Advanced Techniques in Computing Sciences and Software Engineering
Khaled Elleithy

Advanced Techniques in Computing Sciences and Software Engineering

Springer
Dedication

To my Family
Preface

This book includes Volume II of the proceedings of the 2008 International Conference on Systems, Computing Sciences and Software Engineering (SCSS). SCSS is part of the International Joint Conferences on Computer, Information, and Systems Sciences, and Engineering (CISSE 08). The proceedings are a set of rigorously reviewed world-class manuscripts presenting the state of international practice in Advances and Innovations in Systems, Computing Sciences and Software Engineering.

SCSS 08 was a high-caliber research conference that was conducted online. CISSE 08 received 948 paper submissions and the final program included 390 accepted papers from more than 80 countries, representing the six continents. Each paper received at least two reviews, and authors were required to address review comments prior to presentation and publication.

Conducting SCSS 08 online presented a number of unique advantages, as follows:

- All communications between the authors, reviewers, and conference organizing committee were done online, which permitted a short six week period from the paper submission deadline to the beginning of the conference.
- PowerPoint presentations, final paper manuscripts were available to registrants for three weeks prior to the start of the conference.
- The conference platform allowed live presentations by several presenters from different locations, with the audio and PowerPoint transmitted to attendees throughout the internet, even on dial up connections. Attendees were able to ask both audio and written questions in a chat room format, and presenters could mark up their slides as they deem fit.
- The live audio presentations were also recorded and distributed to participants along with the power points presentations and paper manuscripts within the conference DVD.

The conference organizers and I are confident that you will find the papers included in this volume interesting and useful. We believe that technology will continue to infuse education thus enriching the educational experience of both students and teachers.

Khaled Elleithy, Ph.D.
Bridgeport, Connecticut
December 2009
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The 2008 International Conference on Systems, Computing Sciences and Software Engineering (SCSS) and the resulting proceedings could not have been organized without the assistance of a large number of individuals. SCSS is part of the International Joint Conferences on Computer, Information, and Systems Sciences, and Engineering (CISSE). CISSE was founded by Professor Tarek Sobh and I in 2005, and we set up mechanisms that put it into action. Andrew Rosca wrote the software that allowed conference management, and interaction between the authors and reviewers online. Mr. Tudor Rosca managed the online conference presentation system and was instrumental in ensuring that the event met the highest professional standards. I also want to acknowledge the roles played by Sarosh Patel and Ms. Susan Kristie, our technical and administrative support team.

The technical co-sponsorship provided by the Institute of Electrical and Electronics Engineers (IEEE) and the University of Bridgeport is gratefully appreciated. I would like to express my thanks to Prof. Toshio Fukuda, Chair of the International Advisory Committee and the members of the SCSS Technical Program Committee including: Abdelaziz AlMulhem, Alex A. Aravind, Anna M. Madueira, Hamid Mcheick, Hani Hagras, Julius Dichter, Low K.S., Marian P. Kazmierkowski, Michael Lemmon, Mohamed Dekhil, Mostafa Aref, Natalia Romalis, Raya Al-Qutaish, Rodney G. Roberts, Sanjiv Rai, Shivakumar Sastry, Tommaso Mazza, Samir Shah, and Mohammed Younis.

The excellent contributions of the authors made this world-class document possible. Each paper received two to four reviews. The reviewers worked tirelessly under a tight schedule and their important work is gratefully appreciated. In particular, I want to acknowledge the contributions of all the reviewers. A complete list of reviewers is given in page XIX.

Khaled Elleithy, Ph.D.
Bridgeport, Connecticut
December 2009
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Bridging Calculus and Statistics: Null - Hypotheses Underlain by Functional Equations

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Abstract-Statistical interpretation of Cauchy functional equation \( f(x+y)=f(x)+f(y) \) and related functional equations is suggested as a tool for generating hypotheses regarding the rate of growth: linear, polynomial, or exponential, respectively. Suggested approach is based on analysis of internal dynamics of the phenomenon, rather than on finding best-fitting regression curve. As a teaching tool, it presents an example of investigation of abstract objects based on their properties and demonstrates opportunities for exploration of the real world based on combining mathematical theory with statistical techniques. Testing Malthusian theory of population growth is considered as an example.

I. INTRODUCTION. HISTORY OF CAUCHY FUNCTIONAL EQUATION

In 1821, a famous French mathematician Augustin-Louis Cauchy proved that the only continuous function satisfying a condition

\[ f(x+y) = f(x) + f(y), \]  
\[ f(x) = Kx, \]  
where \( K \) is a constant, [1]. The proof provides an interesting example of how the properties of an object, function \( f(x) \) in this case, may be investigated without presenting the object explicitly. In what follows, we follow [2]. First, it can be stated that \( f(0)=0 \), because for any \( x \), \( f(x) = f(x+0)=f(x)+f(0) \), so that

\[ f(0)=0. \]  
The last was obtained by subtracting \( f(x) \) from both sides. From this finding it follows directly that \( f(0) = - f(x) \), because

\[ f(0) = f(x+(-x)) = f(x) + f(-x). \]  
Next, we can show that \( f(nx) = nf(x) \) for any \( x \) and natural number \( n \). It can be easily proved by mathematical induction:

\[ f(2x) = f(x+x) = f(x) + f(x) = 2f(x), \]  
and, provided that it is true for \( n-1 \), we get

\[ f(nx) = f((n-1)x+x) = f((n-1)x) + f(x) = (n-1)f(x) + f(x) = nf(x) \]  
for any natural \( n \). Finally, we can show that \( f((1/n)x) = (1/n)f(x) \) for any natural number \( n \). This follows directly from

\[ f(x) = f(n^{1/n}x) = f(n^{1/n})f(x) = nf(x), \]  
so that the result follows from division of both sides by \( n \). Summarizing, it can be stated that function \( f(x) \) satisfying condition (1) can be represented explicitly as

\[ f(r) = Kr \]  
for all rational numbers \( r \).

At this point, condition of continuity comes into play to allow for expansion of the result for all real numbers \( x \). Let sequence of rational numbers \( r_i \) be converging to \( x \) with \( i \to \infty \). Then based on the assumption of continuity of the function \( f(x) \), we have

\[ f(x) = f(\lim r_i) = \lim f(r_i) = \lim Kr_i = K \lim r_i = Kx, \]  
where limit is taken with \( i \to \infty \). Note, that in this process an object, function \( f(x) \), was first investigated and only after that described explicitly.

The Cauchy finding caused broad interest in mathematical community and served as a source of fruitful researches. Among their main topics were:

a) Does a discontinuous solution exist?

b) Can the condition of continuity be omitted or relaxed?

c) Can a condition be set locally, at a point or in a neighborhood, rather than on the whole domain of the function?

