The application of fuzzy multifactorial evaluation to estimation of the physiological age

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Abstract: We shoose a sample of 150 healthful people, a formula to estimate the physiological age is made by means of the sample, and the formula is used for estimating the physiolosical age of 64 people, the result is reasonable.
Keywords: physiological age; calendar age; membership function; decrepit degree; early aging .

1. Introduction

The calendar age is time of life from date of birth on. It is a mark of the record time of the decrepitude and represents incompletely the decrepit degree. Such as the calendar age of a person is 60, but he looks like about 50 from energies and looks , and a person whose calendar age is 50 looks like 60. This shows that the calenadar age sometimes does not can reflect decrepit degree of a person. physiological age is the total change of the physiological development level to reach definite calendar age in the function and the structure. In the general, the physiological age is in accord with calendar age for the healthful people . owing to the individual difference of the genetic properties and the action of the environmental factor, so that the total change of the physiological development level in the function and the structure give expresion to the large difference in time order, that is the physiological age is out of accord with the calendar age. As above, a person's calendar age is 60, but looks about 50, this person's calendar age is 60, his physiological age can be 50. Physiological age can reflect a person's decrepit degree. In this pager , we apply fuzzy mathematical theory to estimation of the physiological age, and give a estimation formula.

2. Estimation formula of the physiological age

The physiological age is the function of human body function. Given N normal people, let $x_1, x_2, \ldots\ldots, x_m$ be m function states of human body, y_i be the calendar age of person number i and $x_i = (x_{i1}, x_{i2}, \ldots\ldots x_{im})$ be the function state vector of person number i, where x_{ik} is the observation value of function state number k of person number i.

Let $a = \min\{y_1, y_2, \ldots\ldots, y_N\}$, $b = \max\{y_1, y_2, \ldots y_N\}$, then $U = [a, b]$ is divided into r intervals $I_1, I_2, \ldots, I_r$.

(1). Define membership function $\mu_i(x_i)$, $i = 1, 2, \ldots, m$ of single factor of decrepitude.

(2) If any individual function state vector is

$$x = (x_1, x_2, \ldots, x_m)$$

then multifactorial membership function of decrepitude is defined as

$$\mu(x) = \sum_{i=1}^{m} \alpha_i \mu_i(x_i)$$

where α_i is weight number, $\alpha_i > 0$, $i = 1, 2, \ldots, m$, $\sum_{i=1}^{m} \alpha_i = 1$.

(3) Define standard value R_i of the factor X_i in I_i, $i = 1, 2, \ldots, m$, then let

$$A_i(x) = 1 - |\mu(x) - R_i| \qquad i = 1, 2, \ldots, r$$

$$A_0(x) = \min_{1 \le i \le r} \{1 - A_i(x)\} = 1 - \bigvee_{1 \le i \le r} A_i(x)$$

where $x=(x_1, x_2, \ldots, x_m)$.

(4) Estimation formula of the physiological age is defined as

$$y^*(x)=\begin{cases}\dfrac{(a_1-b_1)A_0(x)+a_1A_1(x)}{A_0(x)+A_1(x)} & ,if\ A_0(x)=\bigvee\limits_{1\le j\le r}A_j(x)\ \text{and}\ A_1(x)=A_1(x)\vee A_r(x)\\ \dfrac{a_{i-1}A_{i-1}(x)+a_iA_i(x)+a_{i+1}A_{i+1}(x)}{A_{i-1}(x)+A_i(x)+A_{i+1}(x)} & ,if\ A_i(x)=\bigvee\limits_{1\le j\le r}A_j(x)\ ,i=1,2,\ldots,r\\ \dfrac{a_rA_r(x)+(a_r+b_r)A_0(x)}{A_r(x)+A_0(x)} & ,if\ A_0(x)=\bigvee\limits_{1\le j\le r}A_j(x)\ \text{and}\ A_r(x)=A_1(x)\vee A_r(x)\end{cases}$$

here a_i is mid−point value of interval I_i and b_i is length of interval I_i.

3. Example and analysis

We choose 150 the healthful people of the 41 to 78 age bracket, and determine their 4 physiological indexes respectively: sex function X_1, hair X_2, systolic pressure X_3, systolic pressure minus diastolic pressure X_4. Age set is $U=[41,78]$. The state set of X_1 is {normalcy, abatement, disappearance}, X_2 {thick and black, thick and black and white, sparse and black, sparse and black and white, sparse and white, bald and black and white, bald and white}, $X_3\{x_3 \mid x_3 \geqslant 80\}$, X_4 $\{x_4 \mid x_4 \geqslant 20\}$. Thus any person's the function state is expressed as

$$x=(x_1, x_2, x_3, x_4)$$

Age set $U=[41,78]$ is divided into four subsets:
$I_1=[41,50), I_2=[50,60), I_3=[60,70), I_4=[70,80]$.

