Article

Robot Motion in Radial Mass Density Field

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**Abstract:**  Control of autonomous robot motion in radial mass density field is presented. In that sense the robot motion is described as the function of the radial mass density parameters. The radial mass density field is between the maximal radial mass density and the minimal radial mass density. Between these two limited values one can use *n* points (*n = 1, 2, . . . nmax*) and calculate the related radial mass density for each point. The radial mass density is maximal at the minimal gravitational radius and minimal at the maximal gravitational radius. This conclusion is valid for Planck scale, but also for the scales that are less or higher of that one. Using the ratio of the Planck mass and Planck radius it is generated energy conservation constant with value *κ* = 0.99993392118. Further, in this theory it is possible to connect Planck’s and gravitational parameters as functions of the maximal (or minimal) radial mass density. In that sense the autonomous robot motion in radial mass density field is important for the control of the robot motion at micro and nano scales.

**Keywords:** robot motion control; maximal (minimal) radial mass density; energy conservation constant; micro (nano) robot motion; radial mass density field.

1. Introduction

The autonomous robots have a very large application area. The first one is the

application in the precise production processes. The second one is in the micro and nano

scales as it is in medicine for cell manipulation, drug delivery, medical image acquisition

and non-invasive intervention. For that application, one can use the electrical, or chemical

actuated robots [1,2-5]. The magnetic soft robots have the advantages because of the fast response, unlimited endurance, and no obstruction restrictions [6]. Here, the motion of the autonomous robots is described in the radial mass density field. This field is in the region from the minimal radius (with the maximal radial mass density, *ρr max*) and maximal radius (with the minimal radial mass density, *ρr min*). Between these two limited values one can chose *n* points (*n=1,2,..nmax* ). In the case of the precise robot motiion the number *nmax* should be biger. Contrarery, for the less precise robot motion, the number *nmax* may be smaller.

The very important consequence of the solution of the field equations by including

gravitational energy-momentum tensor (*EMT*) on the right side of the field equations

[7-10] is that the gravitational field exhibit repulsive (positive) and attractive (negative)

gravitational forces. The time transition between quantum states in gravitational field

is present in [11]. In order to precisely follow the desired trajectory of the autonomous

robot motion one can include the new Relativistic Radial Density Theory (RRDT) [12].

The particle transition and correlation in quantum mechanics is discussed in [13]

. Independent position control of two identical magnetic micro-robots in a plane using

permanent magnets and magnetically powereful micro robots is presented in [14]. This

approach represents the new approach to the medical revolution. Magnetically powered

micro-robots are discussed in [15,16].

Further, the robust control of micro-robot motion is presented in [17]. The global

positioning of robot manipulators with mixed revolute and prismatic joints is discussed

in [18]. In the case of vehicle dynamics control, a conjugate gradient-based BPTT-like

optimal control algorithm can be applied [19,20]. The same algorithm can also be adapted

to control autonomous robot (micro-nano robot) motion in combined electromagnetic and

gravitational fields. A robust motion control with antiwindup scheme for electromagnetic

actuated microrobot using time-delay estimation is presented in [21]. Further, the

quantization of the electromagnetic and gravitational fields is pointed out in [22]. The

two indipendet position control of two indentical microrobots motion in a plane are

realized by using rotating permanent magnets [23]. Magnetically powered microrobots

and the robust motion control, with antiwindup scheme for electromagnetic actuated

microrobots, are presented in [24] and [25], respectively. Robotic assisted minimally

invasive surgery is ilustrated in [26]. Design of a novel haptic joystick for the

teleoperation of continuum-mechanism-based medical robotsis is presented in [27]. In this

reference a novel mechanism with series of coupled gears, that aims for the control of

continuum robots for medical applications is pointed out.

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Positioning control of robotic manipulators subject to excitation from non-ideal sources is

discused in [28]. Further, tractor-robot cooperation is ilustrated in [29]. Indor using

positionings systems of mobile robots is presented in [30]. In this article, the problem of

the nonlinear control of the robot motion is solved by using the well known concept of the

external linearization. Recent trends in robot learning and evolution for swarm robotics is

presented in [31]. Multi robot task scheduling for consensus based fault resilient

intelligent behaviour in smart factories is discussed in [32]. A new single leg lower limb

rehabilitation robot with design, analysis and experimental evolution is evaluted in [33].

Some problems in connection with IoT based vision and remote control of a compact

mobile robots is presented in [34]. It is also important to now how the portable

surveillance robots can be used in IoT apllication [35]. The recent trends in robot

learnung and evolution for swarm robotics [36].

Here it is introduced the new notion as “the radial mass density” as the ratio of the

mass and related gravitational radius. This is very important value, because the most of the

physical items can be described by the radial mass density. There exist the maximal and the

minimal radial mass densities. The maximal radial mass density for related mass is at the

minimal radius. On the other hand, the minimal radial mass density is happened at the

maximal radius. The maximal and minimal radial mass densities are constants for the all

amounts of masses. The larger masses have the larger minimal and maximal radiuses. Of

course, the smaller masses have the smaller minimal and maximal radiuses. Since the

Planck’s mass is not the smallest mass in the space-time, the Planck’s length (radius) is not

the smallest length (radius) in it. Here it is started by presentation of the dynamics and

control of the robot motiion in general case. After that the dynamics and control of the

autonomous robot motion in two-potential electromagnetic end gravitational radial mass

density field is calculated.