Weisstein [3] tells the story of the researches regarding these problems. It was shown by Banach [4] and Sierpinski [5] that the Cauchy equation is true for measurable functions. Sierpinski provided direct proof, while Banach showed that measurability implies continuity, so that the result of Cauchy is applicable. Shapiro [6] gave an elegant brief proof for locally integrable functions. Hamel [7] showed that for arbitrary functions, (2) is not true; see also Broggi [8] for detail. Darboux [9] showed that condition of additivity (1) paired with continuity at only one point is sufficient for (2), and later he proved in [10] that it is sufficient to assume that \( xf(x) \) is nonnegative or nonpositive in some neighborhood of \( x=0 \).

Cauchy functional equation (1) was included in the list of principal problems presented by David Hilbert at the Second International Congress in Paris in 1900. The fifth Hilbert’s problem that generalizes it reads: “Can the assumption of differentiability for functions defining a continuous transformation group be avoided?” John von Neumann solved this problem in 1930 for bicom pact groups, Gleason in 1952, for all locally bicom pact groups, and Montgomery, Zipin, and Yamabe in 1953, for the Abelian groups.

For undergraduate research purposes, a simple result obtained by author may be of interest. It states that differentiability at one point is sufficient. Assume that \( f'(a)=K \) exists at some point \( a \). Then for any \( x \):

\[ f'(x) = \lim_{h \to 0} \frac{f(x+h)-f(x)}{h} = \]

\[
\lim_{h \to 0} \frac{f(x + a - a + h) - f(x + a - a)}{h} = f'(a).
\]

This means that the derivative function \(f'(x) = K\) for any \(x\), so that by the Fundamental Theorem of Calculus we have
\[
f(x) = \int_0^x K \, dt + f(0) = K(x - 0) + 0 = Kx.
\]

Geometric interpretation may be as follows, Fig. 1. Cauchy functional equation without any additional conditions guarantees that every solution passes through the origin and varies proportionally with the argument \(x\). In particular, \(f(x) = Kx\) for all rational \(r\). In general, a graph of the function has “dotted-linear” structure that underlies findings of Hamel [7] and Broggi [8]. Additional conditions are aimed at combining all partial dotted lines into one solid line. Cauchy [1] used continuity condition imposed on all values of \(x\). It may be mentioned, however, that linearity of the partial graphs allows imposing conditions locally, because only slopes of the dotted lines should be made equal. Thus, either continuity at one point only, or sign of \(xf(x)\) preserving in the neighborhood of the origin, or differentiability at the origin is sufficient. Results of Hamel [7] and Broggi [8] demonstrate that in general the horizontal section of the graph is weird if no conditions are imposed.

II. FUNCTIONAL EQUATIONS FOR POWER AND EXPONENTIAL FUNCTIONS

Functional equation (1) characterizes a linear function (2). For objectives of this paper we need characterizations of power and exponential functions as well. Power function will serve as an indicator of the rate of growth no greater than polynomial and exponential functions as well. Power function will serve as an indicator of the rate of growth no greater than polynomial and exponential functions as well. Consider composite function \(g(x) = \ln(f(x))\). Then functions \(f(x) = e^x\) and \(g(u) = \ln(u)\) satisfy equation (1), and thus, \(g(x) = Kx\).

Substitution of the function \(g(x) = \ln(f(x))\) back gives
\[
g(x) = \ln(f(x)) = Kx \quad \text{or} \quad f(x) = e^{Kx}.
\]

For characterization of power function, consider equation (14) for positive values of \(x, y, a, v \geq 0\), introduced new variables \(u = e^{x} \text{ and } v = e^{y}\), so that \(u = \ln(x), \quad v = \ln(y)\). Then functions \(f(x) \text{ and } f(y)\) may be rewritten as function of the variables \(u \text{ and } v \) as \(f(x) = f(e^u) \text{ and } f(y) = f(e^v)\), correspondingly. By doing so, we have
\[
g(\ln(x)) \text{ and } g(\ln(y)) = f(x) \text{ and } f(y) = (e^{u})^r = f(e^u) f(e^v).
\]

Consider composite function \(g(x) = f(e^x)\). In terms of \(g(x)\), equation (24) may be presented as
\[
g(\ln(x)) = g(u)g(v).
\]

that is similar to equation (12). The last characterizes the exponential function, so that we have, in accordance with equation (22),
\[
g(u) = e^{Ku}.
\]

Rewriting equation (26) in terms of \(f(x)\), we get
\[
g(u) = e^{Ku} = e^{K\ln(u)} = (e^{ \ln(u)})^K = x^K = g(\ln(x)) = f(e^{\ln(u)}) = f(x),
\]

as desired. More equations and details may be found in [2], [11] and [12].

III. STATISTICAL PROCEDURES BASED ON CAUCHY FUNCTIONAL EQUATION

In this paper, our objective is to develop a statistical procedure that allows for determination of a pattern of growth in time: linear, polynomial, or exponential, respectively. Finding patterns of growth is of practical importance. It allows, for instance, early determination of the rates of expansion of
unknown illnesses, technological change, or social phenomena. As a result, timely avoidance of undesirable consequences becomes possible. A phenomenon expanding linearly usually does not require any intervention. Periodical observations made from time to time are sufficient to keep it under control. In case of polynomial trend, regulation and control are needed and their implementation is usually feasible. Case of exponential growth is quite different. Nuclear reactions, AIDS, or avalanches may serve as examples. Extraordinary measures should be undertaken timely to keep such phenomena under control or avoid catastrophic consequences.

To determine a pattern, we suggest observing the development of a phenomenon in time and testing statistical hypotheses. A statistical procedure used in this paper is paired t-test, [13]. The procedure assumes that two random variables $X_i$ and $X_j$, not necessarily independent, are observed simultaneously at the moments of time $t_1$, $t_2$, ..., $t_n$ (paired observations). Let $d$ and $\overline{d}$ be their differences and sample average difference, correspondingly:

$$d_i = X_{t_i} - X_{t_j}, \quad \overline{d} = \frac{\sum d_i}{n}$$

Then the test statistic formed as shown below has t-distribution with $(n-1)$ degrees of freedom

$$t = \frac{\overline{d}}{\frac{s_d}{\sqrt{n}}}$$

where $s_d$ is standard deviation of $t$.

