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Some new researches of field theory and their applications

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Abstract
When the space-dimension of calculus is extended to n, fractal and complex, and various number-systems, the field theory and its formulas may be correspondingly extended. In these cases, Gauss's theorem and Stokes's theorem, and corresponding extensions on gradient, divergence and curl are searched. Further, field theory may be applied to social science, etc. Its any development will necessarily inspire and apply to more aspects.

Keywords: field, dimension, physics, calculus, social science

Introduction

The field theory is a very important problem in mathematics, physics and many regions. In physics, field has become a basic concept since Faraday was introduced from the classical electromagnetic field and gravitational field [1] to Yang-Mills (YM) gauge field [2] and quantum field [3, 4], etc. Various fields even applied to ecology, economics and some social sciences.
Based on the various limit cycles in particle physics, we investigated the relations among the limit cycle and the oscillation-wave, and the limit cycles in the gauge field and the dynamical model, and the gauge field and the qualitative analysis theory, etc. Further, we researched the limit cycle and some unified theories on particle, and obtained some new mathematical results and equations, and proposed various possible developments of the limit cycle [5]. In this paper, we discuss field theory and some developments and applications.

Fields with n-dimension and Fractal and Complex Dimension

Mathematically, space may be extended from n-dimension to Hilbert's infinite dimensional space and Mandelbrort fractal geometry of nature [6].
First, the space-dimension of mathematics and calculus are extended to higher n-dimensions. The higher-order differential of binary function [7] can be extended to the total n-order differential of m variables:

$$d^n f = (\frac{\partial}{\partial x_1}dx_1 + \frac{\partial}{\partial x_2}dx_2 + \ldots + \frac{\partial}{\partial x_m}dx_m)^n f \quad (1)$$

The differential and partial integral of the product, and Green's theorem, Gauss's theorem, etc., can be extended to n-dimensional space, where the functions u and v can be all kinds of expressions of differential, integral and so on. For example, $u = p^n u'$. All functions of various formulas and theorems in calculus can be extended so continuously.
The integral region is extended to n dimensional Euclidean space, i.e., n multiple high dimensional integral $\int\int\ldots\int f dx_1 dx_2 \ldots dx_n$, and n-dimensional first kinds of curvilinear integral is $\int f(x,y,z,..n)ds$, and second kinds of curvilinear integral and curved surface integral [7]. They are all given expressions, which are replaced by the corresponding line elements and area elements in multiple integral.
When the integral is extended to n times, the main difficulty is that the integral region is different and related to various variables. Just as curve, surface, curved body (n-dimensional) integral is related to the shape of its curved body.
Curvilinear indefinite integral and curved surface indefinite integral and they are extended to n-dimension should be universal expression $\int f(x,y,z)d\sigma$, i.e., n-order indefinite integral. Integral from n multiple integral to curvilinear integral and n-dimensional curved body integral are all from flat Euclidean space extends to curved space.
The indefinite integral should be extended to multiple indefinite integral, and n-dimensional indefinite curvilinear integral and curved surface integral, etc. Leibniz formula corresponding integral is namely that integration by parts is extended to n multiple integral: For three functions

$$\int uvdw = uvw - \int uwdv - \int vwdu \quad (2)$$

It may be extended to n-order derivative of m functions, or n multiple integral, and n extended to any number-system.
Newton binomial theorem has been extended to m term, and n times to any number such as negative number, fraction and so on. It is completely similar to the Leibniz formula with n-order differential of the product of two functions. This can be extended to the product of m functions, and n is extended negative number is n multiple indefinite integral. The relation between n multiple indefinite integral, n-dimensional curvilinear and curved surface indefinite integral, and n multiple definite integral, n-dimensional curvilinear integral and curved surface integral is namely an extension 0f Newton-Leibniz theorem.

