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Simulation of Pick and Place Robotics System Using Solidworks Softmotion

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***Abstract*— This paper presents the design of pick and place robotics system using Solidworks Softmotion software. The software is used to design a Cartesian robot and an articulated industrial robotic arm with different grippers. The robot was designed using the Solidworks 3D CAD software to shorten the robot development time, and improve the speed and quality of the robot design. The Solidworks 3D CAD software consist of four sections which is manual drawing, part module, assembly module and drawing module. Solidworks software was chosen as it enables analysis and simulation of the pick and place industrial robotic arm design. The results of simulation Xpress study and motion study of the modelled articulated robot arm part and assembly are presented to demonstrate the pick and place robotics system. This project indicated that the Solidworks Software is a suitable tool that enabled the design of a robotic system to be carried out in a short duration.**

***Keywords*— Pick and place workstation, Solidworks 3D CAD, Soft motion, Simulation Xpress study, motion study, grippers**

I. Introduction

In recent years, the use of robotic automation in manufacturing industries has increased tremendously. Robotics has enabled flexibility in manufacturing processes that enables production of high quality goods at relatively low cost [1]. Robots that are able to perform task efficiently are now a requirement in most factories.

Thus, there are now increasing need for better robots that are able to perform various tasks. To enable efficient robots to be designed in the shortest time possible at a lower cost, various softwares have been designed to help engineers in their development task. Currently there are softwares that enable the design and simulation of a real world robot into three dimensions (3D) [2]. This paper presents the design of an industrial robot using 3D computer aided design (CAD) software called Solidworks. This software was chosen as it had previously been used by other researchers and was able to help shorten robot development time, increase the productivity of the robot designer and improve the speed and quality of robot design [3].

Solidworks enables development time to be shortened by enabling easy changes to the robot design. The use of Solidworks software is to facilitate the following goals.

- To design a Cartesian robot and articulated robot arms with different gripper for pick and place robotics system which enables to understand the 3D geometry model.
- To analyse the pass stress analysis of articulated robot arm's base by using simulation Xpress study.
- To analyse the movement of articulated robot arm operation by using motion study.

II. Overview of Solidworks

Figure 1 shows the four important sections of Solidworks. As seen in the flowchart, Solidworks contains four important sections which is manual drawing, part module, assembly module and drawing module, as shown in Figure 1.

Manual drawing and part module enables the user to model and design parts of the robot. This section contains Simulation Xpress study: Xpress study enables various simulation tests to be carried out. An example of simulation is to check loading capability of a created part. For example, simulation can be carried out to test loading effect on a modelled part where the load applied will be similar to the load the parts will be exposed to in the real world. The user must enter part information and specifications such as restraint, load and material of the part [4].

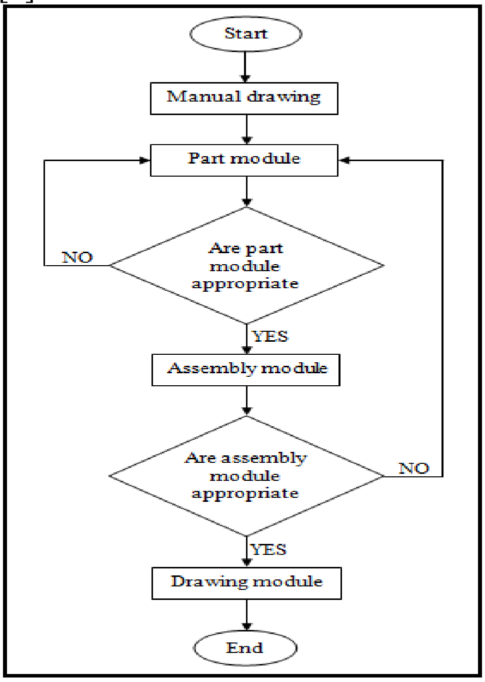


Fig. 1 Solidworks Methodology flowchart

The Assembly module is the section that enables the parts to be modelled in an assembly. It consists of three units which are bottom up assembly, using assemblies and motion study [5]. This section enables the user to assemble the parts together and subsequently carry a motion study on the assembled system. Motion study also known as animator is a study of moving system or mechanism. It enables the user to create movies of movement of the created assemblies. Three types of motion study are available, which are animation, basic motion and motion analysis.

