RoboCup Rescue 2017 Team Description Paper KN2C

Prof. Hamid D.Taghirad, Mohsen Hekmat, Mehrad Ghanbari, M.Sina AllahKaram, Mehrdad Rahimian Aqda, Mehdi HajiSalmani, Alireza SharifiKia, M.Reza Mirzaei, Ali HedayatiRad, Jamal H.Bagheri

Info

Team Name:	KN2C
Team Institution:	K.N. Toosi University of Technology
Team Leader:	Mohsen Hekmat
Team URL:	https://kn2c.ir

RoboCup Rescue 2017 TDP collection:
http://wiki.robocup.org/Robot_League

***Abstract*—This article is about introducing an UGV, built with the focus on minimizing the reliability on prebuilt parts (both electrical and mechanical) and reducing the total cost as well not only for the robotic competitions but with the goal of later, global uses in rescue missions. 3 main parts of this robot consist of mechanics, electronics and software, with each part playing a different role. In mechanics, we discuss the designing of 7-DOF arm and chassis; in electronics, the focus is on carry operator's commands out, and finally in the last part, software and intelligizing the robot, will be discussed.**

***Index Terms*—RoboCup Rescue, Team Description Paper, Unmanned Ground Vehicle, Tele-operative rescue robot.**

I. Introduction

WITH the help of today's technological advances, though earthquakes, flood, fire breakouts and other natural and artificial disasters are being predicted and the number of victims are being limited, they're still unavoidable; so, rescue robots have evolved much during these years. KN2C has been keeping the pace up with this field's advancement with some new and brilliant ideas. This team has achieved outstanding results and multiple prizes in both industrial and research and development scales during it's 12 years of operation. This team, consists of Khaje Nasir Toosi University of Technology's students mostly in bachelor's degree; seeking to combine theoretical and practical knowledge and deploying this, on a robotic platform. This team started it's activity with different robots in UGV, MAV and SSL fields. KN2C's UGV team's robots from the start, are Silver, Achilles, Avril and the recent one, XerXes (figures NO 1, 2). This team tends to compete in non-autonomous robot field of this year's competition and doesn't support full autonomy, yet. This decision was made by the mentioned rescue team with the goal of combining artificial intelligence and manned operatorship together.

Fig. 1. XerXes, KN2C's main rescue robot.

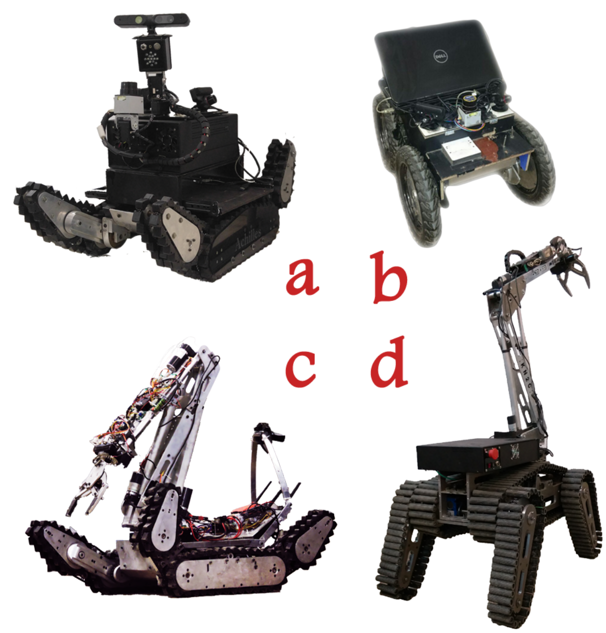

Fig. 2. a. Achilles autonomous robot 2015 to 2017 , b. Avril autonomous robot 2008 to 2014, c. Silver tele-oprated robot 2008 to 2014 and d. XerXes tele-operated robot 2016 to present

II. System Description

Design, implementation and development of all electrical and mechanical parts of this robot was done by the team members; the purpose is to minimize the usage of prebuilt modules. Electronic boards and mechanical parts are all de-

Prof. Hamid Taghirad is the Professor and Dean of the Faculty of Electrical Engineering, K.N. Toosi University of Technology, IRAN, e-mail: Taghirad@kntu.ac.ir.

