (1).

Other than the skin, the only other human organ directly exposed to sunlight is the eye, and sunglasses are typically the most practical method of protecting it from solar radiation. Sunglasses provide a vertical protection barrier to the eyes through the lenses and frame, primarily absorbing and preventing the ultraviolet radiation from reaching them. However, consumers typically purchase sunglasses for fashion or comfort reasons rather than protective ones, and while there is rising public awareness of the benefits of sunscreen and the meaning of sunscreen SPF factors, there is not a similarly standardized and accepted rating system for sunglasses.

There is no reliable and universal method to assess and compare protective properties of lenses. Manufacturers can voluntarily indicate whether the sunglasses are intended for normal use or prolonged sun exposure and whether the sunglass lenses are designed for special purpose, dark, general purpose, or cosmetic tint. However, there are no metric-based requirements for indicating the percentage of radiation the lens absorbs or what wavelengths of radiation are absorbed. There are also no requirements for indicating the amount or spectral location of wavelengths absorbed by the sunglass frame or about how much coverage the frame provide.

The protection effectiveness is generally communicated to the purchasers by sunglasses categories based on lenses only, classifying the entire sun transmission spectrum (ultraviolet, infrared and visible), without accounting the geometry of the frame, nor the back reflection of the lenses, which is a serious problem. Relating to the frame coverage, outdoor studies using mannequins generally show that at least 20 percent of ultraviolet arriving at the cornea comes from around the lenses of conventional sunglass lenses mounted in non-wraparound frames (2). In addition, when displaced only 6mm from the forehead, the ultraviolet radiation reaching the eyes can range up to 44.8 percent (3). Another problem involves the back reflection of the lenses. Citek (4) demonstrated that anti-reflective coatings reflect UVR at high levels, showing that some lenses can reflect up to 40 percent of UVA and UVB. In summary, the effectiveness of protection is highly variable and depends not only of the transmittance spectrum of the lenses, but also of the back reflection and frame coverage of the sunglasses.

The present work develops a fuzzy classification system whose purpose is to create a reliable method to rate and compare sunglasses through their sun protective properties to inform consumers, in a simple way to understand, regarding the sun protective properties of the sunglasses. A fuzzy logic classification system can be used to translate, in mathematical terms, the linguistic rules proposed to associate all the possible combinations of inputs, since fuzzy logic controllers (FLC's) have the following advantages over the conventional controllers: simplicity and flexibility. They can handle problems with imprecise and incomplete data and can model nonlinear functions of arbitrary complexity (5).

2. Methods

Three factors were taken into account to design this fuzzy logic classification system. The first factor is the data regarding the ultraviolet transmittance of the lenses from 280 nm to 400 nm, as this wavelength interval covers the UVB and UVA spectrum. The second factor relates to the back reflection of the lenses, since sun radiation can reach the eye by being reflected from the back of the sunglass lenses. The third factor represents the frame coverage, as sun radiation can also come direct to the eyes from around the sunglass lenses from all directions due to reflected radiation from ground surfaces and diffuse radiation from scattering by clouds and particles (6).

These three factors are in the range from 0 to 100, corresponding to the respective percentage of each factor. The challenge was to associate all the possible combinations of those values to create an ocular sun protection factor (OSPF) classification system to be used to inform consumers, in a simple way to understand, regarding the sun protective properties of the sunglasses they purchase. To accomplish this task, a fuzzy logic classification system was developed.

The fuzzy system elaborated in this work has the following characteristics:

- Connective "and" for the "minimum" intersection operator (T-Standard).
- Mamdani-type implication operator.
- Linguistic connective "then" for the "maximum" aggregation operator.
- Center of Area (CoA) method as defuzzification method.
- Two hundred discretization points for all speech universes.

