1) Names and surnames of authors of the solution

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2) Name of the technical solutions

Program package **REMOT** (**RE**alistic **MOT**ion of CPR system's carrier)

3) Key Words

CPR system in greenhouses, Carrier's position and orientation, kinematic modelling.

4) For whom the decision was done (legal entity or industries)

Scientific Research for the purpose of validation of theoretical assumptions.

5) The year when the decision was completed

2017.

6) Year when it began to be implemented and by whom

The program package **REMOT** implemented in published paper [1], in International Journal of Robotics and Automation, 2018, appropriate category **M23**.
We present the confirmation of theoretical contributions in the subtitle 4**.** The program package **REMOT – Simulation Experiments** using software package **REMOT** in paper [1].

On this basis the software package **REMOT** acquires the right to be ranked in the category **M84, substantially improved technical solution at the national level**.

7) The area and the scientific field, which the technical solution refers to

The phenomenon of deviation of the position and orientation of CPR system's carrier belongs to roots of basic research fields: mathematics, geometry, mechanics with perspective of its kinematic and dynamics models development. It means that results from this paper were demonstrated on a complex configuration of a robotic system.

8) Problem solved by technical solution

The paper contains two contributions: 1. practical and 2. theoretical. The first one is the idea for application of the CPR system intended for monitoring and treating the plants in greenhouses. We have shown several possible examples of implementation of the camera and diffuser carrier, depending upon the type, position, and height of the plants. From the control room, the technologist monitors and diagnoses the plants' state. Based on that information, he/she defines the plants treating procedure and chooses the type of treating: with water or with certain chemical solution. Also, the technologist chooses the velocity and shape of the trajectory of the camera and diffuser carrier. It is possible to treat both, the plants or the soil. The second contribution is a theoretical one. We have identified and defined the problem of deviation of camera and diffuser carrier's position and orientation during its motion. Carrier's hanging point and centre of mass do not overlap in its workspace, which was an idealized presumption in the previously published work. That fact indicates that carrier is influenced by its own weight and that it affects its translation and rotation in the workspace. This motion may set the carrier at the position of labile or stable equilibrium. The conditions when this phenomenon results in a equilibrium have been defined and solved. By using the program package **REMOT**, the simulation experiments have been generated. Based on the presented results, we can conclude that the realistic carrier's position and orientation have big deviations in comparison with the idealized ones, especially when the carrier is closer to the boundaries of its workspace. The weight of the carrier does not influence determination of the realistic carrier's position, although it presents the cause of the problem. The results from paper [1] are being used for designing a proper solution. The studied phenomenon will have a considerable influence on system's dynamic response which will be a part of our future research.

9) State of the problem solution in the world

Problem of the deviation of the position and orientation of CPR system's carrier was not analysed in available world literature. This phenomenon was first analysed in detail in [1] and by program package **REMOT**.

10) Description of the technical solution

This program system **REMOT** was generated in MATLAB. The idea of developing a CPR system for monitoring and treating the plants in greenhouses is completely original and, as far as the authors are

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aware, it has not been implemented so far. The authors consider this idea as unique and promising because by its implementation a number of advantages can be expected: generally higher productivity as well as environmental and financial benefits, to mention some of them. At present, the state of the art is such that workers monitor and treat the crops personally, which may directly threaten their health. For people to be able to approach the plants, the plants must be organized to provide appropriate space between them which means that no maximum utilization of greenhouse surface can be achieved. This problem would be avoided by application of an automated CPR system. The essence of the proposed CPR system is that it has been developed and implemented in a new area: surveillance of plants growth together with fertilizing and watering systems for use in greenhouses. The developed CPR system is adapted for the application in greenhouses for: monitoring, treating, and growing the plants. By using the CPR system the following can be achieved: preventive control of pests and diseases of plants, additional fertilizing, and treating plants and soil with water and chemicals. The CPR system could be integrated with all the other subsystems for collaborate production of plants. The CPR system is autonomous and it performs its task with minimum involvement of human labour. The CPR system is of modular design, its components are lightweight and require small forces in the ropes which enables an effective motion of the CPR system. This provides a wide range of opportunities for its use in both, small or big greenhouses. By using the CPR system, utilization of the available land area (or pots) would be much better. The CPR system allows the programmable camera and diffuser guidance of any "pallet arrangement" of the crops and/or crops arranged in pots. Fig. 1 shows only one possibility of monitoring and treating of plants with CPR system. The indicated motion allows a side treatment of tall plants. From Fig. 1, it can be seen that the load carrier moves between the rows of plants. In this case, the liquid (water or chemical solution) is sprayed spatially around the entire aboveground part of the plant. It can be noticed that the trajectory presents a combination of linear and circular (elliptical) motions. Coordinated motion of the motors moves the camera and diffuser carrier continuously at a desired velocity along the trajectory which is yellow coloured in Fig. 1. The trajectory is smooth and it consists of several simple trajectories: straight lines and circles (ellipses). Velocity of the carrier is chosen by the technologist and it can be either constant or changeable depending upon specific needs. The program logic does not allow abrupt change of the carrier’s velocity because it should stay continuous during the implementation of the task. The camera and diffuser carrier consists of two diffusers which are mounted perpendicularly to the direction of carrier’s motion, i.e. perpendicular to the row of plants. This arrangement of diffusers corresponds to the previously described complex trajectory. Also, a load carrier containing a number of cameras and diffusers can be used. In this fashion, a carrier can cover the entire height of plants. This system has the ability to close the diffusers

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automatically when diffuser(s) is not directed towards the plants. In this example, this occurs when the diffuser is moving along the lateral (left or right) edges of the workspace contour. Only a diffuser which is facing the plants is turned on. The operator can control the carrier including a possibility to stop the whole process or to restart it again on the basis of the information acquired by the corresponding sensors.