Statistical procedure suggested in this paper is this. A sample of observed values is transformed correspondingly and organized into three sets of sampled pairs corresponding to equations (1), (14), or (12), respectively. The equations are used for statement of the corresponding null hypotheses $H_0$. The last are the hypotheses of equality of the means calculated for the left and the right hand sides of the equations (1), (14), or (12), respectively. In testing the hypotheses, the objective is to find a unique set for which the corresponding hypothesis cannot be rejected. If such set exists, it provides an estimation of the rate of growth: linear for the set corresponding to (1), polynomial for the set corresponding to (14), or exponential for the set corresponding to (12). It may be noted that suggested approach is preferable over regression for samples of small or medium sizes. It analyzes the internal dynamics of the phenomenon, while exponential regression equation $f(x)=Ae^{Kx}$ may fail because on a range of statistical observations $Ae^{Kx}=A(1+(Bx)+(Bx)^2/2!+...+(Bx)^n/n!)$ for some $n$, that is indistinguishable from a polynomial.

To explain suggested approach in more details, consider an example. Suppose that observations are made in days 2, 3, 5, and 6, and obtained data are as shown in table 1. What may be plausible estimation of the rate of growth? Calculating the values of $f(x) + f(y) = 7 + 10 = 17$ and $f(x)f(y) = 7 \cdot 10 = 70$, we can see that the only correspondence that is likely held is $f(x+y)=7= f(x)f(y) = 70$. Based on this observation, we conclude that the rate of growth is probably polynomial in this case.

<table>
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<th>Example of Statistical Observations</th>
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<tr>
<td>$x+y$</td>
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<tr>
<td>2</td>
</tr>
<tr>
<td>7</td>
</tr>
<tr>
<td>71</td>
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</table>

In general, we compare sample means calculated at times $x$, $y$, $x+y$, and $xy$, denoted below as $M(x)$, $M(y)$, $M(x+y)$, and $M(xy)$, respectively, and test the following hypotheses:

$$H_{0}^{(1)}: \quad M(x) = M(y) = M(x+y),$$
$$H_{0}^{(2)}: \quad M(x) = M(y) = M(x+y),$$

or

$$H_{0}^{(2)}: \quad M(x) = M(y) = M(x+y).$$

It may be noted that these hypotheses allow for testing more general equations than those given by formulas (2), (14), and (12), namely:

$$f(x) = Kx + C,$$
$$f(x) = Cx^K,$$

or

$$f(x) = Ce^{Kx},$$

where $C$ is an arbitrary constant. To do this, raw data should be adjusted to eliminate constant term $C$. The appropriate transformations of raw data are as follows. Equation (33) is transformed by subtraction of the first observed value from all other ones. This observation is assigned ordinal number zero, $f(0) = C$:

$$f(x) - f(0) = (Kx + C) - C = Kx.$$  \hspace{0.5cm} (36)

Equation (34), is adjusted by division by $f(1) = C$:

$$\frac{f(x)}{f(1)} = \frac{Cx^K}{C(1)^K} = x^K,$$

and equation (35), by division by the value of the observation $f(0) = C$:

$$\frac{f(x)}{f(0)} = \frac{Ce^{Kx}}{Ce^{K0}} = e^{Kx}.$$ \hspace{0.5cm} (38)

To process comprehensive sets of experimental data, we need to compare many pairs of observations, so that a systematic approach to form the pairs is needed. In this paper, we formed pairs as shown in table 2. The table presents a case of ten observations available, but the process may be continued similarly. We start with the observation number two and pair with each of consequent observations until the last observation is achieved in the process of multiplication. Thus, given ten observations, we pair the observation number two with observations number 3, 4, and 5. Then we continue with observation number 3. In this case, observation number 3 cannot be paired with any of consequent, because $3 \cdot 4 = 12 > 10$. The same is true for the observations 4, 5, etc. For compatibility, additive pairs are chosen the same as multiplicative ones.

Table 3 represents expansion of table 2 using spreadsheets. In the spreadsheet, pairs are ordered by
increasing of the product of the ordinal numbers of paired observations, and the set is limited to 25 pairs. As follows from table 3, a critical case is testing the polynomial rate of growth hypothesis that uses observations with ordinal number \(i\). The last product reaches the set boundary pretty soon. At the same time, results obtained for smaller number of pairs than those used for testing two other hypotheses. The Excel statistical function used in the spreadsheets is TTEST(Range-of-first-elements-in-pair, Range-of-second-elements-in-pair, value-2-for-two-tail-test, value-1-for-paired-t-test).

IV. EXAMPLE. TESTING THE MALTHUSIAN THEORY OF POPULATION GROWTH

In this section, we test a theory of Thomas Malthus, who suggested the Principle of Population, http://en.wikipedia.org/wiki/. The main idea was that population if unchecked increases at a geometric rate (i.e. exponentially, as 2, 4, 8, 16, etc.) whereas the food supply grows at an arithmetic rate (i.e. linearly, as 1, 2, 3, 4, etc.). He wrote: “The power of population is so superior to the power of the earth to produce subsistence for man that premature death must in some shape or other visit the human race.” Malthus made a prediction that population would outrun food supply, leading to a decrease in food per person. He even predicted that this must occur by the middle of the 19th century. Fortunately, this prediction failed, in particular, due to his incorrect use of statistical analysis and ignoring development of industrial chemistry, though recently new concerns aroused caused by using of food-generating resources for production of oil-replacing goods, see, for example, http://blogs.wsj.com/energy/2007/04/16/foreign-affairs-ethanol-will-starve-the-poor/.

In this paper, we focus on the hypothesis of exponential growth of population using data of the US Census Bureau for 1950-2050, available on website http://www.census.gov/ipc/www/idb/worldpop.html. For calculations, the following groups of observations were formed: 1950 - 2050, 1950 - 2000, 2000 - 2050, 1950 - 1975, 1975 - 2000, 2000 - 2025, and 2025 - 2050. These groups correspond to the whole period, two halves of the period, and its four quarters, respectively. The first observation in each group was assigned an ordinal number 1 and used for normalization.

Obtained results are shown in table 4 and reveal that for the periods of 2000 - 2025 and 2025 - 2050 are just expectations as well.

Summarizing, we can state that expected situation is not so dangerous as Malthus predicted, because periods of exponential growth of population alternate with the periods of polynomial growth. This alternation together with advances of industrial chemistry allows for the hope that there will be enough food in the world for all.

V. CONCLUSIONS

Suggested approach is two-folded. On one hand, it demonstrates close relationships between Calculus and Statistics and allows for inclusion of statistical components into Calculus courses and vice versa. On the other hand, it may serve as a basis for joint undergraduate research that unites students of different specializations, research interests, and levels of preparation. Taken together, the two aspects help the development of students’ creativity, raise their interest in studying both subjects, and allow for early enrollment in research work.

