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Research Article

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Analytic hierarchy process to tennis ball-picking robot different path programming research

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ABSTRACT

Tennis ball-picking robot is various in kind; ball-picking way mainly divides into recirculation principle, proximity principle and shortest path optimization principle such three kinds. At present, world developed achievements can let robot to pick up random dispersion of tennis. The paper makes use of analytic hierarchy process, it analyzes ball-picking robot different walk path that is picking way, by establishing hierarchical analysis indicators, it researches on ball-picking robot paths differences caused influences, and makes preliminary theoretical basis for path researching directions. Final result thought that shortest path optimization principle has more practical significance in researching significance and development prospect.

Key words: tennis robot, analytic hierarchy process, path, comprehensive evaluation

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INTRODUCTION

In the early 1980s, world firstly put forward proposal of organizing table tennis robot competition, after that all countries in the world started sports kind robot researching; sports robot included competitive sports robot and service type sports robot [1-5]. Service type robot will play an important role in sports in the future. Sports robot will also more rapidly blend in with people daily life's exercising. Low cost, high efficiency, broad prospects are applied values of robot [6-9].

Tennis constantly walks into people's life, more and more people participate in tennis, table tennis and other ball type events, and with movement generated scattering balls spread all field corners, ball picking becomes a kind of trivial and unavoidable thing [10-15]. So in order to solve the problem, ball-picking robot becomes ideal service tool. Formers have made lots of researches on ball-picking robot development aspect, especially for mathematical model aspect model calculates and controls equations as well as other mathematical algorithms research. But ball-picking robot designing is a kind of very complicated task that includes machinery, automation, computer, mathematical model, physical model and control equation so on multiple disciplines, is an interdisciplinary research field. The paper based on analytic hierarchy process, starts from ball-picking robot path perspective, it analyzes and researches on ball-picking path research orientation.

BALL-PICKING ROBOT INDICATOR ANALYSES

Investment costs Picking robot performance

Investment costs is one of key factors that considers introducing ball-picking robot, excessive high investment costs will lead to path research lose more than gain, so that it will restrict ball-picking robot development. Different paths robot, due to its control methods and relative assisting equipments differences, it will lead to investment costs differences, low investment costs is common target among researcher, manufacturer and demander. Therefore robot investment costs are a kind of important indicators in path selection researching problems.

Picking efficiency

Robot should reflect its utility, people's expectation on ball-picking robot of course is it can make self-service to pick up scattering balls and can make self-service and pick up nearly all balls. That reflects picking efficiency indicator requirements on ball-picking robot, and in different ways ball-picking paths, compare their efficiency differences are indispensable.

Research Significance

Different picking paths research corresponding research in other expansion aspects are different, and they have different impacts on education, design, science and technology, economic aspects. Such research has more universality, and can more drive other researches advancement that is the key to research significance. When evaluates ball-picking robot path researching methods, research significance is an important reference indicator.

Stability

In tennis, table tennis and other events, ball dispersion is random and quantity is larger, is unremitting drop balls' picking. Robot work is larger and meanwhile it requires robot work time to be longer. It requires robot has better stability so that let robot carry out trying stable work in whole movement.

ANALYTIC HIERARCHY PROCESS MATHEMATICAL MODEL ESTABLISHMENTS

Establish hierarchical structure

The paper quantize tennis ball-picking robot based on analytic hierarchy process. It establishes target layer, criterion layer and project layer relations. Target layer: ball-picking robot property.

Criterion layer: project influence factor, c_1 is investment costs、 c_2 is picking efficiency、 c_3 is stability、 c_4 is manufacturing difficulty.

Project layer: A_1 is recirculation、 A_2 is proximity principle, A_3 is optimization principle obtained hierarchical structure.

Construct judgment matrix

Based on Table 1 showed 1～9 scale table, it makes weight analysis.