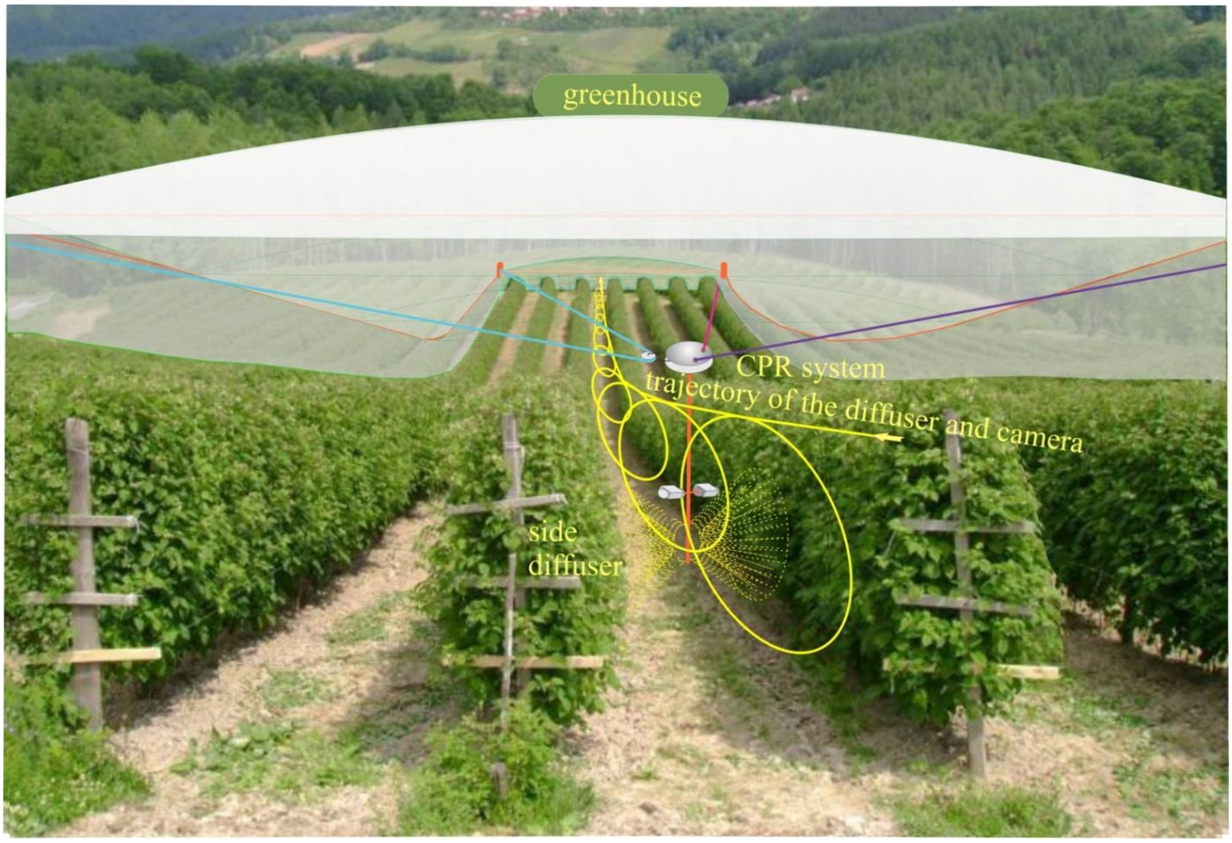

Figure 1. A CPR system for monitoring and treating plants, in 3D space.

In the case of low plants, different types of camera and diffuser carrier could be used, see Fig. 2a). In this example, it is not needed to monitor the plants from the side but only from above. In this case four diffusers are used arranged along a circular line. The camera is positioned at the axis of the carrier. The camera serves for monitoring and identifying the health condition and freshness of the plants from a close range. Based on this information, the technologist makes decisions concerning further treatment of plants. The example of the carrier shown in Fig. 2b) illustrates a system for spraying a liquid only between the plants from certain height above the soil or to the pots where the plants are positioned. By coordinated motion of the motors, camera and diffuser carrier moves continually along the rows of plants at a reference velocity. However, when the plants are in pots, the soil treating process is executed only at discrete points (at the pots). In that case, the (camera and diffuser) carrier does not spray the

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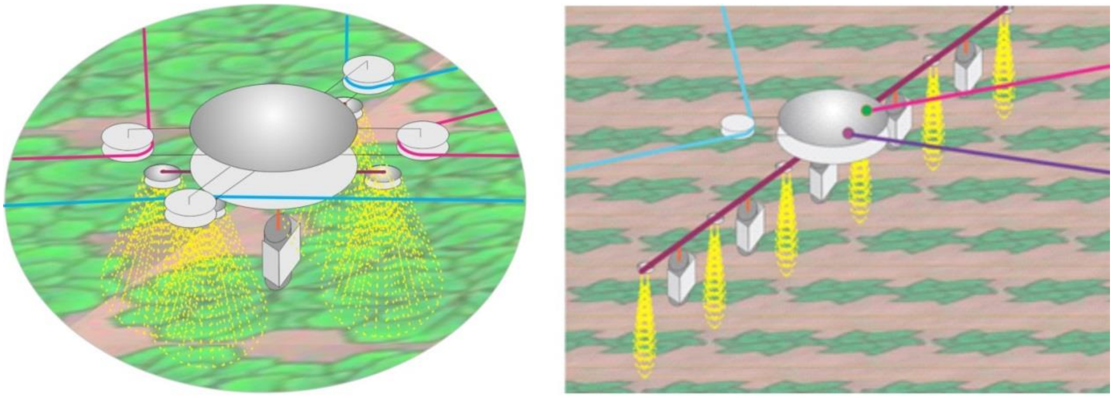
liquid, but only when it is positioned over the pot it discharges by a jet the intended amount of liquid and it repeats this operation cyclically over each pot. The diffuser and camera carrier which is shown in Fig. 2b), consists of six diffusers set perpendicularly to the soil. The intensity and frequency of jets are controlled by the program logic based on the information from sensors, while content of the liquid depends upon the recommendations of the agronomists and/or the current state of the plants.



a) b)

Figure 2. The camera and diffuser carrier for: a) low plants and b) pots.

