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Therefore, the bookserieswillbeofusenotonlyforresearchersandteachersinMechan ical Engineering but also for professionals and students for their formation and future work. The series is promoted under the auspices of International Federation for the Promotion of Mechanism and Machine Science (IFToMM). Prospective authors and editors can contact Mr. Pierpaolo Riva (publishing editor, Springer) at: pierpaolo.riva@springer.com Indexed by SCOPUS and Google Scholar. Amandyk Tuleshov · Assylbek Jomartov · Marco Ceccarelli Editors Advances in Asian Mechanism and Machine Science Proceedings of IFToMM Asian MMS 2024 Editors Amandyk Tuleshov Laboratory of Intelligent Robotics Systems Joldasbekov Institute of Mechanics and Engineering Almaty, Kazakhstan Marco Ceccarelli Department of Industrial Engineering University of Rome Tor Vergata Rome, Italy ISSN 2211-0984 Mechanisms and Machine Science ISBN 978-3-031-67568-3 ISSN 2211-0992 (electronic) Assylbek Jomartov Laboratory of Experimental Research in Mechanics Joldasbekov Institute of Mechanics and Engineering Almaty, Kazakhstan ISBN 978-3-031-67569-0 (eBook) https://doi.org/10.1007/978-3-031-67569-0 ©TheEditor(s) (if applicable) and The Author(s), under exclusive license to Springer Nature Switzerland AG 2024 This work is subject to copyright. All rights are solely and exclusively licensed by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations,recitation,broadcasting,reproductiononmicrofilmsorinanyotherphysicalway,andtransmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed. The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use. The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, expressed or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations. This Springer imprint is published by the registered company Springer Nature Switzerland AG The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland If disposing of this product, please recycle the paper. Preface The first conference on Asian Mechanism and Machine Science, in short Asian MMS, started in Taipei in 2010 as an initiative of IFToMM, the International Federation for the Promotion of Mechanism and Machine Science (MMS), as a specific forum for Asiatic communities to promote better relations and disseminations of MMS activities in Asia. Then, following events were held successfully in Tokyo in 2012, in Tianjin in 2014, in Guangzhou in 2016, in Bengaluru in 2018, and in Hanoi in 2021 in mixed teleconference and presential modes because of the COVID-19 pandemic. This year, the Asian MMSisorganizedinKazakhstanbyaveryactiveIFToMMmemberorganization. Once again, the conference has attracted a large number of researchers coming mainly but not only from Asia in a wide range of topics, within the spirit of collaboration of the IFToMM mission. This seventh event of Asian MMS is organized in Almaty during 28–30 August 2024 with a program for paper presentations thanks to the great effort of local organizers from U. Joldasbekov Institute of Mechanics and Engineering. The Asian MMS, although primarily intended for Asian countries, serves as a global platform for participants to exchange ideas and present their research work in the several f ields of MMS in order to exchange and share new and innovative ideas. The papers in this proceedings volume were accepted after a peer review process and then they are presented in sessions of the conference which covers different topics on History and Education in MMS, Mechanism Design and Theory, Computational Methods, Machine and Robot Design, Gearing and Transmissions, Actuators and Sensors, Dynamics and Control of Multibody Systems, Vibration Techniques, Reliability, Biomechanics, Micro and Nano Systems, Experimental Methods in Mechanics, and Space Engineering and Technology.Wehavereceived78papers,ofwhich58fullpaperswereacceptedafterthe review for presenting and being included in this proceedings volume together with four keynote contributions. The majority of the papers are from Kazakhstan, but submissions camealsofromotherIFToMMcommunitiessuchasChina-Beijing,China-Taipei,India, Japan, Russia, Turkey, and even with collaboration from non-Asiatic countries. We express our grateful thanks to the members of International Scientific Committee for Asian MMS, for the support and promoting activities, namely Marco Ceccarelli (Italy) (Chair), Gondi Kondaiah Ananthasuresh (India), Yusuke Sugahara (Japan), Weizhong Guo (China-Beijing), Yu-Hsun Chen (China-Taipei), Khang Nguyen Van (Vietnam), Erkin Gezgin (Turkey), Jomartov Assylbek (Kazakhstan). We would like to express our sincere gratitude to the reviewers, who contributed to the review process with their experience and expertise in due time with a speedy but rigorous review process. The authors of the papers are also acknowledged for having finalized the papers submission after careful revision according to the review comments. We believe that the published papers can be of interest and stimulus for readers for their future activity also with the aimtocontributewiththeirresultstothenexteventsoftheAsianMMS.Wewouldliketo thank all the team members of the organizing committee at the U. Joldasbekov Institute of Mechanics and Engineering in Almaty, who helped with the conference organizatio