One dimensional definite integral is extended to integral of the first type curve, and n-dimensional $\int \vec{F}\cdot d\vec{l}$. Two and three dimensional integral of the second type curve are extended to n-dimensional $\int\sum_i P_i dx_i$. Two multiple integral is extended to integral of the first type curved surface, and n-dimensional $\iint \vec{a}\cdot d\vec{S}$. Three dimensional integral of the second type curved surface is again extended to n-dimensional $\int\sum_i a_i dx_{i+1}dx_{i+2}$.
Taylor series are extended to $n=-\infty$, i.e., Laurent series, and corresponding coefficients are extended n-order differential to n-order integral.
We extended the fractal dimension D into the complex dimension in both aspects of mathematics and physics [8]. The representation of complex dimension may be:

$$D_z = D + iT \tag{3}$$

When the complex dimension is combined with relativity, whose dimensions are three real spaces and one imaginary time, it expresses a change of the fractal dimension with time or energy, etc., and exists in the fractal's description of meteorology, seismology, medicine and the structure of particle, etc [8-10]. Physical space-time is developed to fractal and complex dimension must obtain fractal relativity [11, 12], which connects with self-similarity of the Universe and an extensive quantum theory [13]. Combining the quaternion, etc., we introduced the high dimensional time

$$ict \rightarrow ic_1t_1 + jc_2t_2 + kc_3t_3 \tag{4}$$

The arrow of time and irreversibility are derived. Then the fractal dimensional time is obtained, and space and time possess completely symmetry. We proposed a generalized Noether's theorem, and irreversibility of time should correspond to non-conservation of a certain quantity [12].
When variable in a function is complex, it is the complex functions. In calculus and various formulas of mathematics, n-order and dimension can be extended to higher n, fraction, decimal, real number, fractal, complex number, arbitrary number, quaternion, ring, number system, function, etc. The mathematics of field theory is closely related to calculus. In a certain way, n variables correspond to n-dimension space and phase space in physics. The functions of n variables can correspond to n-dimension non-Euclidean space and n+1 dimension Euclidean space. From this we should develop calculus with fractal [14].
The extensive Green-Gauss's theorem, i.e., the relation of closed n-dimensional curved surface integral and n+1 multiple integral:

$$\underbrace{\oiint\cdots\oiint}_{n}\left(\sum_{i=1}^{n+1}P_i\cos\alpha_i\right)dS_n = \underbrace{\iiint\cdots\iiint}_{n+1}\left(\sum_{i=1}^{n+1}\frac{\partial P_i}{\partial x_i}\right)\left(\sum_{j=1}^{n+1}dx_j\right) \tag{5}$$

The extensive Green-Stokes's theorem, i.e., the relation of closed n-dimensional curvilinear integral and n-multiple enclosed area integral:

$$\oint P_1dx_1 + P_2dx_2 + \ldots + P_ndx_n = \iint \pm\left(\frac{\partial P_2}{\partial x_1}-\frac{\partial P_1}{\partial x_2}\right)dx_1dx_2 \pm \left(\frac{\partial P_3}{\partial x_2}-\frac{\partial P_2}{\partial x_3}\right)dx_2dx_3 \ldots \pm \left(\frac{\partial P_1}{\partial x_n}-\frac{\partial P_n}{\partial x_1}\right)dx_ndx_1. \tag{6}$$

In (n+1)-dimensional Euclidean space the function has n+1 variables, which can have n kinds of surface integral: from n-dimensional curvilinear integral, n-dimensional surface integral, n-dimensional curved body integral to in n-dimension m(≤n) dimensional curved body integral. They may be the curved integral of the first or second type.

Various Gradient, Divergence and Curl of Field

When the field theory and its formulas, Gauss's theorem and Stokes's theorem are extended to fractal, real number, complex number and various number-systems [15], corresponding gradient, divergence and curl should be extended, and there may be different forms of extensive curl. It may combine the fractal and complex-dimension [9, 12]. The differential of the function for the vector corresponds to the directional derivative, and the inverse operation integral of the directional derivative corresponds to the curve integral. The inverse calculation of surface integral is surface differential. Further, it is extended to volume differential, etc.
The total differential of the vector field $U = U^k e_k$ is

$$dU = (dU^k + U^n\Gamma^k_{nm}dx^m)e_k \tag{7}$$

The one-order covariant derivative of tensor U^{ij}_{rs} is:

$$\nabla_k U^{ij}_{rs} = \frac{\partial U^{ij}_{rs}}{\partial x^k} + \Gamma^i_{kp}U^{pj}_{rs} + \Gamma^j_{kp}U^{ip}_{rs} - \Gamma^p_{kr}U^{ij}_{ps} - \Gamma^p_{ks}U^{ij}_{rp} \tag{8}$$