All diffusers can be used for spraying either water or certain chemical solution. The whole process is completely autonomous and it is executed without direct human manual labour. The elements that affect the type and complexity of the CPR system's trajectory are: dimensions of the workspace, type of plants, dimension of plants, position of the plants, planned spacing between the rows of pallets or pots, type of treatment, soil, type of pots, etc. Generally, CPR system's diffuser and camera carrier used for plants monitoring and treating needs to be hanged at four upper points (O, F, G, H) of the parallelepiped workspace, as shown in Fig. 3a). In this case, the problem of carrier's orientation and position control is critical. For controlling the orientation and position of the carrier, one would need four more cables connected at four lower points of the workspace (O', F', G', H'). However, this construction would not be acceptable because of possible collisions of CPR system's lower cables with plants. We will now analyse the cause of the problem of carrier's position and orientation. In Figs. 4 and 5, we show the case when the camera and diffuser carrier is at idealized position in its whole workspace. The distance between carrier's hanging point *I* and its centre of mass *T* is different at various carrier's positions in its workspace. We can see this phenomenon in Figs. 4 and 5 at positions "I"(" I' ", " I'' "), "II", "III", "IV" and "V". Position "I" is characterized with the fact that it presents the intersection of main diagonals of the workspace, i.e. intersection of lines OG', FH', GO' and HF'. The point of intersection is labeled as M, see Fig. 3a) as well. Central vertical axis of the workspace is labeled as *a*, and it has coordinates:

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$x = d/2$ and $y = s/2$ for any *z* coordinate. Central vertical axis of the carrier is labeled as *b*. Let us consider what happens when the carrier is lowered from the point *M* along the line *a*. The carrier's hanging point *I* is lowered along axis *a* somewhat faster than point *T*. If the carrier is lower, the distance between these two points is bigger. This case is shown as carrier's position " I' " in Fig. 5. In the case when the load is lifted above point *M*, i.e. when $z > -v/2$ and $z < 0$, point *I* rises faster than point *T* along line *a*. The distance between these two points gets bigger and bigger. For $z \approx 0$, the distance between points *T* and *I* is maximal. Because both points are on line *a*, in these cases, there is no disturbance torque M_g which would rotate the carrier (see Figs. 4 and 5). All the time during motion of the carrier along line *a*, torque M_g is zero, and we have a balanced motion. During the motion of the carrier along axis *a*, the distances between points *I* and *T* are: in direction of *x* axis $S_x = 0$ and in direction of *y* axis $S_y = 0$.

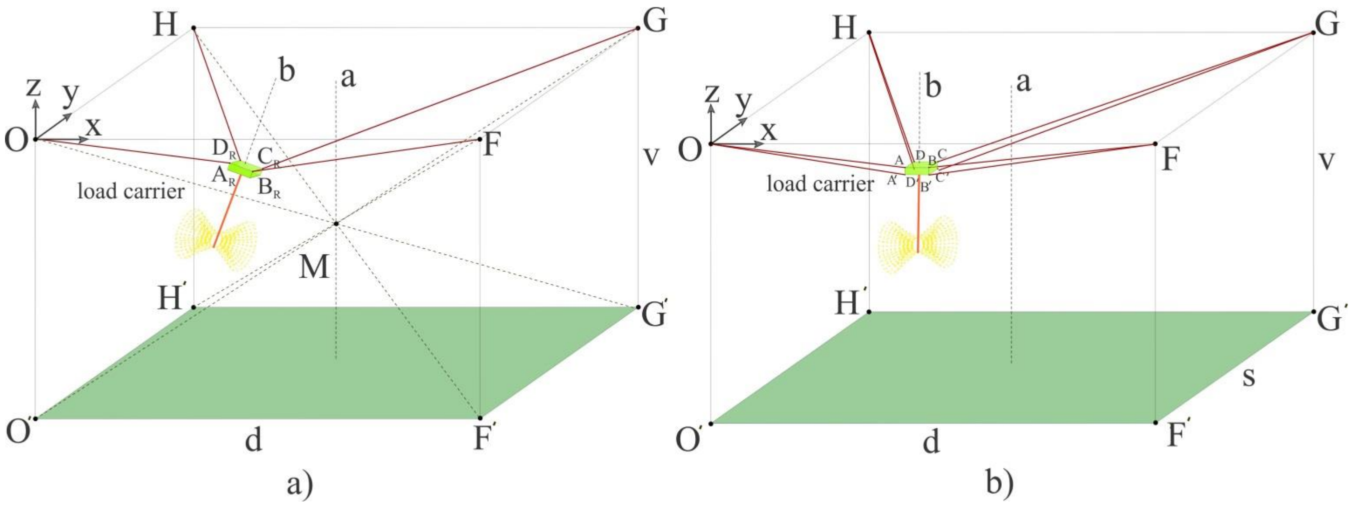

Figure 3. The CPR system hanged at four upper points (O, H, F, G): a) problem and b) solution.