3D Modeling Manipulator Movement and Direct Positional Kinematic Analysis Muratulla Utenov1 ,DaurenBaltabay1,2(B) ,andZhadyra Zhumasheva1 1 Al-Faraby, Kazakh National University, Almaty 0500038, Kazakhstan dauren.baltabay.95@gmail.com 2 L.N. Gumilyov Eurasian National University, Astana 010008, Kazakhstan Abstract. Computer 3Dmodeling ofanyrobotic system has become widespread in the last few years and is used for educational and research purposes. Currently, there are lots of 3D modeling tools available for various fields of robotics research with some advantages and limitations. In this paper, as an example a computer model of the RRRRT manipulator and its movement. To create a 3D model of the manipulator, at first, you need to obtain 3D models of the manipulator com ponents: kinematic pairs, links, grips, etc. in the Maple environment. Next, it is necessary to combine all the parts of the manipulator into one system using the developed program in the Maple environment, while specifying the main con nections between them to create a full-fledged visualized moving model of the manipulator. Also, in this paper, the direct positional kinematics problem of this manipulator is studied in detail. To find the kinematic characteristics of the manip ulator, the Denavit-Hartenberg and Newton-Euler methods were rationally used. The received results are presented in the form of 3D graphs. Such graphs allow you to visually observe how the modules and directions of the given parameters of the manipulator change in the graph, depending on the manipulator position in space. Keywords: computer modeling · kinematics · positional problem · 3D model · manipulators · Maple 1 Introduction Computer 3D modeling of manipulators is one of the most promising directions in the spatial mechanisms studies [1]. Since with the increasing complexity of the designed systems, while their analytical study becomes more difficult, the creation of prototypes costs more expensive, the modeling of spatial manipulators on a computer often turns out to be the leading or even the only available research method [2]. Modeling the spatial manipulators movement even in a kinematic formulation is a complexmathematicaltask.Usingthesoftwarepackagesthatworkwiththeconstruction of three-dimensional models, the creation of objects of any complexity is a painstaking, but solvable task [3]. ©TheAuthor(s), under exclusive license to Springer Nature Switzerland AG 2024 A. Tuleshov et al. (Eds.): Asian MMS 2024, MMS 167, pp. 398–404, 2024. https://doi.org/10.1007/978-3-031-67569-0\_45 3D Modeling Manipulator Movement 399 To create a 3D model of a spatial manipulator can be used CAD systems such as SimMechanics, Autodesk Inventor, SolidWorks, Adams and software environments Matlab, Maple, etc. [4]. This paper focuses on developing algorithms and programs for creating spatial motional 3D models and solving forward positional kinematics of this 3D models of manipulators in the same program environment. Kinematics are determined by imple menting Denavit-Hartenberg, Newton-Euler, and analytical methods. The 3D motional model of manipulator is generated in the Maple math environment. The highlights of this paper are that the created algorithms and program provide building different 3D model of manipulators which can move and is controlled by generalized coordinates. Furthermore, analytical method provides the most accurate outcomes compared to other methodsandoffersanopportunitytoreceivegeneralizedcharacteristicsduringthedesign process. Building a 3D modelofmanipulator movementandsolvingkinematics inasin gle Maple programming environment is a more convenient, affordable, and productive way to conduct research, and results are given in the form of 3D graphs. Such graphs allow for visual observation of how the modules and directions of the given manipulator parameters change in the graph, depending on the manipulator’s position in space. 2 Computer3dModeling of Spatial Manipulators Modeling and assembly of links and connections of manipulators were performed using operators of the Maple software environment. Maple has lots of possibilities for creating a moving 3D model and demonstrating the movement of each link from all sides of the manipulators in space, as well as conducting kinematic and dynamic analysis in the same program, showing any changes and results. Inthissection,asanexampleofthisresearchwastakenRRRRTmanipulatorwithfive degrees of freedom, four rotational and one translational, which might be implemented in almost all spheres manufacturing, engineering and so on. Because of the axes of kinematic links are mutually perpendicular and parallel, it is available to use the method of constructing a coordinate system proposed by J. Denavit and R. Hartenberg in the formation of coordinate manipulator links systems. To create a full-fledged visualized moving manipulator model with the given laws of generalized coordinates of a manipulator, it is necessary to combine all parts of the manipulator into one system using programs in the Maple environment, while specifying the main connections between them