**2. General case of dynamics of autonomous robot motion in radial mass density field**

The problem of the nonlinear control of autonomous robot motion here is discussed

as the function of the maximal radial mass density. In order to simplifay the relared

calculation, here it is started with he concept of the external linearization of the nonlinear

control of the robot motion in the radial mass density field. In that case, in the closed

regulation loop, one obtains the linear behavior of the hole-system. Thus, the problem of

the robot position control in the radial mass density field can be started by the calculation

of the control of the error vector, *e(t)*. This vector is a function of the radial mass density,

, and can be presented by the relations:

 (1)

Here *n=1,2,..,nmax* and *nmax***= / **. Here in (1) the subscript *w* denotes the desired

robot motion, while the variables without this subscript present the real autonomous

robot motion. Further, *Fp* is a potential force, *Ft* is a time - variation force, *Fi* is interaction

force and *N* is the related connection parameter. At the same time the relations (1) also

3 describes the canonical differential equations of autonomous robot motion in the

combination of the electromagnetic and gravitational fields. Vector *rw(t)* is the desired

(nominal) acceleration of the autonomous robot motion in the radial mass density field.

Now following the idea of the external linearization, one can introduce the following

substitution:

 (2)

Here *u(t*) is the internal control vector of autonomous robot motion in radial mass density

field. Further, applying the phase state-space variables, (z1 z2 z3)T , we obtain from (1) the

related state-space model of the robot motion in the radial mass density field:

 (3)

and

 (4)

In (4), parameters *A* and *B* are constant matrices with dimension (6x6) and (6x3),

respectively. Here, it is supposed that the disturbances in state-space model of the robot

motion in the radial mass density field (3 ) and (4) are of the initial condition types. In

order to eliminate the control error of the autonomous robot motion in the radial mass

density field, caused by the disturbances, one can introduce the following internal control:

 (5)

Here, *K* is a state space controller, *Z* is control eror, *Fp* is the potential force, *Ft* is time

variable force, *FI* is an interaction force, *N* is a constant and *c* is the speed of the light in

vacuum. Including the internal control relations (3) and (4) into (5), one obtains the related

potential force equation of radial mass density field in the linear form:

:

 (6)

Now starting from the previous relations one can generate the new equations of the

potential forces *Fp* :

 (7)

It is followed by the inclusion of the control potential force, *Fcp* , that is derived from the

artificial control field with potential control energy *Uc* . After inclusion of the relation (7)

into the relation (6), one obtains the nonlinear control of the autonomous robot (micro –

nano robot) motion in the multi-potential field as the function of the maximal radial mass

density:

 (8)

Now, using (8), the control of the nonlinear system is solved by employing the concept

of the external linearization in in the radial mass density field.

**3. Dynamics of autonomous robot motion in two-potential electromagnetic end**

**gravitational radial mass density field**

The general approach to control of the dynamics of the autonomous robot motion in

radial mass density field for more potential fields, given in (8), can also be applied to the

two-potential electromagnetic and gravitational field. In this sense, let an autonomous

robot be an electric charged particle with charge *q* and rest mass *m0* that is moving with a

non-relativistic velocity (*v << c*) in combined electromagnetic and gravitational potential

fields. Further it is also assumed that the gravitational field is produced by the spherically

symmetric non-charged body with mass *M*. In that case, the total potential energy *U* of

the autonomous robot motion in the two potential radial mass density fields is described

by the relation:

 (9)

Here *Ve* and *Vg* are the related scalar potentials of the electromagnetic and gravitational

radial mass density fields, respectively. Parameter *G* is the gravitational constant and *r* is

the radius as distance between the autonomous robot and center of the mass *M*. Now

applying (9) and using the notations (*Ee,He*) for an electromagnetic field and (*Eg,Hg*) for

gravitational field one can generate the vector equation as the explicit functions of the

Lorentz forces:

 (10)

The parameters *Ee, Eg, He* and *Hg* are vectors described by the relations:

 (11)

In this example, an autonomous robot is a particle with charge *q* and rest mass *m0* and

therefore, the autonomous robot interacts with both electromagnetic and gravitational

radial mass density fields. In that sence the relations (10) and (11) describe the dynamic of

the autonomous robot motion in two-potential electromagnetic and gravitational field.

The components of the vector *Ee* and *Eg* can be calculated by using the following equations:

 (12)

and

 (13)

The components of vectors *Ae*, *Ag, He* and *Hg* in (12) and (13) are given by the relations:

 (14)

and

 (15)

Applying (14) and (15) to the canonical differential equations of the autonomous robot

motion in the two-potential radial mass density field, and usingone obtains

the control error model of the autonomous robot motion as a function of the maximal

radial mass density:

 (16)

and

 (17)

In (17) *rw(t)* is the vector of desired acceleration of the autonomous robot motion.