For all other positions, "II","III","IV" and "V", in Figs. 4 and 5, points *I* and *T* are not at the same position in *x* or/and *y* directions. Let us consider the relative deflection of point *I* in relation to point *T*. In Fig.4, we can see the CPR system's workspace from above. In this figure, we can see the carrier's positions "I", "II", "III", "IV" and "V" and these positions are on the same level, in this case for $z = -v/2$. From this figure, we can notice that with the motion of the carrier from point *M* towards the plane which is characterized with: $y = 0$ (pos. II), $x = d$ (pos. III), $y = s$ (pos. IV) and $x = 0$ (pos. V), the point *I* is more distant from point *T*. They are at distance $\sqrt{S_x^2 + S_y^2}$ and disturbance torque is $M_g = G_m \cdot \sqrt{S_x^2 + S_y^2}$. Fig. 5 shows intersection $J - J$ where we can see the direction of the torque in

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this vertical plane (*x*-*z*). Carrier's positions presented in Figs. 4 and 5 are idealized, because the carrier needs to be vertical during its motion. However, these idealized positions are not sustainable, because of the influence of torque M_g around the carrier's hanging point *I*.

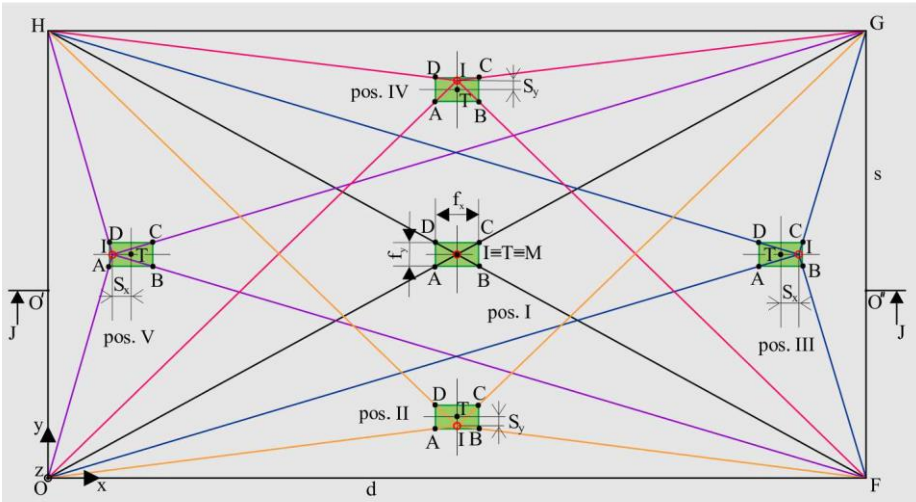

Figure 4. CPR system – the view from above, idealized case.

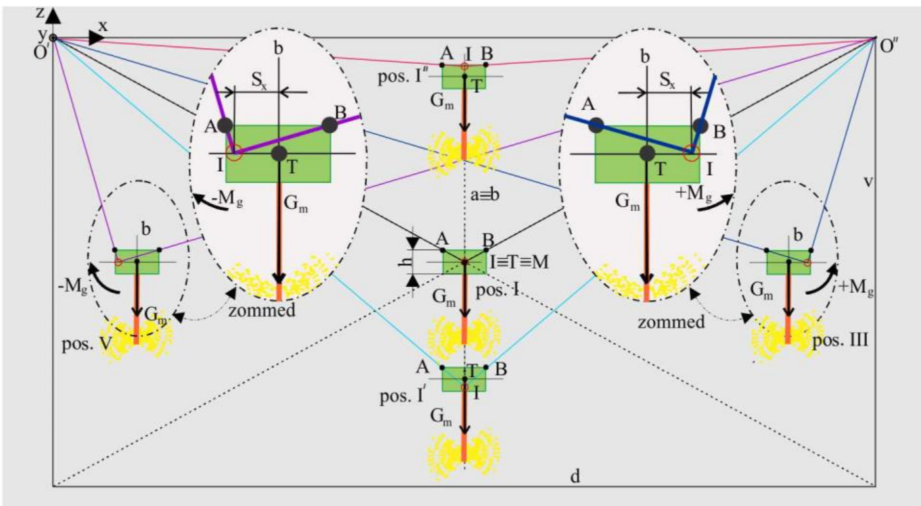

Figure 5. Cross-section JJ of the CPR system of Fig. 4, idealized case.

It is obvious that the carrier's positions from Figs. 4 and 5 are unstable. The carrier's position and orientation require an equilibrium state so that the carrier can take realistic positions. The realistic position of system's carrier presented in Fig. 6 is different from the idealized position of Figs. 4 and 5. When carrier's hanging point is closer to vertical boundary surfaces, vertical load axis *b* is more inclined with respect to line *a*. Each equilibrium point of the carrier, for which load axis *b* is inclined with respect to the vertical, is characterized by the fact that in that equilibrium carrier's center of mass T_R is at the same vertical as hanging point I_R. I_R represents carrier's hanging point at realistic conditions, while T_R represents carrier's centre of mass at realistic conditions. For the carrier to come to the equilibrium point, the following condition needs to be satisfied: $\sqrt{S_x^2 + S_y^2} = 0$, i.e. the disturbance torque at that point must have value $M_g = 0$. It can be concluded that the disturbance torque is always present at different positions in CPR system's workspace before the carrier enters the equilibrium state.