(1) The membership function of the single factor of the decrepitude is defined as

$$\mu_1(x_1)=\begin{cases}0 & x_1=normalcy\\ 0.5 & x_2=abatement\\ 1 & x_3=disappearance\end{cases}$$

$$\mu_2(x_2)=\begin{cases}0.185 & x_2=\text{thick and black}\\ 0.379 & x_2=\text{thick and black and white}\\ 0.521 & x_2=\text{sparse and black}\\ 0.635 & x_2=\text{sparse and black and white}\\ 0.825 & x_2=\text{sparse and white}\\ 0.806 & x_2=\text{bald and black and white}\\ 0.898 & x_2=\text{bald and white}\end{cases}$$

$$\mu_3(x_3) = \begin{cases} 0 & x_3 \leqslant 110 \\ \dfrac{x_3 - 110}{50} & 110 < x_3 < 160 \\ 1 & x_3 \geqslant 160 \end{cases}$$

$$\mu_4(x_4) = \begin{cases} 0 & x_4 \leqslant 40 \\ \dfrac{x_4 - 40}{50} & 40 < x_4 < 90 \\ 1 & x_4 \geqslant 90 \end{cases}$$

(2) The multifactorial membership function of the decrepitude is defined as

$$\mu(x) = 0.2\mu_1(x_1) + 0.6\mu_2(x_2) + 0.1\mu_3(x_3) + 0.1\mu_4(x_4)$$

where weight number is defined according to fitting coefficient

$$R = \sqrt{1 - \frac{\sum_{i=1}^{N}(y_i - y_i^*)^2}{\sum_{i=1}^{N}(y_i - \bar{y})^2}}.$$

We think that the physiological age is in accord with calendar age for the people in the sample .

(3) Standard value R_i is defined as

$R_1=0.2045$ $\quad$ $R_2=0.3924$

$R_3=0.5518$ $\quad$ $R_4=0.6718$

then $A_i(x)$ is defined as

$A_1(x)=1-|\mu(x)-0.2045|$

$A_2(x)=1-|\mu(x)-0.3924|$

$A_3(x)=1-|\mu(x)-0.5518|$

$A_4(x)=1-|\mu(x)-0.6718|$

$A_0=1-\max\limits_{1\le i\le 4} A_i(x)$

(4) Estimation formula of the physiological age is defined as

$$
y^{*}(x)=\begin{cases}
\dfrac{35A_0(x)+45A_1(x)}{A_0(x)+A_1(x)}, & if\ A_0(x)=\bigvee\limits_{0\le j\le 4}A_j(x)\ \text{and}\ A_1(x)=A_1(x)\vee A_4(x)\\
\dfrac{35A_0(x)+45A_1(x)+55A_2(x)}{A_0(x)+A_1(x)+A_2(x)}, & if\ A_1(x)=\bigvee\limits_{0\le j\le 4}A_j(x)\\
\dfrac{45A_1(x)+55A_2(x)+65A_3(x)}{A_1(x)+A_2(x)+A_3(x)}, & if\ A_2(x)=\bigvee\limits_{0\le j\le 4}A_j(x)\\
\dfrac{55A_2(x)+65A_3(x)+75A_4(x)}{A_2(x)+A_3(x)+A_4(x)}, & if\ A_3(x)=\bigvee\limits_{0\le j\le 4}A_j(x)\\
\dfrac{65A_3(x)+75A_4(x)+85A_0(x)}{A_3(x)+A_4(x)+A_0(x)}, & if\ A_4(x)=\bigvee\limits_{0\le j\le 4}A_j(x)\\
\dfrac{75A_4(x)+85A_0(x)}{A_4(x)+A_0(x)}, & if\ A_0(x)=\bigvee\limits_{0\le j\le 4}A_j(x)\ \text{and}\ A_4(x)=A_1(x)\vee A_4(x)
\end{cases}
$$

This formula is used for estimating physiological age of 150 people, fitting coefficient is $R=0.73$, standard deviation

$$
s=\sqrt{\sum_{i=1}^{150}(y_i-y_i^{*})^2/150}=6.77
$$

Judgment principle is :

If $|y^{*}-y|\geqslant 7$, then we think that physiological age is out of accord with calendar age . If $y^{*}-y\geqslant 7$, then this person is thought to be early aging ;if $y^{*}-y\leqslant -7$, then this person is thought to be younger than normal people of the same age as him.