The final section is the drawing module that creates the drawing of the created parts in various formats .

III. DESIGN AND SIMULATION OF PICK AND PLACE WORKSTATION

A. Design And Assemble Of The Parts Of The Pick And Place Workstation

The development procedure followed the flow chart as in Figure 1. First, the dimension of each part was defined and designed such that all parts can be matched together. The smallest parts that do not affect the motion and assembly of robot were ignored. All of the Cartesian robot and articulated robot arms were name. The parts are called: robot 1, robot 2, robot C, base, body, upper arm, fore arm, wrist, gripper, vertical shaft, hand holder, moveable hand and others.

Subsequently, the Cartesian robot and articulated robot arms were modelled. Both robots were chosen for the system it can be programmed to carry out various task. After part modelling, the individual components were assembled into a single assembly file. The movement and rotation of joints were set up in the robot models and motion analysis was introduced. Solidworks was then used to simulate the whole automation assembly system.

Figure 2 shows the components that were used to assemble the robot. Subsequently, other components were added to the assembled robot to create the whole system. Parts that have been created were gathered into robot 1 assembly file, as follows; conveyor A, conveyor B, section A, section B, section C, section D, product base, product cylinder, product cover and others.

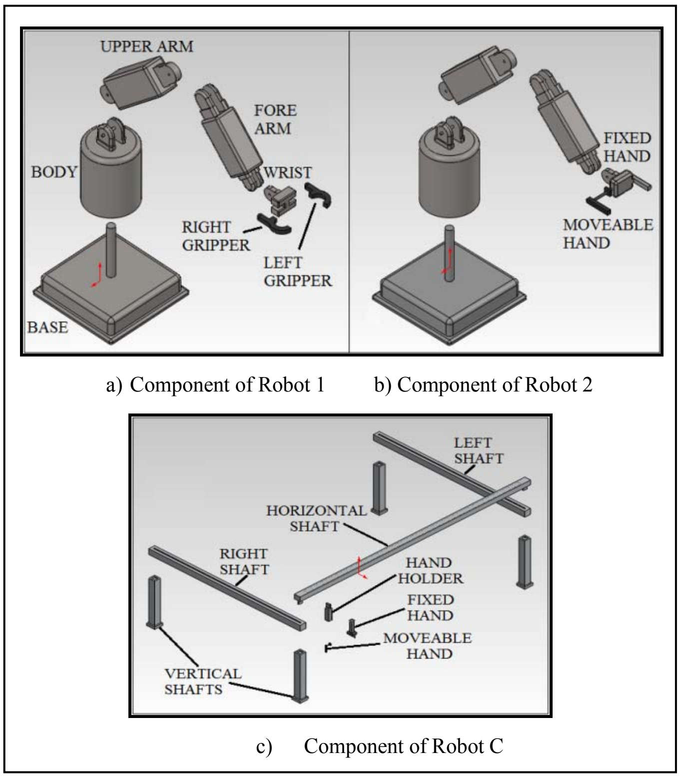
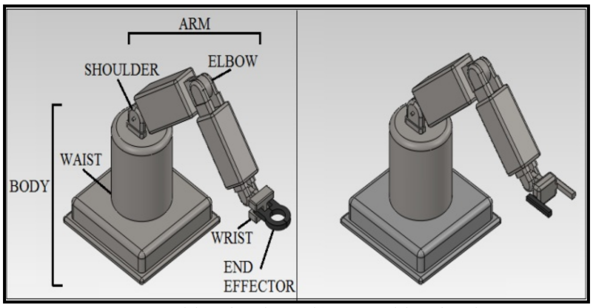
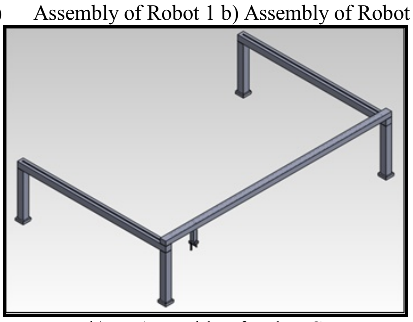


Fig. 2 Component of Robot 1, Robot 2 and Robot C

Figure 3 shows the assembled robot parts. A motion for each part was created in this assembly file. Figure 4 depicts the whole system model.



a) Assembly of Robot 1 b) Assembly of Robot 2



b) Assembly of Robot C

Fig. 3 Assembly of robots: Robot 1, Robot 2 and Robot C..