In the n-dimensional space, the gradient is:

$$Grad u = \sum_{i=1}^{n}\frac{\partial u}{\partial x_i}\vec{i}_i \tag{9}$$

The n-dimensional divergence is:

$$Div\vec{P} = \sum_{i=1}^{n}\frac{\partial P_i}{\partial x_i} \tag{10}$$

The n-dimensional curl is more complex, and is probably:

$$Rot\vec{P} = \sum_{i,j=1}^{n}\left(\frac{\partial P_j}{\partial x_i}-\frac{\partial P_i}{\partial x_j}\right) \tag{11}$$

In curvilinear coordinate system of three dimensional Euclidean geometry:

$$grad\,\varphi = g^{ij}\frac{\partial\varphi}{\partial x^j}e_i \tag{12}$$

$$div\vec{A} = \frac{1}{\sqrt{g}}\frac{\partial}{\partial x^i}(\sqrt{g}a^i) \tag{13}$$

$$rot\vec{A} = \xi^i e_i \quad (14)$$

Here $\xi^i = \frac{1}{\sqrt{g}}[\frac{\partial a_k}{\partial x^j} - \frac{\partial a_j}{\partial x^k}]$ and (i,j,k) rotate according to (1, 2, 3).

For tensor and other fields various results will be more complex. In Riemannian geometry the partial derivative of metric tensor g_{ik} derives Christoffel symbols Γ^i_{jk}, and 2-order partial derivative derives Riemann curvature tensor R^l_{ijk} [1].

Vector $\vec{a}$(t) may extend to $\vec{a}(\vec{b})$, and $\vec{a}(t,\vec{b})$, etc. Then $d\vec{a}(t)/dt$ is vector, and $d\vec{a}/d\vec{b}$ is scalar. The plane curve has curvature K, and the space curve has curvature K and torsion T. Furthermore, for n-dimensional spatial curve, there should be n-1 kind rate, which shows the degree of deviation from straight line, plane curve, 3-dimensional spatial curve to (n-1)-dimensional spatial curve, respectively. It can be completely similar to the definition as $K_n = |dt_{n-1}/ds|$, and corresponding radius $\rho_n = 1/K_n$.

In field theory, the combination of differential and integral is volume derivative (also known as spatial derivative):

$$\lim_{V\to 0}\frac{1}{V}\oint U d\vec{S} \text{ (flux)=gradU} \quad (15)$$

The volume derivative of the scalar field is its gradient.

$$\lim_{V\to 0}\frac{1}{V}\oint \vec{V} d\vec{S} \text{ (scalar flux of } \vec{V}\text{)=div} \vec{V} \quad (16)$$

$$\lim_{V\to 0}\frac{1}{V}\oint \vec{V}\times d\vec{S} \text{ (vector flux of } \vec{V}\text{)=-rot} \vec{V} \quad (17)$$

The volume derivative of vector field may derive its divergence and curl. This can be extended to area derivative and n-dimension volume derivative.

For conservative fields, the combination of circulation and volume derivatives is the Stokes's theorem:

$$\oint V dl = \iint rot V dS \quad (18)$$

Other area derivatives should also be similar to curl, which is a generalized curl. There should be a similar Stokes's theorem. There should be a similar theorem between n-dimension and (n+1)-dimension volume derivatives. It should also be similar to curl, which is a generalization of curl. Gauss's theorem is:

$$\oiint V dS = \iiint div V d\Omega \quad (19)$$

It is namely definition of divergence. Gauss's theorem and Stokes's theorem can also be extended to the relation between n and n+1 multiple integral from geometry. Further, it is extended to the corresponding relations of indefinite integral, n-order and (n+1)-order differential, and the corresponding vector form, geometric form and so on.

The scalar field u has a gradient (vector), and vector field **A** has divergence (scalar) and curl (vector), and the scalar of the scalar field can be du/dt (the rate of change of scalars). It is extended to m-rank tensor, which is similar to three degrees, and can have m+1 kind of field degree (integral or differential form). If the r-order derivative of the tensor field can be called a tensor gradient, it is a (r+1)-order tensor field:

$$GradT_{ik\ldots l} = T_{ik\ldots l,j} \quad (20)$$

Introduce generalized divergence (there are m-rank):

$$\frac{\partial T_{ik\ldots l}}{\partial x_{i(k\ldots l)}} = \frac{\partial T_{1k\ldots l}}{\partial x_1} + \frac{\partial T_{2k\ldots l}}{\partial x_2} + \ldots + \frac{\partial T_{nk\ldots l}}{\partial x_n} \quad (21)$$

In fact, it has been extended in physics, such as momentum $p_i = \frac{\partial S}{\partial x_i}$ in analytical mechanics, and in electrodynamics Maxwell equations [1].