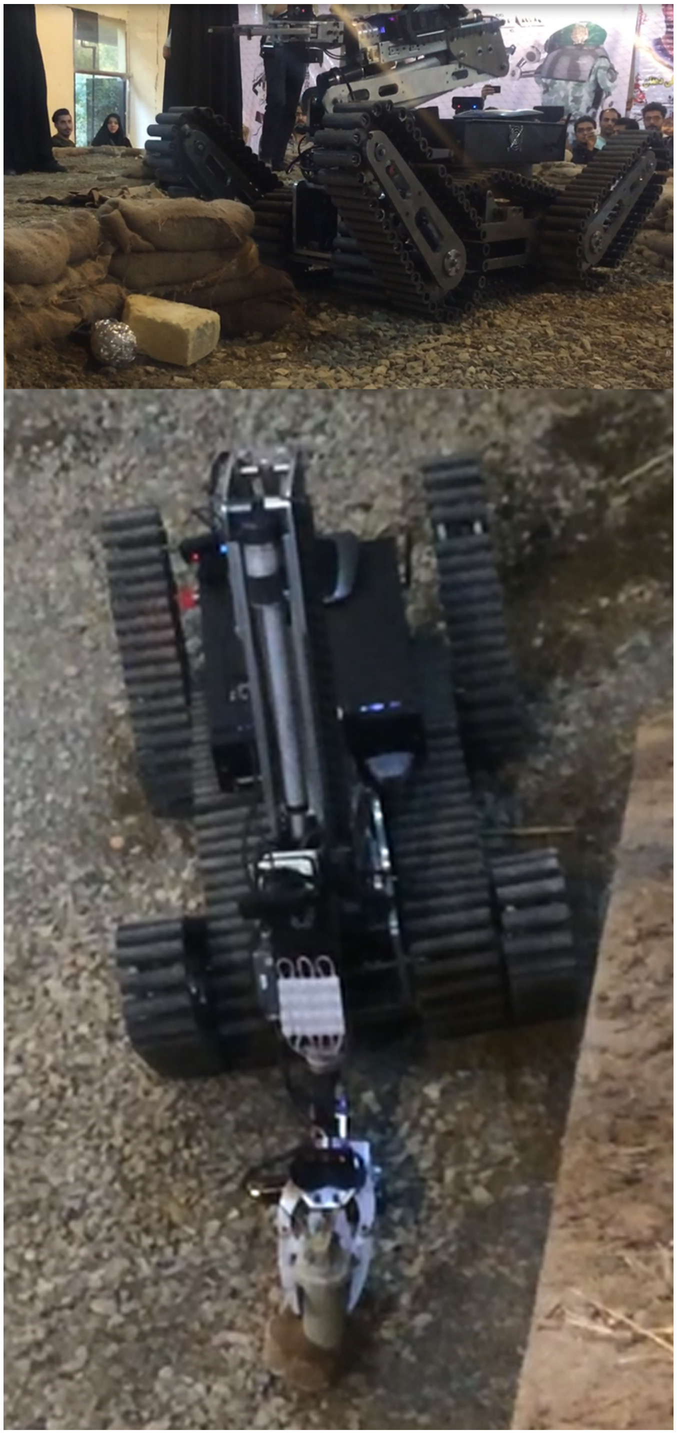

Fig. 3. XerXes can explore, navigate and operate in sandy environment.

signed by team members and with softwares such as Altium Designer and SolidWorks. Mechanical simulations are used to both speed up the design and build process and to relocate Centre of Mass to the lowest level possible for increased stability and better mobility.