The subscript *w* denotes desired values of the related variables. The next step is the

application of the concept of the external linearization in order to transform the equation

in (17) into the new relation:

 (18)

Here *u(t)* is the internal control vector and *n* is the number of the robot steps from the

minimal to the maximal rediuses in radial mass density field. From (17) and (18), one

obtains the related equivalent of the linear control error model of the autonomous robot

motion in the combined electromagnetic and gravitational radial mass density field, given

by (14) and (15).

The phase state-space variables of the system (2) are determined by using (3).

The related state-space model of an autonomous robot motion is given in matrix (6). In

order to eliminate the control error of an autonomous robot motion, caused by

disturbances of the initial condition types, one can introduce internal control in the form

of (7). Applying (7) to (18), one obtains the new relation as the function of the maximal

radial mass density in the :

(19)

Now, let the electric field *Ee* is consisting of the two electric components *Ee* = *Ede + Ece*. Here

*Ede* is a disturbance electric field that is caused by the influence of a two-potential field on

the motion of an autonomous robot in radial mass density field. The component *Ece* is an

artificial electric control field that should control autonomous robot motion in the two

potential field. Including *Ee* into (19), one obtains the nonlinear electric control of the

autonomous robot motion in the two-potential radial mass density field as the function of

the maximal radial mass density :

(20)

Taking into account the relation (11), the canonical differential equations of the

autonomous robot motion, in the two-potential radial mass density field, can be rewritten

as a function of the maximal radial mass density:

 (21)

Applying the nonlinear control *Ece* from (20) to the nonlinear dynamical model of the

autonomous robot motion (21), one obtains the closed-loop system of the linear form:

 (22)

Thus, the equation (20) is the nonlinear control, which in the closed loop with a

nonlinear canonical differential equations of autonomous robot motion (21), results

in linear behavior of the hole system (22). On that way the problem of control of the

autonomous robot motion in the combination of an electromagnetic and gravitational

radial mass density field, has been solved by employing the so-called concept of the

external linearization. This is very important for application of micro and nano robots in

the drag delivery across the human body.

4. The numerical calculation of the robot motion in the radial mass density field

Gravitational field with the mass *Mg* has the maximal and minimal gravitational

radial mass densities given in [12]:

 (23)

and

 (24)

The numerical values in (23) and (24) are constant and are valued for all amounts of the

gravitational mases *Mg*. Here the parameter *κ* is the energy conservation constant that has

been calculated by using Planck mass and Planck length [12]:

 (25)

Using the combination of the equations in (21) and (23) one obtains the canonical

differential equations of the autonomous robot motion at the minimal gravitational radius

by the maximal radial mass density:

 (26)

On the other hand, using the combination of (21) and (24) one obtains the canonical

differential equations of the autonomous robot motion at the maximal gravitational radius

but with the minimal radial mass density:

 (27)

Now, one can calculate the ratio between the maximal and minimal radial mass densities:

 (28)

This ratio is the constant and is valued for the all amounts of the gravitational masses.

Following the relation (28) one can calculate of the maximal steps *nmax* between maximal

and minimal radiuses in gravitational field. Now, for the calculation of the precise motion

of the autonomous robots in the gravitational radial direction one can introduce the varia-

ble step *nvar*. In that case it is possible to select the scale of the desirable step *ndes* of the

robot motion in the radial mass density field. Let the variable step of the robot motion in

the radial direction is given by the amount *nvar* = 100. In that case the number of the robot

steps from the minimal to the maximal radiuses has the value:

 (29)

In this calculation a robot neds cca 303 steps of the motion from the minimal to the

maximal radiuses in the radial direction. If the case that the robot motion is not in the

radial direction tnen one should use the related projection of the radial trasjectory to the

desired robot trajectory.

Now, if one wants to introduce *Ug max*and *Ug min* as the potential energies at the minimal

and maximal gravitational radiuses, respectively, then it is possible to calculate the mini-

mal and the maximal radial lengths, *Lgmin and Lgmax* , respectively, by using the relations:

 (30)

and

 (31)

From the relations (30) and (31) one can see how the potential energies in a gravitational field

can influence to the autonomous robot motion in the two-potential radial mass density

field.

**4. Conclusion**

This article is based on the new Relativistic Radial Density Theory (*RRDT*) that has

been applied to the control of the robot motion in potential fields. This is calculated as the

radial motion from the minimal to the maximal gravitational radiuses and vice-verse. In

that sense the Planck’s and gravitational parameters are described as the functions of the

radial mass density values. It is shown that the maximal radial mass density occurs at the

minimal gravitational radius of the related mass. On the other hand, the minimal radial

mass density is happened at the maximal radius of the related mass. Farther, the both

maximal and the minimal radial mass densities can also be described as functions of the

energy conservation constant *κ*. In that sense, the gravitational length, time, energy, and

temperature can be represented as functions of Planck length, time, energy, and tempera- - ture, respectively. In some of the examples it is necessary to transform the radial motion

into the rectangular coordinates by using related projection. Finally, it is shown that the

rate of the precise motion of the autonomous robots in the gravitational radial direction

can be controlled by the introduction of the variable step of the robot motion.

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