In general relativity $R_{ik,l}$ is 3-order tensor, etc. Generally, the gradient components of the r-order tensor field are reduced, and obtain the tensor divergence, which is the (r-1)-order tensor field:

$$DivA_{ik\ldots l} = A_{ik\ldots l,i} \quad (22)$$

The tensor is j as integer, and the spinor is j as semi-integer. When j is a general real number, complex number, operator and other number systems [15], we can develop various degrees and corresponding quantities. And they may be the expression of matrix, etc.

The directional derivative is easy to be extended to n-dimensional space, and it is:

$$\frac{\partial u}{\partial l} = \sum_{i=1}^{n}\frac{\partial u}{\partial x_i}\cos\alpha_i \quad (23)$$

This represents the rate of change in any direction determined along the n-dimensional space. It corresponds to the first type curve integral in n-dimensional space. Its development is volume derivative and its generalization. The directional derivative is extended to the volume derivative, which should be $\frac{\partial f}{\partial S_{ij}}$ and $\frac{\partial f}{\partial V_{ijk}}$, etc., here S and V are area elements and volume elements, etc., and correspond to surfaces integral and volume integral, respectively. This corresponds also to the derivation of tensor as a variable.

Usual n multiple integral corresponds to the n-order partial derivative. The first-type surface integral is extended to the n-dimensional space, i.e., $\iint f(x_1, x_2, \ldots x_n) dS$. Further, it develops to the volume integral, and m (m $\leq$ n) multiple integrals in n-dimensional space, whose dimension is l^{n+m}. On the contrary,

it corresponds to the area differential, i.e., $\frac{\partial F(x_1,x_2,..x_n)}{\partial S_{ij}}$, which is possibly related to the 2-order differential $\frac{\partial^2 F(x_1,x_2,..x_n)}{\partial x_i \partial x_j}$.
Field theory can be scalar, vector, tensor, spinor and so on. Their variables and functions by differential or integral can still be scalar, vector, tensor, and spinor, etc. a_{ij} (i,j=1,2,…n) are represented by n^2 number, and correspond to the square matrix. Tensor on (k+l)-order $a^{j_1 j_2 \dots j_l}_{i_1 i_2 \dots i_k}$ are represented by n^{k+l} number.

Define the corresponding outward derivative $d\omega$ for any differential type ω [13], for example, the secondary differential type of the first type L = Adx + Bdy + Cdz is:

$$dL = dAdx + dBdy + dCdz = (C_y - B_z)dydz + (A_z - C_x)dzdx + (B_x - A_y)dxdy \quad (24)$$

Its coefficients are exactly the components of curl of the vector R. The outward derivative of the secondary type $\omega = adydz + bdzdx + cdxdy$ is the cubic form:

$$d\omega = dadydz + dbdzdx + dcdxdy = (a_x + b_y + c_x)dxdydz \quad (25)$$

Its coefficients are the divergence divR of vector R. The derivative of cubic differentiation is four times, which is equal to zero. And there is a general Poincare introduction: second outward derivative of any differential type is equal to zero d($d\omega$)=0.
In field theory the extensive Gauss's theorem is

$$\iint \dots \int \left(\frac{\partial P_1}{\partial x_1} + \frac{\partial P_2}{\partial x_2} + \dots + \frac{\partial P_{n+1}}{\partial x_{n+1}} \right) d\Omega =$$
$$\oiint \dots \oint P_1 dx_2 dx_3 \dots dx_{n+1} + P_2 dx_3 dx_4 \dots dx_1 + P_{n+1} dx_1 dx_2 \dots dx_n =$$
$$\oiint \dots \oint PdV = \iint \dots \int DivPd\Omega. \quad (26)$$

$\lim_{\Omega \to 0} \frac{1}{\Omega} \oiint \dots \oint PdV$ =Div$P$(n+1 dimension divergence)= $\sum_{i=1}^{n+1} \frac{\partial P_i}{\partial x_i}$ (27)