A. Hardware

1) Mechanics: Robot's chassis is 60x130 / 60x78 centimeters with flippers opened/closed. All designed parts have a FOS higher than 2, for longer chassis lifespan. Robot has 4 flippers, 2 in front and 2 in back; the front pairs move together like back ones with a maximum speed of 0.6 rad/ sec. The main, movement motor is a gearbox Buhler motor which provides a 1 to 1.5 power transmition for main movement and a 1 to 15 for flippers (see figure NO 4). Chassis consists of one row of roller chain with fasteners on each side. Some important shafts are made of steel, gears are made of iron and all other parts and plates are of 6061 aluminum. All parts designs are done with turning and milling machines and to reduce the total cost even more, no CNC is used. Xerxes also supports a suspension system to increase kinetic friction even more and to soften it's movements. This robot also has a 4-DOF manipulator with a 3-DOF gripper (7-DOF in sum) implemented by a jack system for increased reliability and a decreased total cost. The gripper is able to apply 10 N force, also the 3 finger design is used for easing pick and carry or rotating tasks. Arm's maximum reachable height is 220 centimeters (with flippers on toes).

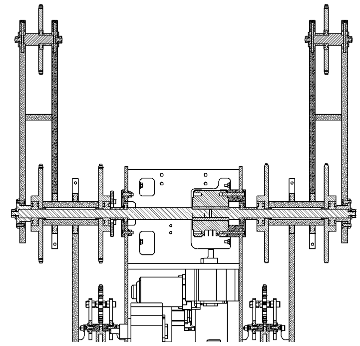

Fig. 4. CAD modeling of internal mechanical parts. gears and important shafts are shown in this picture.

2) Electronics: As it is shown in figure 5, all electronic boards are designed and placed by the electronic team. All boards are designed in modular form to ease the mechanical reshape or building process of later similar robots. All micro controllers are ARM from ST and are less resilient to noises which increases the reliability factor. A driver board with two BTN8982 half-bridge IC is assigned to each motor; a central board for distributing the power between all the modules is also designed and implemented. In picture NO 6 a sample of every designed electronic board is shown. All the boards are connected to a RS485 bus and it is through this protocol which they communicate with the main board and they're connected to the switch via an ethernet-to-serial (See chart NO 9). 2 separate batteries are considered; a 3 cell 12v for electronic boards and devices and another 4 cell and 16 A.H 15C for robot's movements. In order to reduce the chance of motors or electronic parts being damaged, a current control program is considered for micro controllers which will control and limit the torque applied by motors; this option can be tuned in robot's GUI or be set in the automatic on/off mode. Also for better movement, a PID controller is implemented which insures that robot will not disobey operator's commands. our set of sensors, include a MG811 gas sensor, a TPA81 temperature sensor and a microphone to transmit robot's nearby voices to

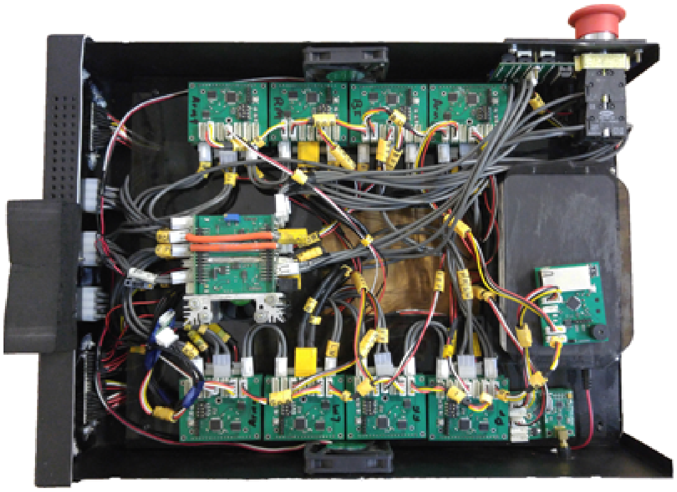

Fig. 5. All electronic devices, are located in a box, installed on XerXes; this box can be seperated from the chassis by 3 main cables.