Regarding the input sets (Figure 1, Table 1 and Table 2), for each input factor, ultraviolet transmittance (Tuv), back reflection of the lenses (BR) and the frame coverage (FC), three sets were defined to classify them by the linguistic terms "Weak", "Medium" and "Strong" according to the respective percentage value. The trapezoidal format was used to represent the "Weak" and "Strong" sets, and the triangular shape for the "Medium" set, according these parameters:

- Linguistic variables: Tuv, BR and FC.
- Language terms: "Weak", "Medium" and "Strong"
- Relevance functions: Trapezoidal ("Weak" and "Strong") and triangular ("Medium").
- Universe of discourse: [0, 100] (%).

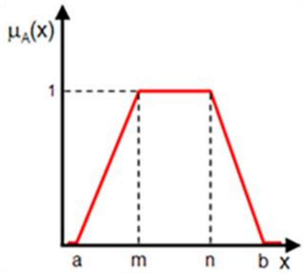

Figure 1. Fuzzy membership graph.

Table 1. Inputs: Tuv and BR.

Linguistic Term	a	m	n	b
Weak	50	75	100	100
Medium	25	50	50	75
Strong	0	0	25	50

Source: The author (2021).

Table 2. Input: FC.

Linguistic Term	a	m	n	b
Weak	0	0	25	50
Medium	25	50	50	75
Strong	50	75	100	100

Source: The author (2021).

For the output sets (Figure 1 and Table 3), six alphabetic rates were chosen to represent the universe of the OSPF, from A to F, which are easy to understand and are ideal for this factor that aims the general public. The trapezoidal format was used to represent the "A" and "F" sets and the triangular shape for the others, according these parameters:

- Linguistic variable: Ocular Sun Protection Factor.
- Language terms: “F”, “E”, “D”, “C”, “B” and “A”.
- Relevance functions: Trapezoidal (“F” and “A”) and triangular (“E”, “D”, “C” and “B”).
- Universe of discourse: [0, 100] (arbitrary unit).

Table 3. Outputs (OSPF).

Linguistic Term	a	m	n	b
F	0	0	10	20
E	10	26	26	42
D	32	50	50	68
C	58	74	74	90
B	80	88	88	96
A	90	96	100	100

Source: The author (2021).

The set of rules elaborated from the input and output sets (Table 4) consists of twenty-seven rules originated from the possible combinations between the input sets, having as output of each rule, one of the six alphabetic rates proposed by this work to represent the OSPF, having the general model as:

- Rule (_) → If Tuv is (_) and BR is (_) and FC is (_), then Output is (_).

Table 4. Format of the linguistic rules.

Rule	Tuv	BR	FC	Output
1	Weak	Weak	Weak	F
2	Weak	Weak	Medium	F
3	Weak	Weak	Strong	E
4	Weak	Medium	Weak	F
5	Weak	Medium	Medium	E
6	Weak	Medium	Strong	D
7	Weak	Strong	Weak	E
8	Weak	Strong	Medium	D
9	Weak	Strong	Strong	C
10	Medium	Weak	Weak	F
11	Medium	Weak	Medium	E
12	Medium	Weak	Strong	D
13	Medium	Medium	Weak	E
14	Medium	Medium	Medium	D
15	Medium	Medium	Strong	C
16	Medium	Strong	Weak	D
17	Medium	Strong	Medium	C
18	Medium	Strong	Strong	B
19	Strong	Weak	Weak	E
20	Strong	Weak	Medium	D
21	Strong	Weak	Strong	C
22	Strong	Medium	Weak	D
23	Strong	Medium	Medium	C
24	Strong	Medium	Strong	B
25	Strong	Strong	Weak	C
26	Strong	Strong	Medium	B
27	Strong	Strong	Strong	A

Source: The author (2021).

As a strategy for defining classes, the intervals shown in Table 5 were used, in which the variable “y” corresponds to the value obtained after the defuzzification stage.

Table 5. Intervals of the output classes. (a < y <= b).

Class	a	b
F	0	16.15
E	16.15	37.29
D	37.29	62.71
C	62.71	83.33
B	83.33	94.40
A	94.40	100

Source: The author (2021).