REFERENCES

### Hypothesis testing for the rate of magnitude (linear, polynomial, exponential)

#### Paired t-test

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<td>exponential rate of growth hypothesis is</td>
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<td>( TTEST(X14:X38,AA14:AA38,2,1) ).</td>
</tr>
<tr>
<td>The result is 0.2816.</td>
<td>The spreadsheet is available from author upon</td>
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<tr>
<td>NOTES:</td>
<td>request.</td>
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</table>

| Example                         | The formula in the cell corresponding to the   |
|                                 | exponential rate of growth hypothesis is      |
|                                 | \( TTEST(X14:X38,AA14:AA38,2,1) \).           |
| The result is 0.2816.           | The spreadsheet is available from author upon  |
| NOTES:                          | request.                                        |

#### TABLE 3

| Example                         | The formula in the cell corresponding to the   |
|                                 | exponential rate of growth hypothesis is      |
|                                 | \( TTEST(X14:X38,AA14:AA38,2,1) \).           |
| The result is 0.2816.           | The spreadsheet is available from author upon  |
| NOTES:                          | request.                                        |

#### Spread sheet Example

| Hypothesis testing for the rate of magnitude (linear, polynomial, exponential) |
|---------------------------------|--------------------------------------------------|
| Example                         | The formula in the cell corresponding to the   |
|                                 | exponential rate of growth hypothesis is      |
|                                 | \( TTEST(X14:X38,AA14:AA38,2,1) \).           |
| The result is 0.2816.           | The spreadsheet is available from author upon  |
| NOTES:                          | request.                                        |
Application of Indirect Field Oriented Control with Optimum Flux for Induction Machines Drives

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Abstract—The rotor flux optimization is crucial parameter in the implementation of the field oriented control. In this paper, we considered the problem of finding optimum flux reference that minimizes the total energy control for induction machine drive under practical constraints: voltage and current. The practical usefulness of this method is evaluated and confirmed through experiments using (1.5kW/380V) induction machine. Simulations and experimental investigation tests are provided to evaluate the consistency and performance of the proposed control model scheme.

Keywords—Indirect Field Oriented Control (IFOC), Induction Machine, Loss Optimization, Optimum Rotor Flux.

I. INTRODUCTION

Induction machines are widely used in various industries as prime workhorses to produce rotational motions and forces. Generally, variable speed drives for induction machines require both wide speed operating range and fast torque response, regardless of load variations. These characteristics make them attractive for use in new generation electrical transportation systems, such as cars and trains. They are also used in ventilation and heating systems and in many other electrical domestic apparatus [8].

By using the advances of power electronics, microprocessors, and digital signal processing (DSP) technologies, the control schemes of induction machines changed from simple scalar or auto-tuning to Field Oriented Control “FOC” and Direct Torque Control “DTC”. The FOC is successfully applied in industrials applications on real time control when dealing with high performance induction machines drives [1], [2], [9], [10], [11].

The FOC is the most suitable way in achieving a high performance control for induction machines. Estimating the magnitude and phase of rotor flux is very crucial for the implementation control field oriented method. Direct ways of sensing the rotor flux by implementing suitable hardware around the machine have proved to be inaccurate and impractical at speed and torque. Indirect methods of sensing the rotor flux employ a mathematical model of induction machine by measuring state variables, like currents and voltages. The accuracy of this method will depend mainly on the precise knowledge time constant. This of rotor machine parameter may change during the operation of the drive, which introduce inaccuracies in the flux estimation as both stator and rotor resistance windings change with temperature [2], [7], [9].

With an aim to improve induction machines performance and stability properties, researches have been conducted to design advanced nonlinear control systems [4], [8], [13]. Most of these systems operate with constant flux norms fixed at nominal rate [8], [19]. In this situation, maximum efficiency is obtained. However machines do not operate at their nominal rate as the desired torque changes on-line or may depend on system states such as position or velocity. It is then technically and economically interesting to investigate other modes of flux operation seeking to optimize system performance. Aware of these facts, some previous works have already used the reference flux as an additional degree of freedom to increase machine efficiency [6], [9].

This problem has been treated by many researchers. In [13], [18], [20], the heuristics approaches used offer fairly conservative results. They are based on measurement of supplied power in approximating the optimum flux algorithm. The convergences of these algorithms are not guaranteed.

In [17], an applied analytical approach has been used directly in real time to obtain the optimal trajectory equation of the control drives, nevertheless this solution is less robust than the heuristics methods.

In this paper, the objective of the newly developed method is to offer a unified procedure by adding the adaptation parameters and reducing losses. Our work will be structured as follows: In section II, the induction machine model is first presented, then in Section III, we will describe the application of field oriented current and voltage vector control. In section IV, a new optimization approach of optimum flux is described and analyzed in both simulation and practical control. Finally, we have applied several techniques reducing losses with optimum rotor flux in indirect field oriented control for induction machine at variable speed. Simulation and practical results are given to demonstrate the advantages of the proposed scheme. Conclusion and further studies are explained in the last section.
II. CONTROL PROBLEM FORMULATION

A. Dynamic induction machine model

Mathematical model of induction machine in space vector notation, established in d-q axis coordinates reference rotating system at \( \omega_s \) speed can be represented in the Park’s transformation shown in Fig.1.

\[
C_{em} = p \frac{L_m}{L_r} (\varphi_{ds} i_{qs} - \varphi_{qs} i_{ds}) \tag{9}
\]

\[
d\omega = \frac{pL_m}{JL_r} (\varphi_{ds} i_{qs} - \varphi_{qs} i_{ds}) - \frac{P}{J} C_{em} - f_r \omega \tag{10}
\]

The difficulty of equation (9), is the strong coupling between flux and current of machine.

B. Indirect Field Oriented Control (IFOC)

For the rotor flux oriented control system, the rotor flux linkage vector has only the real component, which is assumed to be constant in the steady state. From (7) and (8), the rotor currents are given by:

\[
i_{dr} = \frac{1}{L_r} (\varphi_{dr} - L_m i_{ds}) \tag{11}
\]

\[
i_{qr} = \frac{1}{L_r} (\varphi_{qr} - L_m i_{qs}) \tag{12}
\]

Substituting (11) and (12) into (3) and (4), we can extract two expressions of dynamic d-q axis rotor flux components are expressed by:

\[
d\varphi_{dr} \over dt + \frac{R_r}{L_r} \varphi_{dr} - \frac{L_m}{L_r} R_s i_{ds} - \omega_s \varphi_{qr} = 0 \tag{13}
\]

\[
d\varphi_{qr} \over dt + \frac{R_r}{L_r} \varphi_{qr} - \frac{L_m}{L_r} R_s i_{qs} + \omega_s \varphi_{dr} = 0 \tag{14}
\]

\( \omega_{sl} = \omega_s - \omega \) is the slip angular speed.