Table 1:1～9 scale

Scale a_{ij}	Description
1	factor i and factor j have equal importance
3	factor i is slightly more important than factor j
5	factor i is relative more important than factor j
7	factor i is extremely more important than factor j
9	factor i is absolute more important than factor j
2,4,6,8	Indicates middle state corresponding scale value of above judgments
Reciprocal	If compare factor i with factor j, it gets judgment value as $a_{ji}=1/a_{ij}$, $a_{ii}=1$

At first solve judgment matrix, according to above principle, reference 1～9 scale setting, and according to expert and author's experiences as well as reference lots of documents, it gets paired comparison matrix that are respectively Table 2-4.

Table 2: Comparison matrix

G	c_1	c_2	c_3	c_4
c_1	1	1/3	3	3
c_2	1/8	1	5	5
c_3	1/3	1/5	1	1
c_4	1/3	1/5	1	1

Table 3: Comparison matrix

c_1	A_1	A_2	A_3	c_2	A_1	A_2	A_3
A_1	1	1	1/3	A_1	1	5	5
A_2	1	1	1/3	A_2	1/5	1	5
A_3	3	3	1	A_3	1/5	1/5	1

Table 4: Comparison matrix

c_3	A_1	A_2	A_3	c_4	A_1	A_2	A_3
A_1	1	5	8	A_1	1	5	8
A_2	1/5	1	5	A_2	1/5	1	5
A_3	1/8	1/5	1	A_3	1/8	1/5	1

Hierarchical single arrangement and consistency test

Use consistency indicator to test:

Set in comparison matrix, $\lambda_{\max}$ is maximum feature root value, n is comparison matrix order:

$$CI = \frac{\lambda_{\max} - n}{n-1}$$

CI value gets smaller; judgment matrix gets closer to completely consistent. CI value gets bigger, it shows known extent is lower.

Hierarchy total arrangement and its consistency test

$$A = \begin{Bmatrix} 1 & 1/3 & 3 & 3 \\ 3 & 1 & 5 & 5 \\ 1/3 & 1/5 & 1 & 1 \\ 1/3 & 1/5 & 1 & 1 \end{Bmatrix}$$

$$\xrightarrow{\text{By column vector normalization}} \begin{Bmatrix} 0.214 & 0.192 & 0.3 & 0.3 \\ 0.075 & 0.577 & 0.5 & 0.5 \\ 0.121 & 0.115 & 0.1 & 0.1 \\ 0.201 & 0.115 & 0.1 & 0.1 \end{Bmatrix}$$

$$\xrightarrow{\text{Solve sum by line}} \begin{Bmatrix} 1.066 \\ 2.22 \\ 0.386 \\ 0.386 \end{Bmatrix}$$

$$\xrightarrow{\text{Normalization}} \begin{Bmatrix} 0.2515 \\ 0.555 \\ 0.0965 \\ 0.0965 \end{Bmatrix} = W^{(0)}$$

$$AW^{(0)} = \begin{Bmatrix} 1 & 1/3 & 3 & 3 \\ 3 & 1 & 5 & 5 \\ 1/3 & 1/5 & 1 & 1 \\ 1/3 & 1/5 & 1 & 1 \end{Bmatrix} \begin{Bmatrix} 0.2514 \\ 0.555 \\ 0.0965 \\ 0.0965 \end{Bmatrix} = \begin{Bmatrix} 1.012 \\ 2.275 \\ 0.387 \\ 0.387 \end{Bmatrix}$$

$$\lambda_{\max}^{(0)} = \frac{1}{4}\left(\frac{1.054}{0.257} + \frac{2.254}{0.786} + \frac{0.257}{0.045} + \frac{0.457}{0.078}\right) = 4.038$$

$$w^{(0)} = \begin{pmatrix} 0.278 \\ 0.56 \\ 0.045 \\ 0.098 \end{pmatrix}$$

Similarly, it can calculate judgment matrix:

$$B_1=\begin{Bmatrix}1 & 1 & 1/3\\ 2 & 1 & 1/3\\ 3 & 6 & 1\end{Bmatrix}, B_2=\begin{Bmatrix}1 & 5 & 5\\ 1/5 & 1 & 2\\ 1/5 & 1/5 & 1\end{Bmatrix}, B_3=\begin{Bmatrix}1 & 6 & 8\\ 1/5 & 1 & 5\\ 1/8 & 1/5 & 1\end{Bmatrix}, B_4=\begin{Bmatrix}1 & 8 & 8\\ 1/5 & 1 & 5\\ 1/8 & 1/5 & 1\end{Bmatrix}$$