3. Results

The fuzzy logic classification system was implemented and receives the input values Tuv, FC and BR, from which it classifies the corresponding ocular sun protection factor, as proposed in this work.

From the tests performed with the program throughout and after its implementation (e.g. Table 6), it was possible to perform relevant analyses and optimizations in the system, improving the coefficients of the input and output sets (Table 1, Table 2 and Table 3), as well as their relevance functions, in order to better implement the linguistic rules from Table 4.

Table 6. Examples of inputs and output classes (OSPF).

Tuv	BR	FC	Activated rules	y	OSPF
45	25	88	10, 19	13.19	F
57	49	81	1, 4, 10, 13	22.30	E
7	23	7	21	74.00	C
98	84	60	7, 8	40.65	D
45	39	96	10, 13, 19, 22	26.89	E
37	67	51	13, 14, 16, 17, 22, 23, 25, 26	66.30	C
4	16	91	19	26.00	E
24	99	18	27	97.59	A
0	70	31	23, 24, 26, 27	84.63	B
74	74	41	5, 6, 8, 9, 14, 15, 17, 18	57.52	D
28	24	9	12, 21	69.22	C
68	13	25	3, 12	34.88	E
1	47	24	21, 24	83.74	B
95	38	89	1, 4	8.62	F
5	28	64	19, 20, 22, 23	42.09	D

Source: The author (2021).

Through the results it was possible to prove the effectiveness of choosing a fuzzy system for this classification system, as it was able to translate in mathematical terms the linguistic rules, classifying each of the various possible combinations of the inputs to one of the six factors stipulated for the OSPF.

4. Discussion

The fuzzy system approach is innovative for this type of classifier and is positively distinguished due to the ability to deal with linguistic and imprecise information related to the classification limits of each factor without the use of rigid limits, allowing the creation of an ocular sun protection factor that fits the objective of this work. The system proved its viability through the results shown in Table 6, where for each combination of simulated values of possible entries for Tuv, BR and FC, occurred the activation of sets of rules, leading to a respective y value through the defuzzification stage, then resulting in one of the six possible output classes for the OSPF for each case.

5. Conclusions

The fuzzy system presented results that perfectly met the initial proposal, being able to select, according to the linguistic rules, an output class among the six factors proposed for the ocular sun protection factor. It now remains possible adjustments to the functions of pertinence to better represent the actual conditions of the sunglasses, which can be easily performed. With the further development of this project, it will be possible to improve this system with a more realistic data beyond the simulated ones, improving the functions of pertinence to achieve a better ocular sun protection factor to be used to inform consumers, in a simple way to understand, regarding the sun protective properties of the sunglasses they purchase.

References

1. Lucas R. M, Yazar S, Young A. R, et al. (2019) Human health in relation to exposure to solar ultraviolet radiation under changing stratospheric ozone and climate. The Royal Society of Chemistry and Owner Societies 2019. DOI: 10.1039/c8pp90060d
2. Rabbetts R. B, Sliney D. (2019) Technical Report: Solar Ultraviolet Protection from Sunglasses. Optom Vis Sci, 2019, Vol 96(7)
3. Rosenthal F. S, Bakalian A. E, Lou, C et al. (1988) The Effect of Sunglasses on Ocular Exposure to Ultraviolet Radiation. AJPH January 1988, Vol. 78, No. 1
4. Citek K. (2008) Anti-reflective coatings reflect ultraviolet radiation. Optometry, 2008, 79(3):143-8
5. Ibarra L, Webb C. (2016) Advantages of Fuzzy Control While Dealing with Complex/ Unknown Model Dynamics: A Quadcopter Example. New Applications of Artificial Intelligence, IntechOpen. DOI: 10.5772/62530
6. Backes C, Religi A, Moccozet L, et al. (2018) Sun exposure to the eyes: predicted UV protection effectiveness of various sunglasses. Journal of Exposure Science & Environmental Epidemiology, 2018. DOI: https://doi.org/10.1038/s41370-018-0087-0

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