If the vector control is fulfilled such that q-axis rotor flux can be zero, and d-axis rotor flux can be constant, the electromagnetic torque is controlled only by q-axis stator current, therefore from (9), with \( \varphi_{qr} = 0 \), \( i_{dr} = 0 \), yields

\[
d\varphi_{dr} \over dt = 0 \tag{15}
\]

\[
C_{em} = p \frac{L_m}{L_r} (\varphi_{ds} i_{qs}) \tag{16}
\]

Substituting (15) into (3) and (11)-(14) yields

\[
i_{qr} = -\frac{L_m}{L_r} i_{ds} \tag{17}
\]

\[
\varphi_{dr} = L_m i_{ds} \tag{18}
\]

\[
\omega_{sl} = \frac{L_m}{T_r} \frac{i_{qs}}{L_m} = \frac{1}{T_r} \frac{i_{qs}}{i_{ds}} \tag{19}
\]

where \( T_r = L_r / R_r \) is the time constant of rotor, \( \omega = \dot{\theta} \) with 0 is the position of the rotor and \( i_{dr}, i_{qr} \) are the direct and quadrant axis components stator currents, where \( \varphi_{dr}, \varphi_{qr} \) are the two–phase equivalent rotor flux linkages and the rotor speed \( \omega \) is considered as state variable and the stator voltage \( v_{ds}, v_{qs} \) as command variables.

We have shown in equation (9) that the electromagnetic torque expression in the dynamic regime, presents the coupling
between stator current and rotor flux. The main objective of the vector control of induction machine is, as in direct current (DC) machines, to control independently the torque and the flux [4]. This can be realized by using d-q axis rotating reference frame synchronously with the rotor flux space vector. The d-axis is aligned with the rotor flux space vector. Under this condition we have, \( \varphi_{d} = \varphi_{r} \) and \( \psi_{q} = 0 \). In this case the electromagnetic torque of induction machine is given by equation (16). It is understood to adjust the flux while acting on the component \( i_{ds} \) of the stator current and adjust the torque while acting on the \( i_{qs} \) component. One has two variables of action then as in the case of a DC machine.

Combining equations (13), (15) and (16) we obtain the following d-q axis stator currents:

\[
i_{ds}^* = \frac{1}{L_{ms}} (T_{r} \frac{d\varphi_{r}^*}{dt} + \varphi_{s}^*)
\]

\[
i_{qs}^* = \frac{L_{ms}}{pL_{m}} C_{em}^* \frac{d\varphi_{r}^*}{dt}
\]

\[
\omega_{str}^* = \frac{L_{ms}}{T_{r} \omega_{s}^*} \varphi_{s}^*
\]

The torque \( C_{em}^* \) and flux \( \varphi_{r}^* \) are used as references control and the two stator currents \( i_{ds}, i_{qs} \) as inputs variables [13], [19]. Combining equations (21)-(22) we obtain the following expression of reference torque as a function of reference slip speed.

\[
C_{em}^* = P \frac{\varphi_{r}^{*2}}{R_{r}} \omega_{str}^*
\]

with \( \omega_{str}^* = \omega + \omega_{i}^* \)

The references voltages are given in steady state by:

\[
v_{ds}^* = R_{s} i_{ds}^* - \omega_{r}^* \sigma L_{s} i_{qs}^*
\]

\[
v_{qs}^* = R_{s} i_{qs}^* + \omega_{r}^* \sigma L_{s} i_{ds}^*
\]

where \( \sigma \) is the total leakage coefficient given by:

\[
\sigma = 1 - \frac{L_{s}^2}{L_{r} L_{s}}
\]

These equations are functions of some structural electric parameters of the induction machine \((R_{r}, R_{s}, L_{s}, L_{r}, L_{ms})\) which are in reality approximate values. The rotor flux amplitude is calculated by solving (19), and its spatial position is given by:

\[
\theta_{i} = \int_{0}^{t} \left( \omega + \frac{L_{s} i_{qs}^*}{T_{r} \varphi_{s}^*} \right) dt
\]

C. simulation Study of IFOC voltage and current Control

A simulation study was carried out to investigate the following models controls used on a closed loop IFOC system which depend on the loading conditions. The current and voltage control simulations of IFOC are given by Fig.2 and Fig.3.

Fig. 2. Simulation of IFOC - IM drives with current control.

Fig. 3. Simulation of IFOC-IM drives with voltage control.

III. LOSS MINIMISATION IN IFOC INDUCTION MACHINE

A- Power losses of induction machine

In the majority constructions of induction machines, electromagnetic time constant is much smaller than mechanical time constant. For this reason the strategy of torque control which minimizes power losses can be reduced to the steady electromagnetic state. Several loss models are proposed and used in the literature, among this work those of [8], [9] and [10] which take into account the copper losses of the stator, the rotor windings and the iron losses. The total electrical input power of induction machine composed by resistive losses \( P_{R,loss} \), power \( P_{field} \) stored as magnetic field energy in the windings and mechanical output power \( P_{mech} \) expressed in the \( d,q \) variables. Applying the transformation to rotating reference frame on \( d,q \) variables the total power is given by:

\[
P_{el,loss}(t) = \alpha \left( L_{r} \frac{di_{ds}}{dt} + i_{d} \frac{di_{ds}}{dt} \right) - \frac{1}{L_{r}} \left( \frac{d\varphi_{s}^*}{dt} i_{ds} + \frac{d\varphi_{r}^*}{dt} i_{qs} \right) + \frac{L_{r}}{L_{s}} \omega (\varphi_{r} i_{ds} - \varphi_{s} i_{qs}) - \frac{2R_{r} L_{ms} i_{qs}}{L_{s}} (i_{ps} \psi_{r} + i_{qs} \psi_{s})
\]

This equation can be written in a condensed form as:

\[
P_{el,loss} = \frac{dP_{field}}{dt} + P_{R,loss} + P_{mech}
\]

With:
\[ P_{\text{loss}} = R_s(i^2_{ds} + i^2_{qs}) + R_r(i^2_{dr} + i^2_{qr}) \]  

\[ P_{\text{field}} = \frac{L_s}{2}(i^2_{ds} + i^2_{qs}) + \frac{1}{2L_r}(\varphi^2_{ds} + \varphi^2_{qr}) \]  

\[ P_m = \frac{L_m}{L_r} \omega (\varphi_{ds}i_{ds} - \varphi_{qr}i_{dr}) \]

According to the equivalent diagrams, the model of iron losses is described by:

\[ \Delta P_{Fe} = \Delta P_{Fe}^* = R_{Fe} \frac{\varphi^2_r}{L_m^2} \]

### B. Power loss minimization with level flux control

#### B.1 Optimization flux for copper loss minimization

The flux optimization for minimized energy in steady state consists to find the optimal trajectory of flux, \( \forall T \in [0, T] \), which minimizes the cost function. The optimum rotor flux calculation is given by the relation:

\[ \varphi_r = f(C_{\text{em}}) \]

According to the dynamic induction machine, the total electrical power loss can be written:

\[ \Delta P_l = \left( R_s + \frac{R_r L_m^2}{L_s} \right) (i^2_{ds} + i^2_{qs}) + \left( \frac{R_r L_m^2}{L_s} + R_r \right) \left( \frac{\varphi_r}{L_m} \right)^2 \]  

\[ -2 \frac{R_r L_m^2}{L_s} i_{dr} \varphi_r = \beta_1 \varphi_r^2 + \beta_2 \frac{C_{\text{em}}^2}{\varphi_r} \]

Optimum operation point, corresponding to the minimum loss is given by setting:

\[ \frac{\partial (\Delta P_l)}{\partial \varphi_r} = 0 \]

The resolution of this equation, gives the optimum rotor flux:

\[ \varphi_r^{\text{opt}} = \beta_1 \sqrt{C_{\text{em}}} \]

Where

\[ \beta = \left( \frac{L_s^2 R_s + R_r L_m^2}{R_s + R_r} \right)^{\frac{1}{2}} \]

This parameter depends on machine operating.

