ISSN : 0974 - 7435 Volume 10 Issue 10

2014

BioTechnology

An Indian Journal

FULL PAPER

BTAIJ, 10(10), 2014 [4643-4650]

Analytic hierarchy process (AHP) to the tennis ball different robot path planning research

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ABSTRACT

Tennis ball robot of various in form, the way to pick up the ball mainly divided into the reciprocating cycle principle, principle of nearby, and three kinds of shortest path optimization principle. The present results can already make the machine in the world developed to pick up randomly scattered tennis. In this paper, using the analytic hierarchy process (ahp), the walking different paths of the robot to pick up the ball that is the way to pick up the ball is analyzed, by establishing the hierarchy analysis indicators, the research about the differences between the robot path way to pick up the ball, as well as the research direction of the path to make a preliminary theoretical basis. Finally concluded that the shortest path optimization principle on the research significance and the development prospect is more practical significance.

KEYWORDS

Tennis robot; Analytic hierarchy process; Path, Comprehensive evaluation.

INTRODUCTION

In the 1980 s in the world for the first time put forward the initiative, table tennis robot competition held ever since the world began work, the development of the sports robot sports robot including robots and competitive sports service robot. Service robots in the future will play an important role in sports. Sports robots are more rapid integration into the exercise of the People's Daily life. Low cost, high efficiency, broad prospects for a robot application value.

Tennis constantly into people's lives, the more people turned out to the tennis, table tennis, such as ball games, and with movement of the scattered across the ground corner, become a trivial to pick up the ball have something can't be avoided. So in order to solve this problem, the robot to pick up the ball to become the ideal service tools. Predecessors in picking up the ball ball robot development has done a lot of research work, especially mathematical model model, calculation of the control equations and other mathematical study of the algorithm. But see the ball robot design is a very complex task, including mechanical, automation, computer, mathematical model, the physical model and control equation and so on many disciplines, is a cross subject research. In this paper, based on the analytic hierarchy process (ahp) from the Angle of the path of the robot to pick up the ball, analysis and study the path of the research direction to pick up the ball.

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: $CI = \frac{\lambda_{\max} - n}{n-1}$, $CR = \frac{CI}{RI}$, 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.

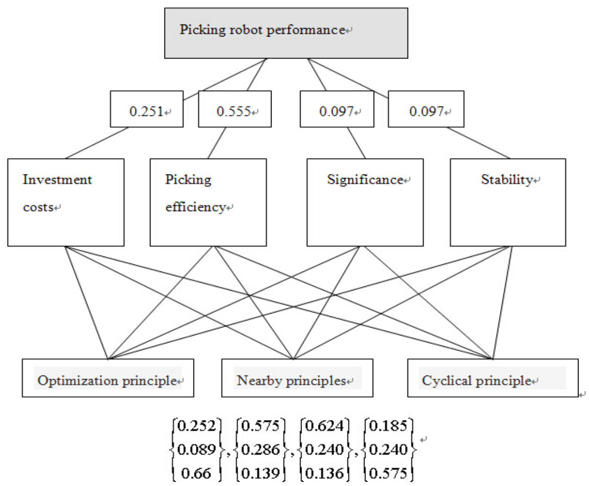

Figure 1: Target layer to project layer structural chart

Calculation structure as following:

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

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

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

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.

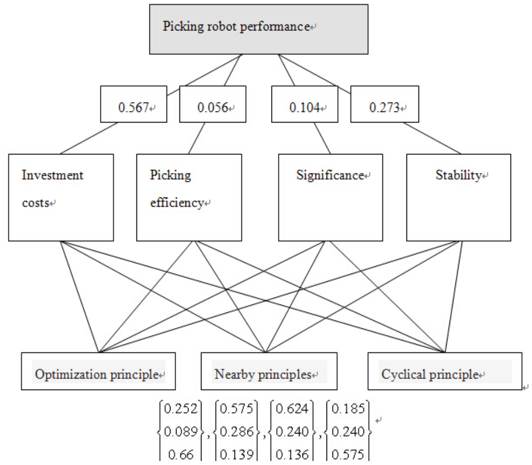

Figure 2 : Improved target layer to project layer hierarchical structural chart

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

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

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

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

This paper USES the analytic hierarchy process (ahp), the robot to pick up the ball with the method of different paths, using optimization algorithm can promote the development of robot can be determined, belong to improve the research process should vigorously develop the research project. And adjacent principle and the path of the reciprocating cycle has low cost, but a comprehensive technology, and the overall evaluation is lower than optimal path algorithm.

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