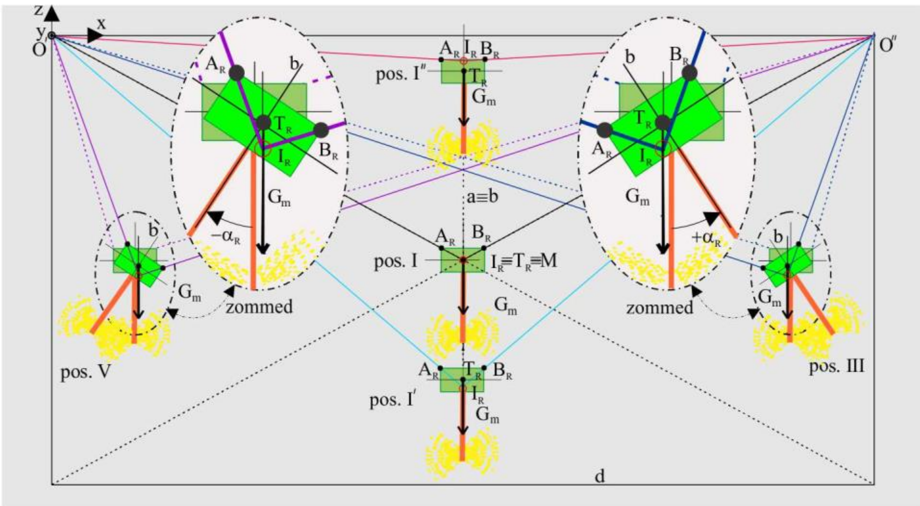

Figure 6. Cross-section *J-J* of the CPR system from Fig. 4, realistic case.

The torque is not present only during the motion along line *a*. Torque M_g grows when the distance from central axis *a,* is growing and it also grows when the carrier is closer to the boundary positions of the CPR system's workspace. When point T_R is above point I_R, we have a state of labile equilibrium (pos. " I' ","III" and "V" in Fig. 6) and when point T_R is under point I_R, we have a state of stable equilibrium (pos. " I" " in Fig. 6). This phenomenon is possible because the following conditions apply: $AO = A_R O$, $BF = B_R F$, $CG = C_R G$, and $DH = D_R H$. For the purpose of describing this phenomenon mathematically, in order to facilitate the presentation and understanding of this phenomenon, we will consider 2D case presented in Fig. 7. Coordinate system $x_1 - z_1$ is positioned at point $O_1(0,0)$. In idealized case, the cable length between point O_1 and point *A* is labeled as *m*, while in realistic case the distance between O_1 and A_R is labeled as m_R. Analogously, distances between point O_2 and points *B* and B_R are labeled as *n* and n_R, respectively. Distances *m* and m_R have the same value at any carrier's position. In the same way, distance *n* has the same value as distance n_R. If we presume that in idealized case we can determine all the variables that change during carrier's motion, we need to define four equations to determine variables: x_{AR}, z_{AR}, x_{BR} and z_{BR}. From Fig. 7 it follows:

$$f_x^2 = (x_{BR} - x_{AR})^2 + (z_{BR} - z_{AR})^2, \tag{1}$$

$$m_R^2 = x_{AR}^2 + z_{AR}^2, \tag{2}$$

$$n_R^2 = (x_{BR} - d)^2 + z_{BR}^2. \tag{3}$$

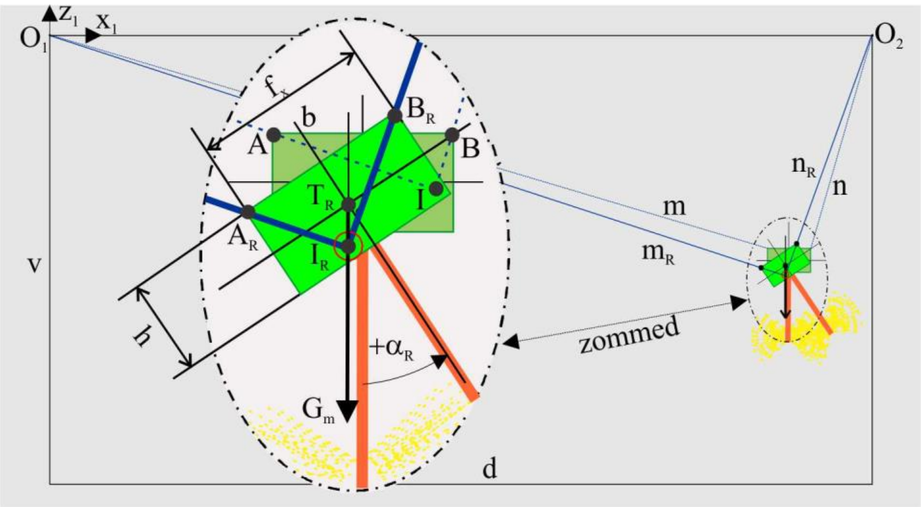

Figure 7. 2D presentation of idealized and realistic carrier's motion.

We need one more condition to determine all four variables and this is the condition that points T_R and I_R need to be on the same vertical line at the equilibrium state:

$$x_{TR} = x_{IR}. \tag{4}$$

To define the position of point T_R, we have used geometric relations from Fig. 7, to arrive at the following equation:

$$x_{TR} = x_{AR} + \frac{f_x/2}{\sqrt{1+\left(\dfrac{z_{BR}-z_{AR}}{x_{BR}-x_{AR}}\right)^2}} + \frac{h/2}{\sqrt{1+\left(\dfrac{x_{BR}-x_{AR}}{z_{BR}-z_{AR}}\right)^2}}. \tag{5}$$

From the condition of intersection of lines $O_1 I_R$ (direction of line m_R) and $O_2 I_R$ (direction of line n_R), we obtain the following equation:

$$x_{IR} = \frac{x_{AR} z_{BR} d}{z_{BR} x_{AR} + z_{AR}(d - x_{BR})}. \tag{6}$$

Now, by substituting equations (5) and (6) in equation (4), we arrive at the final equation:

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$$x_{AR}+\frac{f_x/2}{\sqrt{1+\left(\frac{z_{BR}-z_{AR}}{x_{BR}-x_{AR}}\right)^2}}+\frac{h/2}{\sqrt{1+\left(\frac{x_{BR}-x_{AR}}{z_{BR}-z_{AR}}\right)^2}}=\frac{x_{AR}z_{BR}d}{z_{BR}x_{AR}+z_{AR}\left(d-x_{BR}\right)}. \quad (7)$$