From the equations (20) and (21) we deduce that the optimal control in the steady state is given by:

\[ u_r^o = T_r \left( \frac{d\varphi_r^{\text{opt}}}{dt} + \frac{1}{T_r} \varphi_r^{\text{opt}} \right) \]

The optimization method consists in minimizing the copper losses in steady state while imposing the necessary torque defined by the speed regulator. To check the simulation results and to evaluate the feasibility and the quality of control, we carried out experimental test on the copper loss minimization by the flux variation method. It’s noticed that the experimental result, Fig.6 is similar to the result found by simulation Fig.7.

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**Fig.4.** Experimental optimum flux variation

**Fig.5.** Simulation results of optimal control with flux variation, Cr= 5 N.m

**Fig.6.** Simulation result of loss minimization, Cr=5N.m

Comparison between nominal & optimal
C. Copper loss minimization with \( i_{ds} = f(i_{qs}) \)

The optimization loss is given by using the objective function linking two components of stator current for a copper loss minimization. The expression of power losses is given by:

\[
\Delta P_t = \sigma L_s \left( i_{ds} \frac{di_{ds}}{dt} + i_{qs} \frac{di_{qs}}{dt} \right) - \frac{L_m}{T_s L_r} \varphi_{ds} i_{ds} \\
+ \left( R_s + \frac{L_m^2}{L_r T_r} \right) (i_{ds}^2 + i_{qs}^2)
\]

In steady state, the minimum of power losses is reached for:

\[
i_{ds} = \left( 1 + \frac{L_m^2}{R_s L_r T_r} \right)^{\frac{1}{2}} i_{qs}
\]

The behavior of the machine is simulated by using the block diagram of figure 7. The simulation results are presented on figure 8 under light load application. This method shows an important decrease in copper losses under low load torque.

D. Copper and iron loss minimization with \( i_{ds} = f(i_{qs}, \omega) \)

Loss Minimization is presented by introducing the mechanical phenomena. Copper and iron losses are given by:

\[
\Delta P_t = R_s \left( i_{ds}^2 + i_{qs}^2 \right) + \frac{R_s R_{fe}}{R_r + R_{fe}} i_{qs}^2 - \frac{L_m^2}{R_r} \omega^2 i_{ds}^2
\]

\[
i_{ds} = \sqrt{\frac{R_s R_r + R_s R_{fe} + R_r R_{fe}}{L_m^2 \omega^2 - R_r (R_r + R_{fe})}} i_{qs}
\]

The simulation results of Fig.8 shows a faster response time speed.

Fig.7. Simulation result of copper loss minimization, \( Cr=5N.m \) Comparison between nominal & optimal

Fig.8. Simulation result of copper and iron loss minimization, \( Cr=5N.m \) Comparison between nominal & optimal

IV. CONCLUSION

In this work, we have presented a new method in reducing losses while considering and keeping under control machine parameters. This method could be important for the implementation in real time field oriented control. It has successfully demonstrated the design of vector field oriented control technique with optimum rotor flux using only the stator currents and position measurements. The main advantages of this method is that it is cheap and can be applied in both open and closed loop control.
induction motor parameters: \( P_n = 1.5 \text{ kw}, \)
\( U_n = 220 \text{ v}, \quad \Omega_n = 1420 \text{ tr/min}, \quad I_n = 3.64 \text{ A(Y)} \ 6.31 \text{A(\Delta)}, \)
\( R_s = 4.85\Omega, \quad R_r = 3.805\Omega, \quad L_s = 0.274 \text{ H}, \quad L_r = 0.274 \text{ H}, \quad p = 2, \)
\( L_m = 0.258 \text{ H}, \quad J = 0.031 \text{ kg.m}^2, \quad f_m = 0.008 \text{ Nm.s/rd}. \)

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Urban Cluster Layout Based on Voronoi Diagram

— A Case of Shandong Province

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Abstract: The optimum layout of urban system is one of important contents in urban planning. To make regional urban system planning more suitable to the requirements of urbanization development, this paper tests a quantitative method based on GIS & Voronoi diagram. Its workflows include calculating city competitiveness data, spreading the city competitiveness analysis by aid of spatial analysis and data mining functions in GIS, getting the structural characteristics of urban system, and proposing the corresponding optimum scheme of the allocation. This method is tested using the data collected from Shandong Province, China.

Keywords: City competitiveness; Spatial analysis; Voronoi Diagram; GIS; Optimum layout

1 INTRODUCTION

The urbanization level embodies comprehensively the city economic and social development level, and is the important mark that city--region modernization level and international competitiveness. Now facing the economical globalization, the cities increasingly becoming the core, carrier and platform of competition in the world.

No matter in a nation or in a region, constructing the urban platform with all strength, optimizing the urban system structure, developing the urban economy, advancing the urbanization level, all of these should be done well, which can strengthen the developing predominance and international competitiveness, further win the initiative in future. Completely flourishing rural economy and accelerating the urbanization course, which are the important contents and striving aims of constructing the well-off society completely that put forward in 16th Party Congress [1]. All of these should be considered from the region angle, and by planning the more reasonable regional urban system to be achieve.

The optimum layout of urban system is always an important content of urbanization construction and urban planning study. Many scholars have conducted studies on this aspect [2,3,4,5,6]. These researches considered more about the urban space structure and evolution than its economic attraction, effectiveness and competitive superiority in the urban system, which did not consider the combined factors when conducting the urban system planning. To solve the problem, we tested a method and used the calculation data of urban competitiveness, by aid of the spatial analysis and data mining functions in GIS, Voronoi Diagram[7,8,9,10], then discussed the analysis and technical method about the optimizing scheme suggestion of urban system layout. Taking Shandong Province as an example and comparing with the past achievements, we found that the method in this paper is more scientifically reasonable.