Similar (n+1)-dimensional gradient should be:

$$\lim_{\Omega \to 0} \frac{1}{\Omega} \oiint \dots \oint UdV = \text{GradU} = \sum_{i=1}^{n+1} \frac{\partial U}{\partial x_i} \quad (28)$$

And

$$\oiint \dots \oint UdV = \iint \dots \int GradUd\Omega \quad (29)$$

The curve integral is represented by a surface integral, in which 2-dimension is Green's theorem, and 3-dimension is Stokes's theorem. This is extensive Stokes's theorem, in which the n-dimensional closed curve integral is represented by n-dimensional surface integral:

$$\oint Pdl = \iint RotPdS \quad (30)$$

In this case the n-dimensional curl is:

$$Rot\vec{P} = \sum_{i,j=1}^{n} \left(\frac{\partial P_j}{\partial x_i} - \frac{\partial P_i}{\partial x_j} \right) \quad (31)$$

The closed curved surface integral represented by volume integral is Gauss's theorem. It is extended to the n-dimensional closed surface integral represented by the n-dimensional volume integral, which is generalized Gauss's theorem. More generally, (m-1)-dimensional closed volume integral can be represented by m-dimensional curved volume integral in n-dimensional space.
In n-dimensional space the directional derivative (23) corresponds to the gradient of n-dimensional space:

$$Gradu = \sum_{i=1}^{n} \frac{\partial u}{\partial x_i} \vec{i}_i \quad (32)$$

In n-dimensional space the form of the gradient Grad(u) and the divergence Div $\vec{A}$ are unique. But the extension of curl Rot $\vec{A}$ in n-dimensional space has probably several different forms:

1. $Rot\vec{A} = \left(\frac{\partial a_3}{\partial x_2} - \frac{\partial a_2}{\partial x_3} \right)\vec{i} + \left(\frac{\partial a_4}{\partial x_3} - \frac{\partial a_3}{\partial x_4} \right)\vec{j} + \dots$ (n term) (33)

It is the same with Eq. (32).

2. $Rot\vec{A} = \left(\frac{\partial a_4}{\partial x_2} \pm \frac{\partial a_3}{\partial x_3} - \frac{\partial a_2}{\partial x_4} \right)\vec{i} + \left(\frac{\partial a_5}{\partial x_3} \pm \frac{\partial a_4}{\partial x_4} - \frac{\partial a_3}{\partial x_5} \right)\vec{j} + \dots$ (n term) (34)

Here () may add continuously term until (n-1); at the same time, these terms can be combined differently.

3. $\begin{vmatrix} \vec{i}\frac{\partial}{\partial x_1} & \vec{j}\frac{\partial}{\partial x_2} & \dots & \vec{h}\frac{\partial}{\partial x_n} \\ a_1 & a_2 & \dots & a_n \\ \dots & \dots & \dots & \dots \\ W_1 & W_2 & \dots & W_n \end{vmatrix}$ (35)

4. Lower n-dimension $\underbrace{\oiint \dots \oint}_{n} \vec{A}d\vec{s} = \underbrace{\iint \dots \int}_{n+1} Rot\vec{A}d\vec{S}$ higher n+1 dimension.

According to the correspondence principle, these forms can be transformed into ordinary curl in the three dimensional space; on the contrary, these forms may be different extensions of ordinary curl, which will lead to a widely developed fields, and may especially combine various geometries and manifolds. ∇ is a vector operators, vectors and scalars have only one operation, i.e., gradient. Vector and vector have two operations, namely divergence and curl. Vector and tensor, spinor, twistor and so on may have n kinds of operation.
The directional derivative of scalar field should also be

extended to vector, tensor, spinor field and so on, i.e., $\frac{\partial u}{\partial l}$, $\frac{\partial A_\mu}{\partial l}$, $\frac{\partial F_{ik}}{\partial l}$, etc. But, there first are derivatives of vectors, tensors, spins, etc. In a word, any scalar, vector, and general field theory of everything can be extended to tensor, spinor, etc. On the contrary, it can be extended ∇ to tensor, spinor and so on, or there are $\nabla_{\mu\nu}$, etc., for various dimensional spaces.

According to the method [9,12], when gradient, divergence, and curl are extended to fractal, in which one term is a special fractal (decimal) term, and one row and one column of the matrix in curl are special fractal (decimal) rows and columns.

