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ОДЕСЬКА НАЦІОНАЛЬНА АКАДЕМІЯ ХАРЧОВИХ ТЕХНОЛОГІЙ

ІНСТИТУТ КОМП'ЮТЕРНИХ СИСТЕМ І ТЕХНОЛОГІЙ
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XII МІЖНАРОДНА НАУКОВО-ПРАКТИЧНА КОНФЕРЕНЦІЯ

ІНФОРМАЦІЙНІ ТЕХНОЛОГІЇ І АВТОМАТИЗАЦІЯ – 2019

INFORMATION TECHNOLOGIES AND AUTOMATION– 2019

Збірник доповідей

Частина I

Одеса,
17-18 жовтня 2019

Секція 1

Наукові напрямки:

Комп'ютерні телекомунікаційні мережі та технології

Математичне моделювання та інформаційні технології

Список
скорочень організацій, представники яких взяли участь у конференції

Таблиця 1

Скорочення	**Повна назва організації**	**Місто**	**Країна**
BNTU	Belarusian National Technical University	Minsk	Belarus
CAFU	CRIAME of Armed Forces of Ukraine	Kyiv	Ukraine
DMTSAU	Dmutro Motornyi Tavria State Agrotechnological University	Melitopol	Україна
DNU	Vasyl' Stus Donetsk National University	Вінниця	Україна
EKSTU	East Kazakhstan State Technical University D. Serikbayev	Ust-Kamenogorsk	Kazakhstan
IAEl SB RAS	Institute of Automation and Electrometry of the Siberian Branch of the Russian Academy of Sciences	Novosibirsk	Russia
IRTC IT&S NAS AND MES	International Research and Training Center for Information Technologies and Systems of the National Academy of Sciences (NAS) of Ukraine and Ministry of Education and Science (MES) of Ukraine	Kyiv	Ukraine
KGES	Kharkiv general education school	Kharkov	Україна
LPNUU	Lviv Polytechnic National University	Lviv	Ukraine
NTU “KhPI”	National Technical University "Kharkiv Polytechnic Institute"	Kharkov	Україна
NTU «KPI»	National Technical University "Igor Sikorsky Kyiv Polytechnic Institute"	Kyiv	Ukraine
NU «OMA»	Національний університет «Одеська морська академія»	Одеса	Україна
NULESU	National University of Life and Environmental Sciences of Ukraine	Kyiv	Ukraine
NUOS	NATIONAL UNIVERSITY OF SHIPBUILDIN NAMED BY ADM. MAKAROV	Nikolaev	Ukraine
ONAFT	Odessa National Academy of Food Technologies	Odessa	Ukraine
ONU	Odessa I.I.Mechnikov National University	Odessa	Ukraine
SSU	Sukhumi State University	Sukhumi	Georgia
VNTU	Vinnytsia National Technical University	Vinnytsia	Ukraine
БНТУ	Белорусский национальный технический университет	Минск	Белоруссия
ВНТУ	Вінницький національний технічний університет	Вінниця	Україна
ДВНЗ «КНУ»	Державний вищий навчальний заклад «Криворізький національний університет»	Кривий Ріг	Україна
ДонНТУ	Донецький національний технічний університет	Покровськ	Україна
ІК НАН України	Інститут кібернетики імені В.М. Глушкова НАН України	Київ	Україна
НТУ «ХПІ»	Национальный технический университет "Харьковский политехнический институт"	Харків	Україна
НТУУ "КПІ"	Національний технічний університет «Київський політехнічний інститут» імені Ігоря Сікорського"	Київ	Україна
НУ «ЛП»	Національний університет «Львівська політехніка»	Львів	Україна
ОДАТРЯ	Одеська державна академія технічного регулювання та якості	Одеса	Україна

Продовження таблиці 1

Скорочення	**Повна назва організації**	**Місто**	**Країна**
ОНАЗ	Одеська національна Академія зв'язку ім. О.С. Попова	Одеса	Україна
ОНАПТ	Одесская национальная академия пищевых технологий	Одесса	Украина
ОНАХТ	Одеська національна академія піщевіх технологій	Одеса	Україна
ОНПУ	Одеський національний політехнічний університет	Одеса	Україна
ОНУ	Одеський національний університет імені І. І. Мечникова	Одеса	Україна
ОТК ОНАХТ	Одеський технічний коледж Одеської національної академії харчових технологій	Одеса	Україна
ПНПУ	Південноукраїнський національний педагогічний університет ім. К.Д. Ушинського	Одеса	Україна
ХНУРЕ	Харківський національний університет радіоелектроніки	Харків	Україна
ХРТК	Харківський радіотехнічний технікум	Харків	Україна
ЦНДІ ОВТ ЗС України	Центральний науково-дослідний інститут озброєння та військової техніки Збройних Сил України	Київ	Україна
ЮНПУ	Южноукраинский национальный педагогический университет им. К.Д.Ушинского	Одесса	Украина