3 AForwardPositionalKinematicsSolutionofSpatial Manipulators Inthissection,theforwardpositionalkinematicsproblemofthisspatialmanipulatoris studiedindetail.Tofindthekinematiccharacteristicsofthemanipulator, theDenavit HartenbergandNewton-Eulermethodswererationallyimplemented.Receivedmatrix, equationsoflinearandangularvelocity,accelerationwassolvedbyanalyticalmethod usingMapleenvironment. Aspecialchoiceofcoordinatesystemsofthemanipulatorlinksallowsusingonly fourparameters(notsix,asinthegeneralcase)todescribethetransitionfromonesystem toanother.ThesystemOi−1Xi−1Yi−1Zi−1canbetransformedintothesystemOiXiYiZi bymeansofrotation,twotransfersandonemorerotation. The resulting transitionmatrix connecting the systemsOi−1Xi−1Yi−1Zi−1 and OiXiYiZi istheproductoftheabovematrices: Ai−1 i =R(Zi−1,θi)T(Zi−1,si)T(Xi−1,ai)R(Xi,αi) (1) ThematrixAi−1 i iswritteninthefollowingform. Ai−1 i = Ri−1 i −→ Oi−1 i 0 1 , (2) 3D Modeling Manipulator Movement 401 Fig. 1. 3D motional model of the RRRRT manipulator in several positions Theposition and orientation of the i-th link of the manipulator in the reference frame O0X0Y0Z0 associated with the rack is determined as follows [5]: A0 i = A0 1A1 2A2 3 ...Ai−1 i The angular velocity − → = R0 i −→ O0 i 0 1 . (3) ωi of the i-th link relative to the base coordinate system is represented as follows [17]: −→ ωi = −→ → ωi−1 +R0 i−1 − −→ z 0˙ qi, if the i − th kinematic pair is rotational, ωi−1,if the i − th kinematic pair is translational, Then the angular acceleration − → (4) ε i of the i-th link relative to the base coordinate system is determined by the expression: ⎧ ⎨ εi = ⎩ εi =εi−1 + R0 i−1z0¨qi +ωi−1 × R0 i−1z0˙ qi , if the i − th kinematic pair is rotational, εi−1, if the i − th kinematic pair is translational

Definition and Visualization of Distributed Dynamic Loads of Manipulators Muratulla Utenov1 ,Nurzhan Utenov1, Yerbol Temirbekov1(B) Saltanat Zhilkibayeva2 ,Zhadyra Zhumasheva1 , ,Bolat Yespayev1, and Dauren Baltabay3 1 Al-Farabi Kazakh National University, 050010 Almaty, Kazakhstan umu53@mail.ru 2 M.Auezov South Kazakhstan University, 160000 Shymkent, Kazakhstan saltanat.zhilkibaeva@auezov.edu.kz 3 L.N.Gumilyov, Eurasian National University, 010008 Astana, Kazakhstan Abstract. In this paper, an approach to 3D modeling of spatial manipulators using the Maple 2023 is proposed. Algorithms and program codes have been developed in order to obtain 3D computer models of manipulators controlled by generalized coordinates. Implementation of developed algorithms and program codes made it possible to create 3D computer models of manipulators with the accurate images of links and their cross sections, kinematic pairs, grips and loads, with various structures and degrees of freedom and which are clearly visible in three-dimensional space. Whenmanipulators move, from own masses of links the distributed dynamic loads of a complex nature arise in the links. Such dynamic loads cause the prob lems: for example, due to large dynamic loads or due to large deformation of the links, the manipulator may fail, etc. Therefore, analytical approaches have been developed to determine the patterns of dynamic loads distribution along the longitudinal axes of manipulator links. Algorithms and program codes have been developed for constructing diagrams of distributed dynamic loads in mutually per pendicular planes formed by the main axes of the cross sections of the links and the axes passing along the links. Through this it is possible to see changes in the direction and magnitude of distributed dynamic loads in all cross sections of the links for the full working process of the manipulator. This enables to consider the found dynamic loads in strength and stiffness calculations of manipulator links, which are important in design of new innovative manipulators. Keywords: Manipulators · Computer 3D Modeling · Maple 2023 · Kinematics · Dynamic Loads · Dynamic Loads Diagrams 1 Introduction In recent years, 3D computer modeling of robotic systems has been widely used for research and educational purposes, since it is one of the most promising and effective areas ofresearchonspatialmanipulators.Withtheincreasingcomplexityofthedesigned ©TheAuthor(s), under exclusive license to Springer Nature Switzerland AG 2024 A. Tuleshov et al. (Eds.): Asian MMS 2024, MMS 167, pp. 405–413, 2024. https://doi.org/10.1007/978-3-031-67569-0\_46 406 M. Utenov et al. robotic manipulators, their analytical study becomes more difficult, and the creation of experimental samples becomes more expensive. 