The fifth condition is determination of angle α_R:

$$\alpha_R=a\tan\left(\frac{z_{BR}-z_{AR}}{x_{BR}-x_{AR}}\right). \quad (8)$$

From equations (1) - (3), (7) and (8) we can determine all the variables needed for description of realistic carrier's 2D motion. These equations are too complicated and solutions cannot be determined analytically, so we have developed a program package in MATLAB for numerical determination of realistic carrier's motion. This program package is named **REMOT** (REalistic MOTion of CPR system's carrier). The logic used for 2D case can be used for analysis and definition of 3D case. Program package **REMOT** consists of two subroutines. The first subroutine is used for definition of idealized carrier's motion, while the second subroutine is used for determination of realistic carrier's motion defined by equations (1) – (8). We will now present one set of the simulation experiments carried out by using this program package. Dimensions of CPR system's 2D carrier's workspace are $d\times(-v)=3.2\times(-2)[m]$ and dimensions of the carrier are $f_x\times h=0.09d\times0.09(-v)[m]$. We presume that the reference trajectory of idealized hanging point I (see Fig. 7) is straight line from point $PI_{start}=[0.1,-1][m]$ to point $PI_{end}=[3.1,-1][m]$. For idealized motion, angle $\alpha=0[rad]$. This motion is presented in red colour in Fig. 8. For this reference trajectory of idealized hanging point *I*, we have also determined realistic 2D motion of carrier's hanging point I_R and angle α_R.

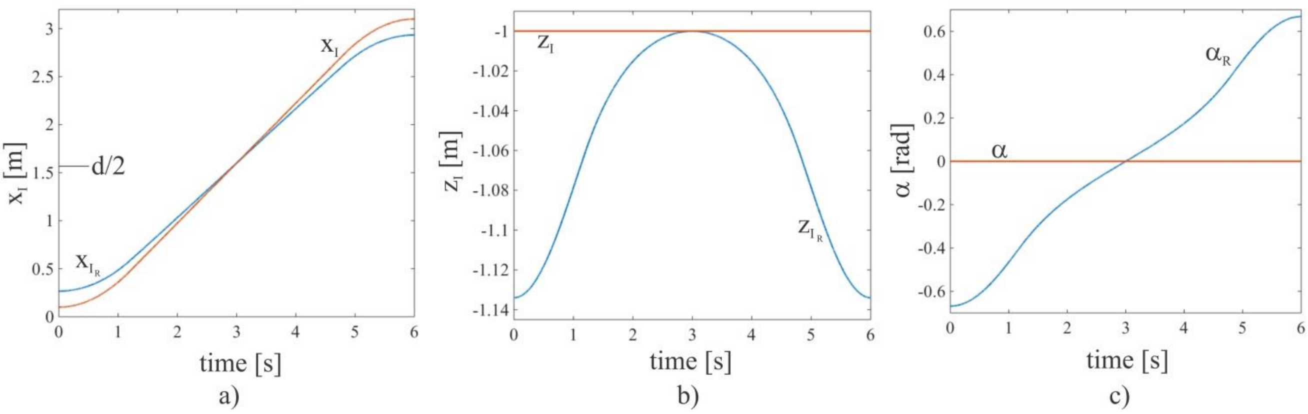

Figure 8. The simulation experiments for idealized and realistic conditions, a) *x* coordinate, b) *z* coordinate, and c) angle α. These results are presented in blue colour in Fig. 8. From these results, we can conclude that realistic motion of CPR system's carrier has big deviations in comparison with its

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idealized motion. This can be seen as big deviations along *x*, *z*, and α coordinates. We can also conclude that during the calculation of realistic motion of the carrier, carrier's mass does not participate in generation of the realistic trajectory, although it causes drastic changes of the realistic motion in comparison with the idealized one. For our future research, we will work on a solution of this problem. A hint of the possible solutions is presented in Fig. 3b). This CPR system consists of additional four cables which are connected between the upper four points of carrier's workspace and points A', B', C' and D' of the carrier.

This research was supported by the Ministry of Education, Science and Technological Development, Government of the Republic of Serbia through the following two projects: Grant TR-35003, "Ambientally intelligent service robots of anthropomorphic characteristics", by Mihajlo Pupin Institute, University of Belgrade, Serbia, and Grant OI-174001, "The dynamics of hybrid systems of complex structure", by SANU Institute Belgrade and Faculty of Mechanical Engineering University of Nis, Serbia.

References

[1] Ljubino Kevac, Mirjana Filipovic, Aleksandar Rakić: CONTRIBUTION TO MODELLING THE CABLE-SUSPENDED PARALLEL ROBOT INTENDED FOR APPLICATION IN GREENHOUSES, International Journal of Robotics and Automation, DOI: 10.2316/Journal.206.2018.2.206-5432,Vol. 33, No.2, pp. 194-201, 2018, ISSN 0826-8185, IF=0.674.