Therefore, it gets maximum feature value and feature vector as following show:

$$\lambda^{(1)}{}_{\max}=3.64, \omega^{(1)}{}_1=\begin{Bmatrix}0.254\\ 0.247\\ 0.652\end{Bmatrix}$$

$$\lambda^{(2)}{}_{\max}=3.30, \omega^{(1)}{}_2=\begin{Bmatrix}0.557\\ 0.281\\ 0.1032\end{Bmatrix}$$

$$\lambda^{(3)}{}_{\max}=3.22, \omega^{(1)}{}_3=\begin{Bmatrix}0.625\\ 0.236\\ 0.154\end{Bmatrix}$$

$$\lambda^{(4)}{}_{\max}=2.98, \omega^{(1)}{}_4=\begin{Bmatrix}0.658\\ 0.224\\ 0.56\end{Bmatrix}$$

Use consistency indicator to test: $CI=\dfrac{\lambda_{\max}-n}{n-1}$, $CR=\dfrac{CI}{RI}$, RI value is as Table 5 show.

Table 5: RI value

n	1	2	3	4	5	6	7	8	9	10	11
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51

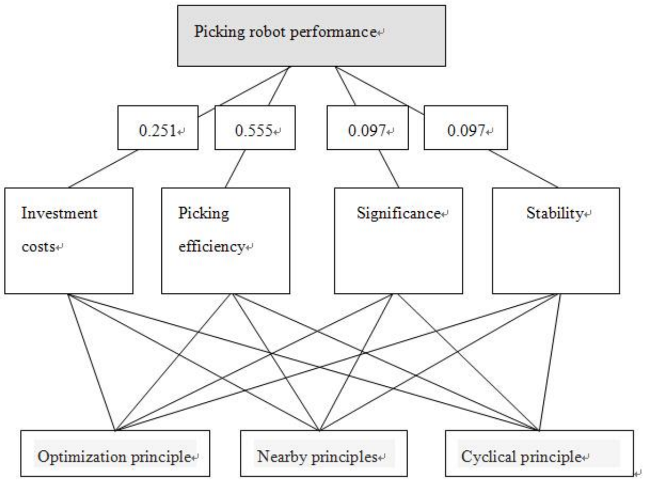
It gets judgment matrix A, $\lambda^{(0)}{}_{\max}=4.073, RI=0.9$

$$CI=\frac{4.073-4}{4-1}=0.24$$

$$CR=\frac{CI}{RI}=\frac{0.024}{0.90}=0.027<0.1$$

It represents A inconsistency test is effective and it moves in permissible range, it can use A feature vector to replace weight vector.

Similarly, to judgment matrix B_1, B_2, B_3, B_4, it takes consistency test and gets weight vector.
Utilize hierarchical chart drawing out calculation results from target layer to project layer, as Figure 1 show.



$$\begin{Bmatrix}0.252\\ 0.089\\ 0.66\end{Bmatrix}, \begin{Bmatrix}0.575\\ 0.286\\ 0.139\end{Bmatrix}, \begin{Bmatrix}0.624\\ 0.240\\ 0.136\end{Bmatrix}, \begin{Bmatrix}0.185\\ 0.240\\ 0.575\end{Bmatrix}$$

Figure 1: Target layer to project layer structural chart

Calculation structure as following:

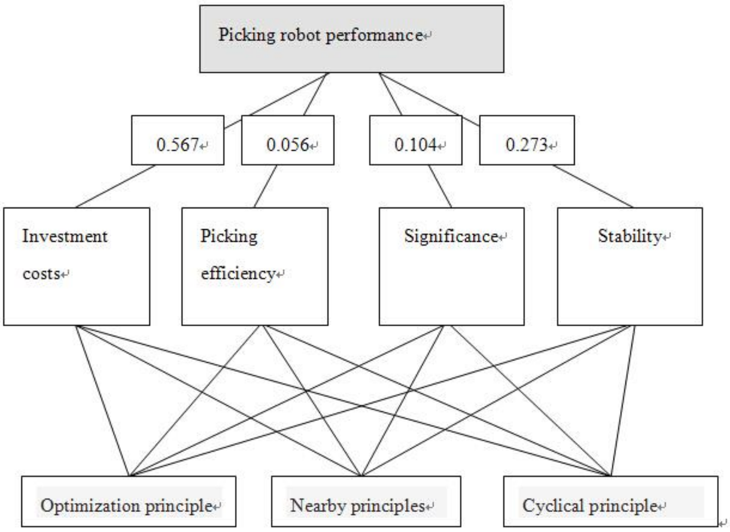
$$\omega^{(1)} = (\omega_1^{(1)}, \omega_2^{(1)}, \omega_3^{(1)}, \omega_3^{(1)}) = \left\{\begin{matrix} 0.624 & 0.185 & 0.252 & 0.575 \\ 0.234 & 0.240 & 0.089 & 0.286 \\ 0.136 & 0.575 & 0.66 & 0.139 \end{matrix}\right\}$$

$$w = w^{(1)} w^{(0)}$$

$$= \left\{\begin{matrix} 0.252 & 0.575 & 0.624 & 0.185 \\ 0.089 & 0.286 & 0.240 & 0.240 \\ 0.66 & 0.139 & 0.136 & 0.575 \end{matrix}\right\} \left\{\begin{matrix} 0.567 \\ 0.056 \\ 0.104 \\ 0.273 \end{matrix}\right\} = \left\{\begin{matrix} 0.290 \\ 0.157 \\ 0.553 \end{matrix}\right\}$$

MODEL IMPROVEMENTS

Proximity principle is different from other any paths, it puts emphasis on analysis from its own surrounding perspective of every ball distance in the field to make analysis and solve shortest path. But in case ball quantity is little or relative scattering, compared to optimization movement, its weight is smaller. Establish hierarchical structure as Figure 2 show.



$$\left\{\begin{matrix} 0.252 \\ 0.089 \\ 0.66 \end{matrix}\right\}, \left\{\begin{matrix} 0.575 \\ 0.286 \\ 0.139 \end{matrix}\right\}, \left\{\begin{matrix} 0.624 \\ 0.240 \\ 0.136 \end{matrix}\right\}, \left\{\begin{matrix} 0.185 \\ 0.240 \\ 0.575 \end{matrix}\right\}$$

Figure 2: Improved target layer to project layer hierarchical structural chart

Calculation structure as following: $\omega^{(1)} = (\omega_1^{(1)}, \omega_2^{(1)}, \omega_3^{(1)}, \omega_4^{(1)}) = \left\{\begin{matrix} 0.252 & 0.575 & 0.624 & 0.185 \\ 0.089 & 0.286 & 0.240 & 0.240 \\ 0.66 & 0.139 & 0.136 & 0.575 \end{matrix}\right\}$

$$w = w^{(1)} w^{(0)}$$

$$= \left\{\begin{matrix} 0.252 & 0.575 & 0.624 & 0.185 \\ 0.089 & 0.286 & 0.240 & 0.240 \\ 0.66 & 0.139 & 0.136 & 0.575 \end{matrix}\right\} \left\{\begin{matrix} 0.567 \\ 0.056 \\ 0.104 \\ 0.273 \end{matrix}\right\} = \left\{\begin{matrix} 0.244 \\ 0.187 \\ 0.563 \end{matrix}\right\}$$

By result analysis, recirculation accounts for 56.3% of investment costs, and optimization only accounts for 24.4%, proximity principle accounts for 28% of research significance, and optimization principle accounts for 54.1%, the paper concludes that ball-picking robot is a kind of larger weight research in research significance aspect.

CONCLUSION

The paper utilizes analytic hierarchy process, adopts different paths to research on ball-picking robot, it can define that adopts optimization algorithm can propel to robot development, improve research process, and it belongs to research items that should strive to develop. And proximity principle and recirculation path have lower investment costs, but technical synthesis and overall evaluation is lower than optimization path algorithm.

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