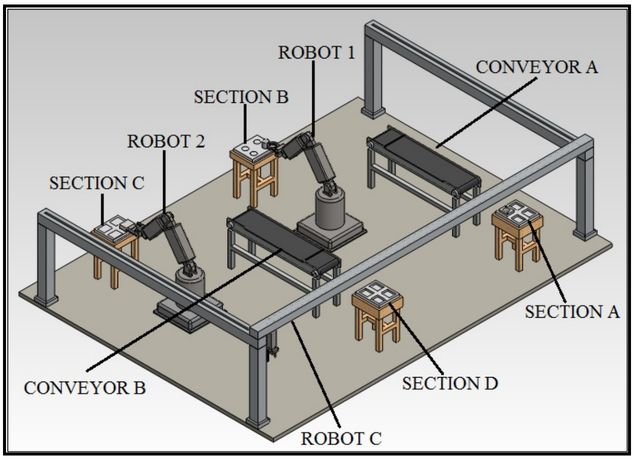


Fig 4: Pick and place robotics system.

B. Simulation Of Pick And Place Workstation

On completion of the part modeling and assembly section, the operation and sequence for the pick and place operation of the robotics system was designed. The sequence is given in Table 1.

Positioning of the components with angles such as upper and forearm were calculated in order to place it at the desired position. Pythagorean Trigonometric Identity was used to place upper and forearm at the correct angle.

TABLE I
EXAMPLE OF OPERATION SEQUENCE FOR THE PICK AND PLACE OPERATION OF THE ROBOTICS SYSTEMS

1	Hand holder of robot C move to section A to grasp and pick product base then placed it onto conveyor A.
2	Roller 1 of conveyor A rotate to move product base to the other side.
3	Robot 1 move to grasp and pick product cylinder at section B then placed it into product base.
4	Hand holder of robot C grasp and pick product. Cylinder and base combination then placed it onto conveyor B.
5	Robot 2 move to grasp and pick product cover at section C then placed it onto product base and cylinder combination.
6	Roller 2 of conveyor B rotates to move completed product to the other side.
7	Hand holder of robot C grasp and pick completed product then placed it into storage slot of section D.
8	Hand holder of robot C then return to its origin location

IV. RESULTS AND DISCUSSIONS

The completed 3D model of the pick and place robotics system that was assembled using a combination of the created robots was then tested using Xpress study and its movement and operation analysed using motion study.

A. Simulation Xpress study

The stress analysis was carried out on the base of robot 1. All faces and edges were selected except the cylinder's face and edge of the base as the fixtures to remain fixed during the analysis [6]. Force with a negative Y-axis direction was applied as load to the top face of cylinder. The mass that the robot base accommodates include body, upper arm, forearm, wrist and gripper was calculated. The weight of this components m= 22.21084 kg.

Newton Second Law, Equation {1}, was used to calculate the force applied to the robot base.

$$\{1\} \quad \mathbf{F=ma} \text{ ,}$$

Where :

F=force (N)

m=mass (kg)

a=acceleration (m/s2) = 9.80665m/s^2.

Therefore, estimated force to be applied is F=217.8139N. Stainless steel was assigned as the robot base material as it can accommodate this force as it is relatively cheap and is highly corrosion resistance [7].

To test the strength of the cylinder when the calculated force is applied, stress distribution, displacement distribution and factor of safety (FOS) tests were carried out. As shown in Figure 5, the stress distribution maximum value is 0.586MPa while the minimum value is 0MPa. The maximum value is at the end of cylinder since it is the highest part that accommodates the force or stress applied. Maximum yield strength value of the cylinder is 292MPa, that is, if a force or stress larger than 292MPa, the cylinder part will yield.