2 DEFINING CITY COMPETITIVENESS

Competitiveness assessment is necessary in this competitive era. In urban system planning, we also need to think about the urban competitiveness assessment. Michael Porter suggested that the core of competitiveness be the concept of “Clusters” after he analyzed the comparative superiority theory in Nation Competitive Advantage [11]. In fact, the district which only possesses the superior natural resources will not become the prosperous district in the 21st century. The striding development will realize in some districts, which depend on the development of cluster (zone) to some degree.

The most influencing competitiveness assessment now in the world is WPY, founded by the World Economy Forum (WEF) and the Switzerland Lausanne international management and development college (IMD) in 1980. This assessment designed the integrated quantitative assessment index system according to the solid theoretical research with theoretical research, and began to take effect in 1989. The number of the assessment indices which are adopted at present reaches 314, and the number of nations and districts which are evaluated are up to 49. And 36 academic organizations and 3532 experts in the world are invited to participate in cooperating. Many organizations in China have had the research about competitiveness, such as the Renmin
The urban land is the carrier of all activities in a city. The city development is reflected by the change of the land to a great extent, and it is particularly true under the market economy condition. In order to study city competitiveness, we can take urban land as core and analyze the influencing factors, such as the maturity degree of urban land market and urban land use benefit, etc., and then indirectly evaluate the city competitiveness. If the urban land use condition is the result of the joint interaction of the nature, society, economy and market materials in a city, and if the urban land use benefit in a city is high, its city competitiveness generally is also comparatively high. So we analyzed and compared urban land assessment index system and city competitiveness evaluation system. We found that they have many similar contents, thus decided to use urban land evaluation results to reflect city competitiveness evaluation results, and called them the city competitiveness.

3 METHODS

The city competitiveness factors have great influence on the city development, and embody the city’s advantages of economic, social and natural conditions among cities. They are generally divided into two levels: factor and indicator.

3.1 SELECTION PRINCIPLE

(1) The changes of index have notable influence to city;
(2) The index values have clearer variable range;
(3) The index can reflect the differences among different quality cities;
(4) The indexes reflect the city development trend at present time; and have influence on city development in future.

(5) Making full use of the city statistical data which were published by national bureau of statistics of China;
(6) Adopting the non-statistics investigation data as much as possible that are collected by the authoritative organizations, like construction department and planning bureau etc.

3.2 METHOD OF EVALUATION SELECTION FACTORS

There are a lot of factors and indicators that influence the synthetic quality of urban land, which include macroscopic and microcosmic, static and dynamic, direct and indirect, and mutually contact and interaction. In order to select representative indices, adopting the following basic procedure: use the existing documents as reference, and investigate and analyze general factors and indicators that probably influence the urban land quality, finally select 82 indexes. Because it is not easy to procure effective data directly by part of the indexes, a total of 68 factors and indicators participate in the beginning of the analysis, then using SPSS10.0 to process principal components analysis. We obtain the principal components used in evaluation. The number of grading indexes is 58.

After removing the similar and repeated indexes, and extensively consulting experts across and outside the province, the final result is that the Shandong provincial city grading index system includes eight factors, 31 sub-factors and 58 indicators. The eight factors include: (1) City location, including transportation location, external radiant capacity, urban built-up area; (2) City concentration size, including population size, population density and the proportion of the urban built-up area; (3) City economy condition, including GDP, financial condition, fixed assets investment condition, commerce activity condition, external trade activity condition and finance condition; (4) City public service conditions, including school condition, medical and hygienic treatment condition; (5) Urban land use efficiency, including municipal service condition, capital construction investment intensity, the secondary and tertiary industrial increment intensity, trade intensity and labor input intensity; (6) City environmental conditions, including afforestation condition, waste treatment; (7) City economy development level, including GDP, financial condition, fixed assets investment condition, commerce activity condition, external trade activity condition and finance condition; (8) City development potential, including science and technology level, agriculture population per capita cultivated land and water resources condition etc.

3.3 IDENTIFYING THE WEIGHTS OF GRADING FACTORS

The weights of the grading factors and indicators were identified by five criteria: (1) Weights are direct ratio to the
factors’ influence on land quality, which value between 0 and 1 and their sum is 1; ② Weight values of indicators that related with every evaluation factor vary from 0 to 1, and their sum is 1; ③ the invited experts should be related domain technologist, high level administrative decision-maker, who are familiar with urban land and society economy development condition as well as have higher authority. The total is 10 - 40 persons; ④ According to corresponding work background and marking demonstration, experts give mark, and they should independently mark without consulting.

According to the above principles and adopting Delphi method, we identified the weights of grading factors and indicators in Shandong provincial city competitiveness evaluation.

### 3.4 DATA PROCESSING

In the process of evaluating city competitiveness, datum involved and dimension among each index are different, so we firstly standardized the datum. There are many methods of data standardization. According to data characteristic and research purpose, we selected order standardization law. The formula is as follows:

$$Y_{ij} = 100 \times \frac{X_{ij}}{n}$$

where $Y_{ij}$ is the score of indicator j of city i; $X_{ij}$ is the sequence of city i, which is gotten according to the value of indicator j of every city sequencing, and when the index is positive correlation with city competitiveness, the sequencing is for ascending order, otherwise for descending order. n is the number of evaluated cities.

The concrete process is as follows. Firstly, sequencing every index and counting its value, then counting sub-factors’ score through adopting the adding weights to sum method, taking the same step to count score of sub-factors. Finally we take adding weights to sum method to count synthetic score.

We calculated the index scores using the formula:

$$F_{ik} = \sum_{j=1}^{n} (W_{kj} \times Y_{ij})$$

where $F_{ik}$ is the score of index k of city i; $W_{kj}$ is the weight of factor k corresponding with indicator j; $Y_{ij}$ is the score of index i of city j; n is the number of indicators included in factor k.

We calculated the synthetic index scores by the formula:

$$S_i = \sum_{k=1}^{n} (W_k \times F_{ik})$$

where $S_i$ is the synthetic scores of grading object i; $W_k$ is the weight of factor k; $F_{ik}$ is the score of factor k of grading object i; n is the number of factors.

All the provincial cities get their total score respectively based on the calculation results of eight synthetic factors. What needs to be explained is that when taking the place order method to standard, for making the cities that participated in the competitiveness evaluation processes comparable, we carry on the unified standardization according to Shandong regionalism in 2001, which includes 17 cities, 31 county level cities, 60 counties and 12 independent and not entirely linking the piece areas under the jurisdiction of municipality, and amounting to 120 towns.