ЗМІСТ

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A NUMERICAL METHOD FOR ANIMATING THREE-DIMENSIONAL OBJECTS

A numerical method for 3D object animation is proposed. Numerical algorithms are universal in terms of the ability to solve the inverse kinematics problem for any number of degrees of freedom. It is also important to move from the problem of finding a solution without restrictions on variables (i.e. rotation angles) to the problem of finding a solution with restrictions on variables.

Inverse kinematics is a widely used method of model animation. It is used to create motion in both simple and complex hierarchical models. When using inverse kinematics, it is not necessary to animate each individual node of a hierarchically connected chain to obtain its motion as a whole. To do this, you can set the necessary parameters, and the calculation of the chain motion taking into account the connectivity will be performed automatically on each frame.

The inverse kinematics chain is a hierarchy where the interaction between objects is carried out "from the bottom up", from the child object to the parent object. For example, take the classic model of a man - a bipod. If you move the body (parent object) in space, the arms, legs, and head (child objects) will move with it as if they were rigidly fixed. This is a chain of direct kinematics, where the impact on the parent object affects its child objects. If the reverse kinematics chain is implemented in this bipod, the movement in the space of a child object, for example, a hand, will lead to the movement of the parent objects: forearm, shoulder, trunk.

For the algebraic solution of the inverse kinematics problem, it is required to solve the equation for 2N independent variables [1, 2]. Since the dimension of the matrices is an element, it is possible to obtain four linearly independent equations, which makes it possible to find four variables. In fact, I would like to have a solution for an arbitrary number of variables, because the greater the number of degrees of freedom involved, the more objects can be in the chain, the more universal the manipulator. The algebraic method gives solutions for manipulators with no more than six degrees of freedom. The ability to find six variables at four linearly independent equations appears because the local matrices of objects in the chain as a whole are strongly sparse. This allows you to get a small number of solutions, and then choose from them using a certain criterion the most acceptable and reasonable. In General, six degrees of freedom allow you to create a full-fledged three-wheeled (manipulator of three objects in the chain) manipulator that meets most of the tasks of robotics, where manipulators are usually used. The disadvantages are a small number of degrees of freedom (no more than six) and difficulties with the control of restrictions on the degree of freedom.

In the geometric method, the solution in the analytical form is obtained using the geometry of the chain. In work [3], the coordinate methods described in [4] are used to obtain the analytical solution of the manipulator with seven degrees of freedom. This method is applicable to any manipulator with known geometry. The disadvantages of the method are that for its operation it is necessary to know the analytical solution for the first three objects of the chain, as well as the fact that the geometric approach is applicable only for the previously known geometry of the manipulator [5]. Algebraic and geometric methods are used together to obtain an analytical solution in [6] for a manipulator with seven degrees of freedom.

The essence of iterative methods is that the solution is achieved in the course of iterative approximation. The main problems that arise in this case are the convergence of such methods. Most iterative methods are based on algorithms for numerical minimization of a nonlinear function, but there are also algorithms that use a geometric approach.

Numerical algorithms are universal in terms of the ability to solve the inverse kinematics problem for any number of degrees of freedom. Also important is the transition from the problem of finding solutions without restrictions on variables (i.e., the angles of rotation) to the problem of finding solutions with restrictions on variables. Restrictions on the degree of freedom are essential, since the simulated objects, for which the problem of inverse kinematics appeared; usually in nature have physical restrictions on the possibility of rotation. For example, the algebraic method does not take these restrictions into account, and it is difficult to implement the restrictions using the algebraic solution. The iterative method, because the iterative approximation to the solution, which naturally gives the solution with constraints on the variables [7]. The disadvantages of the method are the complexity of calculation and convergence control.

In work [1] the iterative method using geometrical approach is described, it is a method of cyclic coordinate descent. The cyclic coordinate descent method minimizes the distance from the final effector to the target by adjusting each joint angle in turn. The method starts with the last node in the chain and works backwards, adjusting each hinge on the way. The action continues up the chain reaches the root of the chain. Then the process is repeated, starting again with the last hinge in the chain. In the end, two cases are possible: end of chain reached the goal or the cycle was repeated a number of times and was broken, when it is impossible to make the regular rotation of the end joint. This means that the distance from the base node to the target is greater than the sum of all links.