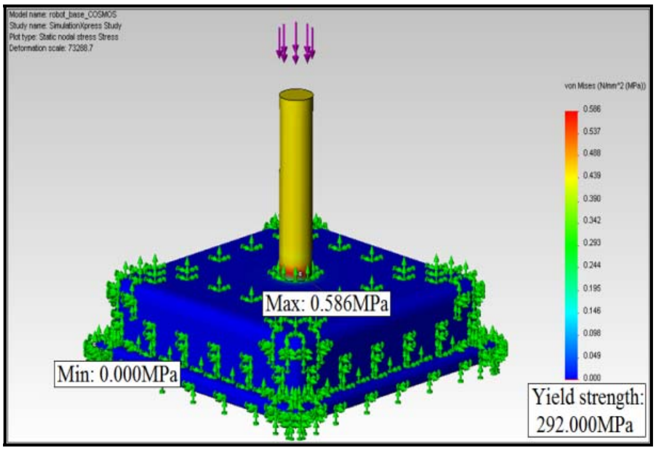


Fig. 5 Stress distribution

Figure 6 shows the cylinder displacement test results. When force or stress is applied, the displacement distribution result indicated a maximum value of 3.005e-004mm and a minimum value of 1.000e-030mm.

Figure 7 shows safety of the base design test results. When force was applied, the FOS results show a maximum value of 55,732,192.00 and a minimum value of 498.65. This indicates that the base is not overstressed and that the design is safe since the FOS value is greater than 1.0.

B. Motion Study

The motion analysis of the motor of Robot 1 was carried out. The analysis is for the movement of the product which is a cylinder from section B to conveyor A.

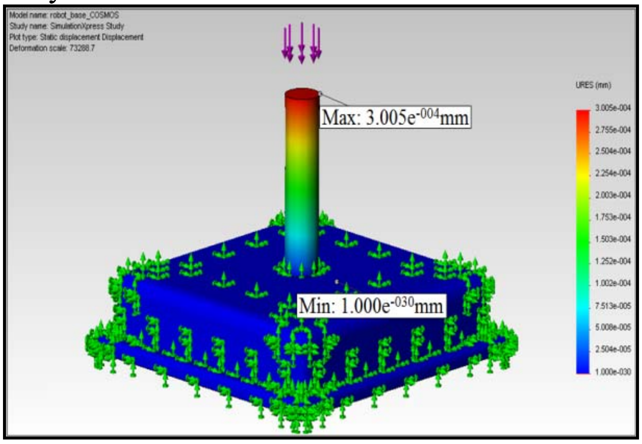


Fig. 6 Displacement distribution

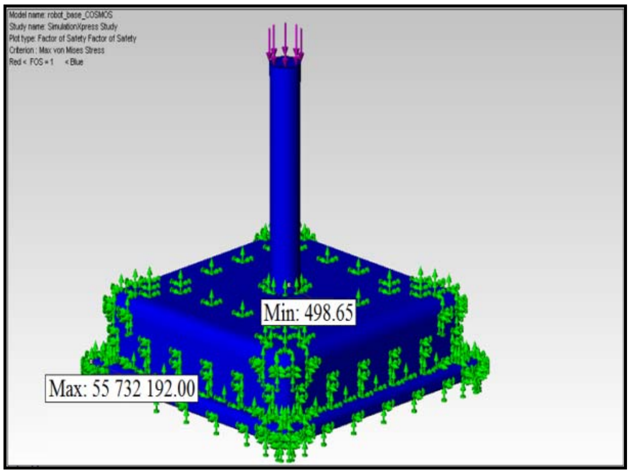


Fig. 7 Factor of safety (FOS)

The Solidworks software enables joint analysis via two graphs which are displacement versus time and angular velocity versus time graphs. The graphs proved that the displacement of the rotary motor achieved the specified displacement within the set time.

The timeline for robot 1 is depicted in Figure 8. As shown, at 0sec until 3sec time bar, the shoulder joint move to positive Y-axis in 10 degree, elbow joint move to negative Y-axis in 5 degree and wrist joint fixed to negative Y-axis in 0 degree. At 3s until 6s time bar, waist joint rotate to positive X-axis in 90 degree, as shown in Figure 8. All the movement displacement and timing was as designed.