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Subject: Opinion on meeting the criteria for recognition of the technical solution

According to the submitted material and in accordance with the provisions of The Rules of procedures and methods of evaluation and quantitative presentation of scientific research results of researchers, brought by the National Council for Scientific and Technological Development of Serbia ("Official Gazette of the Republic of Serbia", No. 38/2008) **reviewer: Prof. dr Ana Djuric, Wayne State University , 4855 Fourth St. Detroit, MI 48202, U.S.A,** *has evaluated that conditions for the recognition of the properties of the technical solution are fulfilled for the following result:*

Title: program system **REMOT** (**RE**alistic **MOT**ion of CPR system's carrier), (*Projects:* Ambientally intelligent service robots of anthropomorphic characteristics, TR-35003 and "Dynamics of hybrid systems of complex structures" OI-174001*)*

Author: **Mirjana Filipovic, Ljubinko Kevac**

Category of technical solution: **M84** *„**Substantially improved technical solution at the national level**", Program system– **Software.***

Explanation

Objective and significance: *The goal is to identify the phenomenon of deviation of the position and orientation of CPR system's carrier in comparison with its idealized motion during the task implementation. The main objective is mathematical definition of the problem of the camera and diffuser carrier position and orientation of the CPR system. The significance of this research is possibilities and advantages of application of the Cable – suspended parallel robot (CPR system) in the process of monitoring and treating the plants in greenhouses are highlighted.*

Proposed solution is done in: *2017.*

Area to which the technical solution refers is: *The phenomenon of deviation of the position and orientation of CPR system's carrier belongs to roots of basic research fields: mathematics, geometry, mechanics with perspective of its kinematic and dynamics models development. It means that results from this paper were demonstrated on a complex configuration of a robotic system.*

Problem that is being solved with this technical solution: *The two contributions: 1. practical and 2. Theoretical are solved. The first one is the idea for application of the CPR system intended for monitoring and treating the plants in greenhouses. The second contribution is a theoretical one. We have identified and defined the problem of deviation of camera and diffuser carrier's position and orientation during its motion.*

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DOI: 10.2316/Journal.206.2018.2.206-5432,Vol. 33, No.2, pp. 194-201, 2018.

Essence of technical solution. *We have identified and defined the problem of deviation of camera and diffuser carrier's position and orientation during its motion. Carrier's hanging point and centre of mass do not overlap in its workspace, which was an idealized presumption in the previously published work. That fact indicates that carrier position is influenced by its own weight, that it affects its translation and rotation in the workspace. This motion may set the carrier at the position of labile or stable equilibrium. The conditions when this phenomenon results in a equilibrium have been defined and solved. By using the program package* ***REMOT****, the simulation experiments have been generated. Based on the presented results, we can conclude that the realistic carrier's position and orientation have big deviations in comparison with the idealized ones, especially when the carrier is closer to the boundaries of its workspace. The weight of the carrier does not influence determination of the realistic carrier's position, although it presents the cause of the problem. The results from this paper are being used for designing a proper solution.*

Characteristics of the proposed technical solution are following:

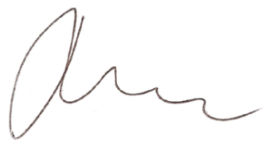
- The identification of deviation of the position and orientation of CPR system's carrier in comparison with its idealized motion during the task implementation.
- The mathematical definition of the problem of the camera and diffuser carrier position and orientation of the CPR system.
- The possibilities and advantages of application of the CPR system in the process of monitoring and treating the plants in greenhouses.

Possibility of implementation of proposed technical solution: *The developed program package* ***REMOT*** *was tested on the CPR system. This opens a space for new research, not only in the field of Robotics, but much wider.*

On the basis of all above mentioned, the reviewer has concluded that the program system REMOT includes the expert knowledge, the original scientific research contribution, and it is meeting the criteria for the recognition of the technical solutions.

Belgrade,
09.01.2019.

Reviewer:



Prof. dr Ana Djuric,
Wayne State University , 4855 Fourth St.
Detroit, MI 48202, U.S.A.

Subject: Opinion on meeting the criteria for recognition of the technical solution

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Title: program system **REMOT** (**RE**alistic **MOT**ion of CPR system’s carrier), (*Projects:* Ambientally intelligent service robots of anthropomorphic characteristics, TR-35003 and “Dynamics of hybrid systems of complex structures“ OI-174001*)*

Author: **Mirjana Filipovic, Ljubinko Kevac**

Category of technical solution: **M84** *„**Substantially improved technical solution at the national level**“, Program system–* ***Software.***

Explanation

Objective and significance: *The goal is to identify the phenomenon of deviation of the position and orientation of CPR system’s carrier in comparison with its idealized motion during the task implementation. The main objective is mathematical definition of the problem of the camera and diffuser carrier position and orientation of the CPR system. The significance of this research is possibilities and advantages of application of the Cable – suspended parallel robot (CPR system) in the process of monitoring and treating the plants in greenhouses are highlighted.*

Proposed solution is done in: *2017.*

Area to which the technical solution refers is: *The phenomenon of deviation of the position and orientation of CPR system’s carrier belongs to roots of basic research fields: mathematics, geometry, mechanics with perspective of its kinematic and dynamics models development. It means that results from this paper were demonstrated on a complex configuration of a robotic system.*

Problem that is being solved with this technical solution: *The two contributions: 1. practical and 2. Theoretical are solved. The first one is the idea for application of the CPR system intended for monitoring and treating the plants in greenhouses. The second contribution is a theoretical one. We have identified and defined the problem of deviation of camera and diffuser carrier’s position and orientation during its motion.*

State of the problem solution in the world: *Problem of the deviation of the position and orientation of CPR system’s carrier was not analysed in available world literature. This phenomenon was first analysed in detail in [1] and by program package* ***REMOT****.*

[1] Ljubino Kevac, Mirjana Filipovic, Aleksandar Rakić: CONTRIBUTION TO MODELLING THE CABLE-SUSPENDED PARALLEL ROBOT INTENDED FOR APPLICATION IN

GREENHOUSES, International Journal of Robotics and Automation, DOI: 10.2316/Journal.206.2018.2.206-5432,Vol. 33, No.2, pp. 194-201, 2018.