The chain may contain restrictions on the degrees of freedom for the individual hinge, which keeps it from rotating, which is physically unacceptable for the model. In other methods of inverse kinematics, this can complicate the solution sufficiently, but in the method of cyclic coordinate descent, such restrictions are easily introduced. Each step is a turn of the hinge, which makes it easy to include restrictions on these turns. It is enough to check whether the angle of rotation is beyond the permissible limits. If yes, the hinge rotates only to the limit. The use of restrictions of degrees of freedom allows more flexible manipulation of the dynamic chain. This method is simple to understand and easier to implement than numerical iterative methods. In addition, it is significantly faster than numerical algorithms, but there are some requirements of inverse kinematics, which it cannot provide or their implementation for such an algorithm is difficult. However, part of the parameters (joint friction, joint priority, etc.) to adjust the dynamics of the chain cannot be implemented, or their implementation is difficult.

Mixed methods can complement each other. In particular, in [1] used two algorithms of minimization: the method of cyclic coordinate descent (CCD) and Broyden-Fletcher-Shanno (BFS). The CCD method was used to find the initial value for the BFS algorithm. The problem with such combinations of algorithms is that such a tool as inverse kinematics requires not only control of the connected chain, but also many other adjustable parameters. Different algorithms provide tuning parameters to the parameters in different algorithms vary. Thus, when implementing a combination of algorithms, there is a problem of correct settings and transmission of such parameters within a single process of finding a solution.

Analysis [1, 8, 9, 10] of the current state of Affairs in the field of minimization of nonlinear functions showed that there are several competing algorithms that solve such problems.

The numerical algorithm is universal in terms of the ability to solve the inverse kinematics problem for any number of degrees of freedom (DOF). In the problem of inverse kinematics (IK), it is also important to move from the problem of finding a solution without restrictions on variables (i.e. on rotation angles) to the problem of finding a solution with restrictions on variables. The limitations of DOF are significant, since modeled objects, for which the IK task has appeared, usually have physical limitations on the possibility of rotation in nature. For example, the algebraic method does not take these restrictions into account, and it is difficult to implement the restrictions using the algebraic solution. The iterative method, by virtue of iterative approximation to the solution, naturally yields a solution with constraints on variables. As mentioned above, when solving the problem, we aim to get as close as possible gm_{EE} to gm_{goal}, however, we are satisfied with the equality of the extreme right columns of matrices that characterize the position in the space of the final effector and the goal behind which the chain moves. From these considerations, we define our target function as:

$$IK(\vec{q}) = \sum_{i=x,y,z} \left(g_i - e_i\right)^2$$

As you can see, it characterizes the square of the distance between the desired position of the final object and its current position. Of the variable degrees of freedom are 2n variables, that is $\vec{q} = \left(q_1, q_2, q_3, \ldots, q_{2n}\right)$. The initial value of this vector is the current values of the involved angles in the entire IK-chain. Using the algorithm of minimization of the nonlinear function of many variables, we minimize the function $IK(\vec{q})$ on the vector $\vec{q}$.

If the object characterized by the matrix gm_{gaol} lies within reach of the chain of objects. You can "straighten" the chain of objects by varying the components of the vector $\vec{q}$. In fact, by varying the rotation angles of local object matrices. As a result, the matrix values of the right columns gm_{EE} and gm_{goal} will be very close.

Such a task of minimization of a nonlinear function is solved iteratively and within the framework of this approach, several algorithms competing with each other in efficiency are known. Summarize:

$$gm_{EE} \longrightarrow gm_{goal}$$

$$goal\ function: IK(\vec{q}) = \sum_{i=x,y,z} \left(g_i - e_i\right)^2$$

$$vector: \vec{q} = \left(q_1, q_2, q_3, \ldots, q_{2n}\right)$$

The solution of the problem is to find the vector q, which is the minimum of the objective function.

The accuracy of calculations of the IK function is the accuracy with which the float type is calculated, but in fact, this question requires a detailed consideration and application of the Hamming algorithm for these purposes. It is important to be able to correctly calculate the derivative of finite differences, as in the Wood function. For example, it was experimentally shown that the variation of such a parameter as the characteristic value of the type variables used in the calculation of derivatives leads to a 25% increase in the performance of the algorithm over time. In particular, when typx = 1, the algorithm works 74 ms, and in the case of typx = 0.6, the algorithm produces a more accurate solution for 55 ms. Note that this performance improvement can be crucial in real time. This example shows that the IK-function, after its implementation, also requires significant research for the selection of optimal parameters for the algorithm.

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Збірник включає доповіді учасників XII Міжнародної науково-практичної конференції «Інформаційні технології і автоматизація – 2019»

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