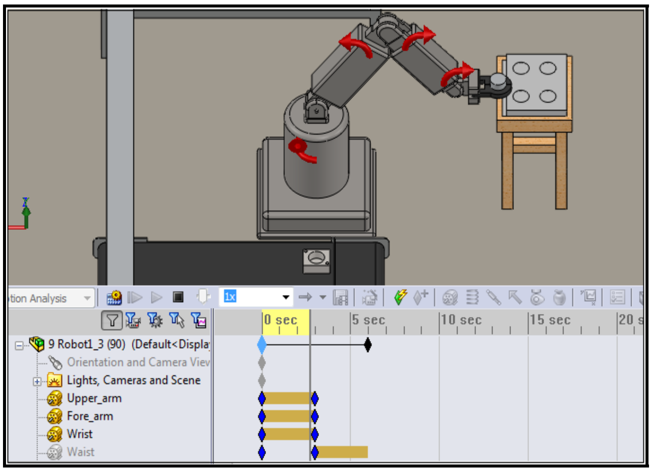
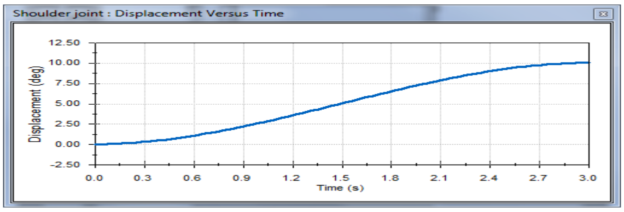
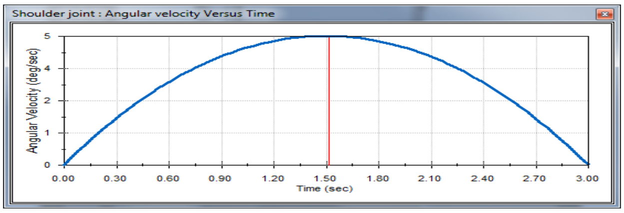


Fig. 8 Timeline for robot 1.

Figure 9 show the results for shoulder joint movement. From the displacement versus time graph, it shows 10 degree displacement in 3secs. From the angular velocity versus time graph, it shows the highest angular velocity is 5 degree per second at 1.5s. This met the designed specification.



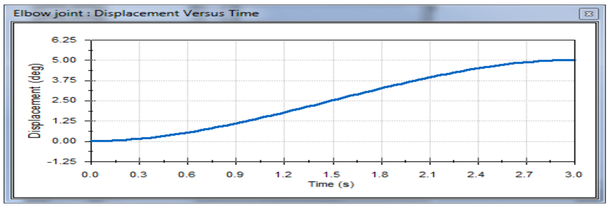
(a) Displacement versus time



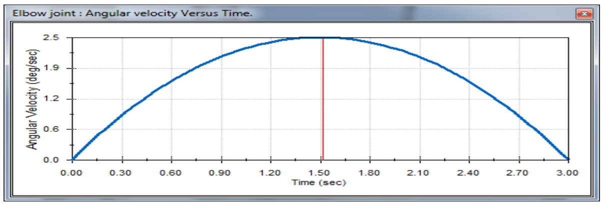
(b) Angular velocity versus time

Fig 9: Shoulder joint: (a) a displacement versus time and (b) a angular velocity versus time

Figure 10 shows the results for elbow joint. From the displacement versus time graph, it shows 5 degree displacement in 3secs. From the angular velocity versus time graph, it shows the highest angular velocity is 2.5 degree per second at 1.5s. Similarly this joint also met the designed specification.



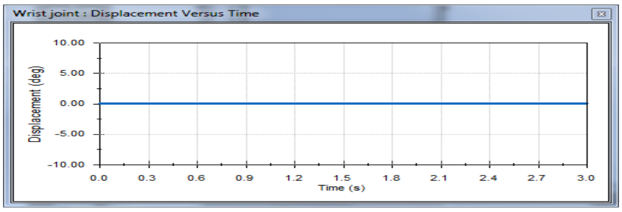
(a) Displacement versus time



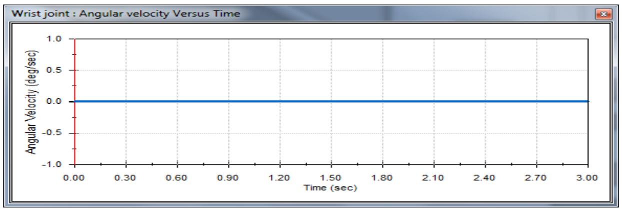
(b) Angular velocity versus time

Fig 10:Elbow joint: (a) a displacement versus time and (b) a angular velocity versus time.