If $|y^{*}-y|<7$, then we think that the person's physiological age is in accord with calendar age, that is normal decrepitude.

Now the formula is used for estimating physiological age of 64 people , the result follow as:

Table 1

samples	calendar age	physiological age	$\mu_1(x_1)$	$\mu_2(x_2)$	$\mu_3(x_3)$	$\mu_4(x_4)$
1	49	49.0	0	0.185	0.2	0.2
2	48	49.5	0.5	0.185	0	0
3	49	49.0	0	0.185	0.2	0.2
4	46	48.8	0	0.185	0.2	0
5	48	49.0	0	0.185	0.2	0.2
6	49	49.0	0	0.185	0.4	0
7	43	49.5	0.5	0.185	0	0
8	48	49.4	0.5	0.185	0	0.2
9	49	54.5	0	0.521	0	0
10	45	49.0	0	0.185	0.2	0.2
11	49	49.3	0.5	0.185	0.2	0.4
12*	46	54.5	1	0.185	0	0
13*	47	54.5	0.5	0.185	0.8	0.2
14*	47	54.9	0.5	0.379	0.4	0
15	49	54.6	0.5	0.379	0	0
16	49	54.6	0	0.379	0.6	0.4
17	45	49.4	0.5	0.185	0	0.2
18	48	54.6	0.5	0.379	0	0
19	55	55.1	0.5	0.379	0.4	0.2
20	55	55.2	0.5	0.379	0.4	0.4
21	54	54.6	0.5	0.379	0	0
22	56	55.1	0.5	0.379	0.4	0.2
23	59	65.1	0.5	0.635	1	0.2
24	54	54.9	0.5	0.379	0.4	0
25	58	55.2	0.5	0.379	0.4	0.4
26	52	49.4	0.5	0.185	0.2	0
27	55	55.6	0.5	0.521	0.4	0

samples	calendar age	physiological age	$\mu_1(x_1)$	$\mu_2(x_2)$	$\mu_3(x_3)$	$\mu_4(x_4)$
28	50	49.4	0	0.185	0.6	0.2
29	55	55.4	0.5	0.379	0.8	0.2
30	58	55.6	0.5	0.521	0.2	0.2
31	56	55.4	0.5	0.521	0.2	0
32	52	49.4	0.5	0.185	0.2	0.2
33	59	55.5	0.5	0.379	0.8	0.4
34	55	54.6	0.5	0.379	0	0
35	59	64.9	0.5	0.635	0.6	0.4
36	67	70.8	0.5	0.635	1	1
37	61	55.5	0	0.635	0.2	0.4
38	66	64.8	0.5	0.635	0.6	0.2
39	67	64.8	0.5	0.635	0.6	0.2
40	60	55.6	0.5	0.521	0.2	0.2
41	68	65.1	0.5	0.635	0.6	0.6
42	65	64.7	0.5	0.635	0.4	0.2
43**	64	54.9	0.5	0.379	0.2	0.2
44	64	65.0	0.5	0.635	0.6	0.4
45	61	65.0	0.5	0.635	0.6	0.4
46	65	64.8	0.5	0.635	0.6	0.2
47*	60	70.7	0.5	0.806	0.8	0.6
48	65	65.5	0.5	0.635	1	0.6
49	66	64.8	0.5	0.521	0.8	0.6
50	70	70.7	1	0.635	1	1
51	71	65.3	0.5	0.806	0.4	0
52**	78	70.6	1	0.806	0.2	0.6
53	72	71.3	1	0.806	1	0.6
54	73	70.7	1	0.635	1	1
55	71	71.4	1	0.825	1	0.6

samples	calendar age	physiological age	$\mu_1(x_1)$	$\mu_2(x_2)$	$\mu_3(x_3)$	$\mu_4(x_4')$
56	70	65.0	0.5	0.806	0	0
57	76	70.7	1	0.635	1	1
58	71	71.3	1	0.806	1	0.6
59	75	70.7	0.5	0.806	0.8	0.6
60	71	70.8	1	0.825	0	0
61	75	71.7	1	0.806	1	1
62	71	70.8	1	0.825	0.6	0.4
63	73	71.6	1	0.825	1	0.8
64	71	71.6	1	0.898	0.6	0.2

Where * shows early aging and * * younger.

The example verifies that the formula is reasonable.

References

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