The probability theory there is the random field. In mathematics the extremal field and its direction field-flow may apply calculus of variations, and satisfy the Euler-Lagrange equation [16, 17], and correspond to the principle of least action in physics.

Various Fields in Social Sciences

Because of the importance of field in physics and psychology, the social field was researched very early. In 1951 Lewin discussed the field theory in social science [18]. Wilkinson searched the concept of field in social organization, and studied the theory and method of collective as a social field [19]. In 1973 S.F. Moore studied the semi-consistent social field as an appropriate topic of legal and social change. Social fields may be the microscopic fields or the macroscopic fields. Both is related each other [20, 21].

The interactions between social members, social system and environment form different social fields on politics, economy, society, culture, religion and so on. Helbing discussed the social field not only as an external environmental factor, and also as a mathematical model of individual interaction on individual behavior [22]. Levitt, *et al*., discussed the transnational social field perspective on society [23]. Rawolle studied the cross-field effect and temporary social field of recent Australian knowledge economy policies [24].

Generally, the field in social science is social field. Based on the social physics, we researched general social fields, which study social system by mathematical and physical methods. It can define the distribution, and social potential, force, energy, entropy, etc., and determine the field equation, and can establish qualitative analysis and the mathematical model [25]. On the contrary, the potential can be determined by equations. Mutation theory has been different potentials.

Social field can be applied to management, leadership, history, development, military science, tourism, journalism and so on. Social fields may be the scalar, vector, tensor, spinor fields, etc. These fields must be nonequilibrium and nonuniform. They form gradient for the scalar field, and divergence and curl for the vector field [25]. We may research their social meanings: for example, gradient can express the different income class, the destruction rate of the environment, the bigger gradient shows rocket cadres, increase quickly wages and so on. If the gradient is too large, the society and the environment is unstable, corresponds to the pyramid. The divergence of social field can correspond to the loss of capital.

Physics and mathematics is a powerful and important tool in modern ecology and environment science [26, 27]. Ecological field is also useful concept. Its complete mode is the unification field of human-nature in Chinese traditional culture. Using the similar formulas of the preference relation and the utility function, we proposed the confidence relations and the corresponding influence functions that represent various interacting strengths of different families, cliques and systems of organization. It produces a multiply connected topological economics. This model may describe a corruption field in usual economic system. Further, we discussed the binary periods of the political economy by the complex function and the elliptic functions [27].

We proposed the social extensive electrodynamics, and the social extensive general relativity. Everyone possesses fate and luck. Fate is various innate fields and surroundings, and corresponds to mass self. Luck is acquired activity and fortune, and corresponds to life orbit and movement, they are changeable. Both aspects may be influenced each other. General relativity shows that matter, mass and their movement determine the space-time of everyone. “The era produces their heroes, and heroes produce their era.” This exhibits unification between inevitability and chanciness in history. The era is big surroundings and conditions of historical evolution, while chance and hero, etc., are various occasional factors of happened historical events. The big mass of the center and its movement correspond to the great countries and great men that determine space-time and era, from which everyone's mass and efforts determine the orbits of life. Both determine the evolution of whole society and mankind. This as a universal physical representation of causality is a great contribution of general relativity to modern social science. It is the causality field as a common basis of various natural sciences, Buddhism and some social sciences [28].

Based on the social structure we introduced the social individual-wave duality, and researched the social topology and the social strain field [29]. A variant of the damage field D(r,t) should agree with the damage field equation.

In 1981 Lehman discussed ‘field’ in Theravada Buddhist society [30]. In 1992 Bechert researched the Buddha-field. Based on many experiments and quantum theory, we proposed the thought field [31], whose basic formula is $E = H\nu$. They form four basic functional states. The thought field is related to the extensive quantum biology and seems be new fifth interaction. In Chinese culture there have Qigong field. Generally, there is the mind-matter unification field. In psychology there is the situational force field [32]: The Situational force may influence good people turn evil.

In a word, the applications of physics and mathematics are necessarily an important direction of modern social science at 21 century. In natural science and social science there are widely change and evolutionary fields. The development of physics often leads to the progress of natural science and social science, in whose many regions field theory has been widely applied. Any development of field theory will necessarily inspire and apply to more aspects.

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