3D computer modeling of robotic manipulators is often the most appropriate research method, or even in some cases may be the only available method. Currently, there are CAD, CAM and CAEsystemscapable ofcreating 3D models of spatial manipulators,suchasSimMechanics,AutodeskInventor,SolidWorks,CadMech, Adams and others. AroboticOLPsystemcalledRobSim,basedonSolidWorksMicrosoftVisualStudio 2010 was developed [1]. RobSim is designed as an additional tool for the widely used SolidWorks CADsoftware. Integrating of SolidWorks and Matlab/Simulink in the Mat lab/Simulink, performed through the implementation of CAD models created earlier in the SolidWorks program was described [2]. A computer model of a three-bar vertically walking robot in the Matlab was developed, which shows in general terms the principle of operation of such robots [3]. The simulation of the motion of a vertically walking robot was carried out using the SimMechanics library of Simulink in the Matlab. SolidWorks is a CAD software system with great performance in 3D modeling, visualization and simulation with a rich API containing hundreds of functions. Unfor tunately, there are no existing add-ons or toolkits in SolidWorks to control the created 3Dmodelsofrobotic manipulators. The strength of parallel manipulators with statically determinate and indeterminate structures was investigated, taking into account dynamic loads [4–6]. One difficulty of analyzing the stress-strain state of manipulator links is due to the fact that the manipulator under study is in motion and at the same time distributed dynamic loads of a complex nature arise from the mass of the links in each cross section of the links. These dynamic loads change their magnitude, direction and depend on the kinematic characteristics of the links. Since the manipulator is moving, it is not known in which cross section of the link and at which position of the manipulator the maximum value of any internal force or deformation occurs. Therefore, it is necessary to study the stress-strain state of the manipulator for a full working cycle. It is also necessary to visualize the stress-strain state of all links during the full operating cycle of the manipulator so that all types of dynamic loads, internal forces and deformations are clearly visible in all cross sections of the links. This permits the designer to analyze the stress-strain state of each link and make the right decision when calculating the strength and stiffness of manipulator links. 1.1 Algorithm for 3D Modeling of Manipulators in the Maple’23 TheMaple2023softwareincludesthree–dimensionalprimitivesoftheplottoolspackage allowing design engineers to build three-dimensional shapes and surfaces– cones, cylin ders,parallelepipeds,cubes,polyhedra,etc.Withthehelpoftheseprimitives,links,racks, grips andkinematicpairsofmanipulatorsarebuilt.Theobtainedthree-dimensionalparts in the Maple 2023 can bemovedinthedirection of three axes of space and rotated along these three axes. Usingtheobtainedlinks, kinematic pairs, grips, racks a 3Dmodelofthe manipulator canbeassembled.Further,alltheelementsofthemanipulatorarecombined into one system by introducing basic joints (kinematic pairs) from the grip to the rack, with the construction of a complete visual moving model of a manipulator controlled by Definition and Visualization of Distributed Dynamic Loads of Manipulators 407 generalized coordinates. In the Maple 2023, it is possible to join links rigidly or allow ing relative motion to each other. Therefore, the designer can build manipulators of the necessary structure and degree of freedom. Using the mentioned algorithms, program codes for building 3D models of manipulators, the movement of which is controlled by generalized coordinates, have been developed in the Maple 2023. The implementation of the developed algorithms and program codes made it possible to create 3D computer models of manipulators with clear images of links and their cross sections, kinematic pairs, grips and loads, with various structures and degrees of freedom, well-viewed from all sides of the space (see Fig. 1, 2). Using this algorithm, the designer can build 3D computer models of manipulators with any desired structure and with different degrees of freedom. By setting certain patterns to the generalized coordinates of the obtained manipula tors, their movement in space can be seen. Fig. 1. A six-bar manipulator with five degrees of freedom (RRRRT), with four rotational and one translational kinematic pairs