Figure 11 shows the results for wrist joint. From the displacement versus time graph, it shows 0 degree displacement in 3s. From the angular velocity versus time graph, it shows the angular velocity is 0 degree per second.



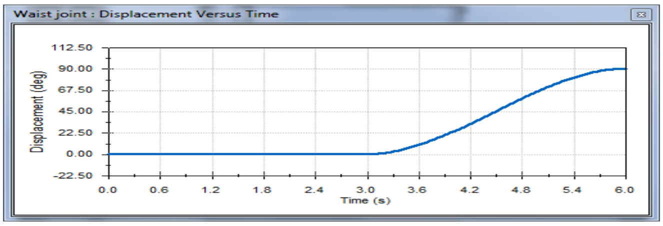
(a) Displacement versus time



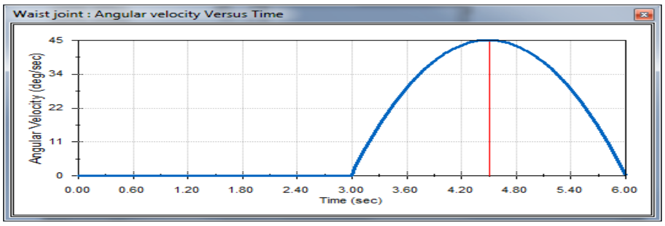
(b) Angular velocity versus time

Fig 11: Wrist joint: (a) a displacement versus time and (b) a angular velocity versus time.

Figure 12 shows the waist joint motion analysis results. From the displacement versus time graph, it shows 90 degree displacement from 3s until 6s. From the angular velocity versus time graph, it shows the highest angular velocity is 45 degree per second at 4.5s. This timing and movement met the specification.



(a) Displacement versus time



(b) Angular velocity versus time

Fig 11:Waist joint: (a) a displacement versus time and (b) a angular velocity versus time.

V. Conclusions

Solidworks Motion which is a 3D CAD software was used to successfully design a Cartesian robot, articulated robot arms, conveyors and products that which are parts of an automated pick and place robotics system. The software enabled easy simulation of the system and was able to quickly detect errors in the design of the parts. The analysis of the simulation Xpress study and motion study shortened the design period and improve the modelled the robot system efficiency. The simulation Xpress study enabled stress analysis to ensure that the modelled parts are safe. The motion study enabled the user to develop the most efficient movement by minimizing displacement to shorten time to reach the targeted positions.

VI. Recommendation for Future Development

Certain sections in Solidworks, could be improved. For example, Xpress study could be enhanced by enabling the animation that shows the deformation of parts to be captured in video. This video will then enable users to determine what happened to the parts as they can see the impact of the force in slow motion. This information can then be used to further improve the models.

In addition the motion study component can be improved by combining Solidworks simulation and LabVIEW. This integration will enable the development of virtual prototyping using linear motion and rotary motion. All the Solidworks motion study data such position, acceleration, velocity and torque then can be controlled using LabVIEW. [13]

References

[1] Thet T. Mon, Wan. M. Zulhasifi, Rosli A. *Baker, Virtual design of multi-axis positioning for robotic application*, IEEE Mechatronic and Embedded Systems and Applications, 2008. MESA 2008.

[2] http://www.solidworks.com.

[3] Tingjun WANG, Shenshun HU, Jun XU, Dewei YAN and Jiawen BI, *Simulation design and application of music playing robot based on SolidWorks*, IEEE Measuring Technology and Mechatronics Automation, 2009.

[4] *SolidWorks 2006 training manual*, SolidWorks Essentials Parts and Assemblies, SolidWorks Corporation, 300 Baker Avenue, Concord, Massachusetts 01742 USA

[5] Coman, M., Stan, S-D., Manic, M., Bălan, R., *Design, simulation and control in virtual reality of a RV- 2AJ robot*, Industrial Electronics, 2009,IECON'09, 35th Annual Conference of IEEE.

[6] R. C. Hibbeler, "Mechanics of materials", Seventh Edition, SI Conversion by S. C. FAN Nanyang Technological University.

[7] William F. Smith, Professor Emeritus of Engineering, University of Florida, Javad Hashemi, Ph.D. Professor of Mechanical Engineering, Texas Tech University, "Foundations of Material Science and Engineering", Fourth Edition.