Essence of technical solution. *We have identified and defined the problem of deviation of camera and diffuser carrier's position and orientation during its motion. Carrier's hanging point and centre of mass do not overlap in its workspace, which was an idealized presumption in the previously published work. That fact indicates that carrier position is influenced by its own weight, that it affects its translation and rotation in the workspace. This motion may set the carrier at the position of labile or stable equilibrium. The conditions when this phenomenon results in a equilibrium have been defined and solved. By using the program package **REMOT**, the simulation experiments have been generated. Based on the presented results, we can conclude that the realistic carrier's position and orientation have big deviations in comparison with the idealized ones, especially when the carrier is closer to the boundaries of its workspace. The weight of the carrier does not influence determination of the realistic carrier's position, although it presents the cause of the problem. The results from this paper are being used for designing a proper solution.*

Characteristics of the proposed technical solution are following:

- The identification of deviation of the position and orientation of CPR system's carrier in comparison with its idealized motion during the task implementation.
- The mathematical definition of the problem of the camera and diffuser carrier position and orientation of the CPR system.
- The possibilities and advantages of application of the CPR system in the process of monitoring and treating the plants in greenhouses.

Possibility of implementation of proposed technical solution: *The developed program package **REMOT** was tested on the CPR system. This opens a space for new research, not only in the field of Robotics, but much wider.*

On the basis of all above mentioned, the reviewer has concluded that the program system REMOT includes the expert knowledge, the original scientific research contribution, and it is meeting the criteria for the recognition of the technical solutions.

Belgrade,
09.01.2019.

Reviewer:

Dr Milovan Živanović, dipl.inž,
Digital Control Systems Oziris, Kosmajska 32, 11450 Sopot,
Belgrade, Serbia

WAYNE STATE UNIVERSITY

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DECLARATION

OF USING THE PROGRAM SYSTEM **REMOT**

The program system: **REMOT (RE**alistic **MOT**ion of CPR system's carrier**)**, *Projects:* "Ambientally intelligent service robots of anthropomorphic characteristics" TR-35003 and "Dynamics of hybrid systems of complex structures" OI-174001, whose authors are Mirjana Filipovic, Ph.D,El.Eng., and Ljubinko Kevac, Ph.D,El.Eng. presents a scientific and technical achievement in robotics which we, the below-signed, use in education and research purposes as well as during the realization of our theoretical and practical solutions. We, the below-signed, confirm that we have used the program system **REMOT** since 2017.

15, January 2019.

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DIVISION OF ENGINEERING TECHNOLOGY DATE 15.1.2019

DIVISION OF ENGINEERING TECHNOLOGY WSU APPROVED AND ENDORSED

ИНСТИТУТ МИХАЈЛО ПУПИН ДОО БЕОГРАД
Број: 3249/21 -18
23. јануар 2019. године
Б е о г р а д

На основу чл. 24. Статута Института „Михајло Пупин“ ДОО Београд – Пречишћен текст („Билтен“ бр.4/2016.), а у вези чл. 25. Закона о научноистраживачкој делатности („Сл. гласник РС“ бр. 110/2005, 50/2006-испр., 18/2010 и 112/2015) и Прилога 2 Правилника о поступку и начину вредновања и квантитативног исказивања научноистраживачких резултата истраживача („Сл. гласник РС“ бр. 24/2016, 21/2017 и 38/2017), Научно веће ИНСТИТУТА МИХАЈЛО ПУПИН ДОО БЕОГРАД доноси следећу:

О Д Л У К У

ПРИХВАТА СЕ **техничко решење под називом:** Program package **REMOT** (**RE**alistic **MOT**ion of CPR system's carrier**).**

Реализатор: authors.

Аутори: Mirjana Filipovic, Ljubinko Kevac.

Број аутора: **2**, Година када је комплетирано: **2017**, Пријављена категорија: **M84**, substantially improved technical solution at the national level.

Техничко решење је рађено за: for scientific purposes, for the purpose of confirming scientific contributions.

Техничко решење користи: Wayne State University, 4855 Fourth St. Detroit, MI 48202, U.S.A. од: 2017.

Техничко решење је резултат рада на пројекту (ев.број):

- "Ambientally intelligent service robots of anthropomorphic characteristics" TR-35003,
- "Dynamics of hybrid systems of complex structures" OI-174001.

Кратак опис решења:

This program system **REMOT** was generated in MATLAB.We have identified and defined the problem of deviation of camera and diffuser carrier's position and orientation during its motion. Carrier's hanging point and centre of mass do not overlap in its workspace, which was an idealized presumption in the previously published work. That fact indicates that carrier is influenced by its own weight and that it affects its translation and rotation in the workspace. This motion may set the carrier at the position of labile or stable equilibrium. The conditions when this phenomenon results in a equilibrium have been defined. By using the program package REMOT, the simulation experiments have been generated. Based on the presented results, we can conclude that the realistic carrier's position and orientation have big deviations in comparison with the idealized ones, especially when the carrier is closer to the boundaries of its workspace. The weight of the carrier does not influence determination of the realistic carrier's position, although it presents the cause of the problem. The results from this paper are being used for designing a proper solution. The studied phenomenon will have a considerable influence on system's dynamic response which will be a part of our future research.

Рецензенти:

1. Prof. dr Ana Djuric, Wayne State University , 4855 Fourth St. Detroit, MI 48202, U.S.A.,
2. Dr Milovan Živanović, dipl.inž, Digital Control Systems Oziris, Kosmajska 32, 11450 Sopot, Belgrade, Serbia.

На основу позитивног мишљења два рецензента – експерта из области техничког решења, Научно веће је донело предметну одлуку и исту упућује надлежном Матичном научном одбору на Мишљење.

ИНСТИТУТ МИХАЈЛО ПУПИН ДОО БЕОГРАД
НАУЧНО ВЕЋЕ
П р е д с е д н и к

за

Проф. др Ђуро Кутлача*, дипл. инж.,*
Научни саветник

Достављено:
- ауторима
- Секретаријату Института