### 4 SPATIAL ANALYSIS METHOD

The spatial analysis originated from the “Computation Revolution” in geography and regional science in the 60’s. At the beginning stage, it chiefly applied quantitative (chiefly being statistic) methods to analyze the spatial distribution model of point, line and polygon (Hi Prof. Zheng, do you have any reference for this part? Thank you!). Afterwards, it even more emphasized the character of geographical space itself, spatial decision course and the temporal and spatial evolution course analysis of the complicated space system. In fact, from the map appearance (what is appearance?), people are carrying on all kinds of spatial analysis all the time consciously or unconsciously.

The spatial analysis is the general designation for analysis technology of spatial data. According to different data quality, it can be divided into: ① the analysis operation based on spatial graph data; ② the data operation based on non-spatial attribute; ③ combined operation of spatial and non-spatial data. The foundation that spatial analysis relies on is the geographical space database, and the mathematic means of its application including the logic operation, quantitative and statistical analysis, algebraic operation, etc. Its final purpose is to solve geographical space factual question that people encountered, draw and transmit geographical spatial information, especially implied information, and assist decision-making.

GIS is a science that integrates the newest technology of many disciplines, such as the relational database management, effective graphic algorithm, inserting value analysis, zoning and network analysis, which provides powerful spatial analysis tools and makes the complicated and difficult assignment become simple and easy to do. At present there are the spatial analysis functions in most GIS software. This
The article mainly depends on MapInfo Professional 7.0 [14] terrace, and uses the development languages such as Mapbasic [15] to carry on the function module developing, and realize the spatial analysis of competitive assessment in the town. The process generalized in the following:

1. Digitize 1:500000 “Shandong district map” which is published by Shandong publishing company in the year 2001;

2. Establish a database for town space position and competitiveness power assessment index, and the connection by way of administration code establishment;

3. Build Voronoi Diagram[16], as shown in Fig.1;

4. Optimize the layout of the town cluster based on Voronoi diagram: calculating the amount of town cluster (zone) (such as 4, 5, 6, 7, 8 and so on), calculating the central position of the town cluster (zone) (which is called the center of mass in town cluster) using the total point value of town competition power as the weight of grading. It has the smallest sum of distance from the location to the surrounding towns. Through the trail, the amount of the center of mass chosen this time is 8, as shown in Fig. 2.

5. Use data mining technology to carry on spatial analysis and the knowledge discovery, serve as the new layout object with the group center of mass in town, and establish Voronoi diagram again. So we can obtain the scope of town cluster;

6. Establish competitiveness power evaluation picture (dividing the value with total points value and factor serves as the radius, and the seat is the centre of a circle with the town), which includes the total points value and factor branch value picture, as Fig. 2 and Fig. 3 show;

7. Optimize the layout based on optimizing principle, which means adjusting suitably on the contrary to the facts, like incorporation and displacement, etc., analyzing competing power space analysis picture comparatively and making the final decision for the project of optimizing layout.

5 DISTRIBUTION CHARACTERISTICS AND THE LAYOUT OPTIMIZATION

According to the grand blueprint that strides across the century of the planning “Development Report of National Economy and the Society of Distant View Objective Outline of 9th Five-Year Plan and in 2010 in Shandong” [17]: build the necessary mutually modernized town systems of four administrative levels in big or middle or small city and the villages and towns, and form four industry gathering zones Jiaoji, Xinshi, Dedong, Jingjiu based on heavy chemical industry bases and the high, new technology industry and three modernized agriculture areas each having its characteristic in the construction Jiaodong area coast, one of the warring states into which China was divided during the Eastern Zhou period, located in the southern portion of modern Shandong Province Central South mountain area and one of the warring states into which China was divided during
the Eastern Zhou period, located in the southern portion of modern Shandong Province northwest China plain are quickened to put into effect Huanghe River delta to develop and “at sea Shandong” to build two striding across the century the engineering greatly, and promote to economize entirely economical to realize division of labor reasonably, harmonious development in the high administrative levels.

According to the planning mentioned above, based on the Shandong province town Voronoi diagram, there are 5 town clusters (zone) of Shandong province by optimizing: the central Shandong Province town cluster ( Jinan, Taian, Zibo, Laiwu), the coastal town cluster (Qingdao, Wei Fang, Rizhao), peninsula town cluster (Yantai, Weihai), delta town cluster ( Dongying, Binzhou ), lake area town cluster (Jining, Linyi, Zaozhuang) and Jingiu town cluster (Dezhou, He ze, Liaocheng ).

The five clusters (zone) cover 85.83% of 120 towns in Shandong province which is known from the competing power percentage of the five cluster (zone) (Fig. 4). The central Shandong town cluster has the strongest competing power, whose number of towns is placed in the middle, but the infrastructure, the efficiency of land use, the economy development level, the integrated strength are all at the first place in Shandong province. This region which aims to be the leader modern province capital in China pays more attention to develop high, new technological industry such as micro-electronics, precise engine instrument, new materials, fine chemical combination, biological project and so on, the third industry which is high level such as finance trade, business service, tourism and entertainment, science and technology consultation, higher education, science research, medical treatment, sanitation and so on by the aid of the persons with ability, developed traffic, the powerful foundation of economy technology in province capital. Industry diffusing and grads transfer should be done better especially with the chance of the region financial centre which Jinan has been made by the country. Solidify and improve the position of region centre, try best to build Jinan to be a modern integrated central city with multi-function.

Both the coastal town cluster and the lake area town cluster have their own characteristics. Qingdao is the central city in the coastal town cluster where the position condition of the town and the ecological environment are at the fist place all over the province. It is superior to other clusters for the lake area town on the centralizing scale of town, the infrastructure of town and the region develop potential. Qingdao is the central city in coastal town cluster which has the superior region position and perfect infrastructure, with the large opening, large economy and trade and extraversion. The coastal town cluster has the biggest port in Shandong and the town system with fine function which should make full use of being open to the outside in order to speed up the develop of the whole province, develop the economy and technology cooperation with other countries energetically, take part in international division of labor, catch the trends of the newest technology home and abroad, putting forth effort development high and new technology industry and the export-oriented economy and makes hard this area become the whole nation to be open one of the highest and economic the strongest export-oriented economy region of Vigour of level. The lake area town cluster is with Jining for the center, and each town distributes in minute hill lake vicinity, and takes resource exploitation and the commodity trade as the major characteristic here is that Shandong develops the largest district of latent capacity in the 21st century.

The peninsula town cluster and the delta town cluster are two characteristic town clusters of Shandong. The focal point that crowd in delta town is a Shandong is built one of engineering, the very big result had been gained in the town infrastructure construction here, town economy development standard and town public installation constructions etc, the rich superiority of petroleum resource be fully given play to, and the industry made a good job of that the petroleum is processed and the petroleum is formed a complete set or system. At the same time, adopt the method that protection nature has developed, and positively develop using the natural resources such as wasteland etc, and develop petroleum replacement such as foodstuff and agriculture by-product process, salt chemical industry, machinery, builds the material,