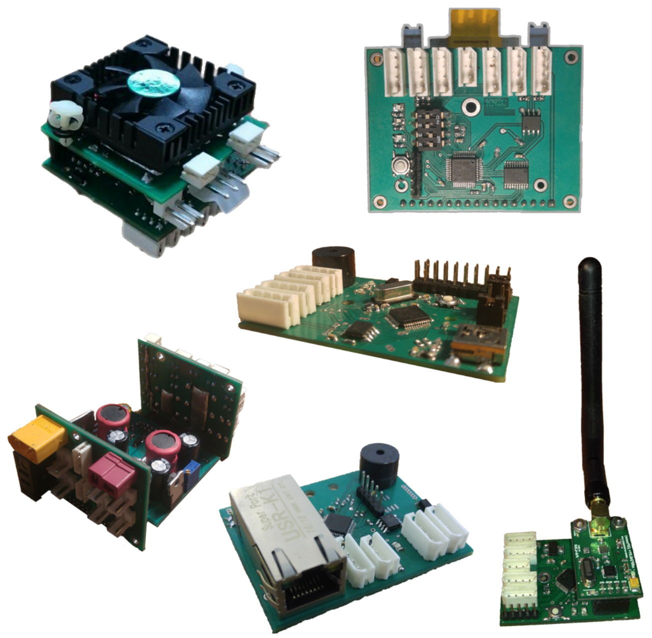

Fig. 6. some important electronic boards, including main board, motor drivers, power distribution system and etc.

the operator station.

B. Software

Our programming team supports both Linux and Microsoft Windows operating systems. We're using OpenCV for image and video processing and basicOCR project (a neural network based system with KNN algorithm) for pattern recognition. GUI is also designed by Qt IDE in C++ language as you can see in picture NO 7. For the mapping procedure, we've used ROS and hectorSLAM project. Our URG Hokuyo 04lx sensor laser scanner has a 4 meters radius (see figure NO 8). To increase operator's speed and to ease their work, a full autonomous procedure has been also implemented for arm's closing action, when operator's finished their task with it; this operation is done easily by reading the feedbacks from sensors that read the arm's angle.

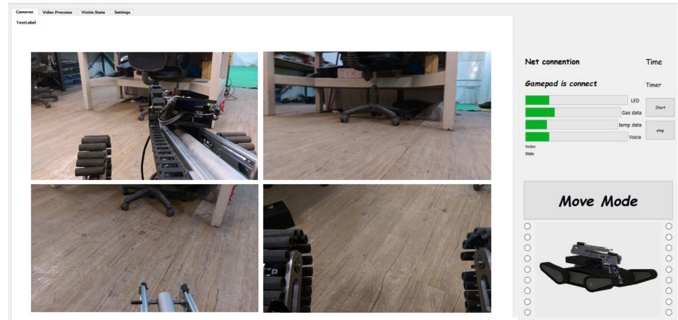

Fig. 7. Graphical User Interface for XerXes.

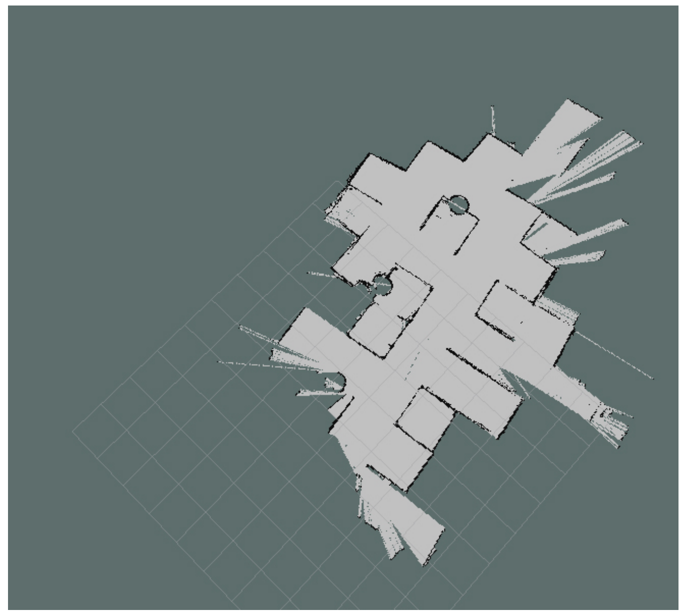

Fig. 8. A blank map obtained by Avril robot in IranOpen2014 competition.

C. Communication

As it is shown in chart NO 9, both wired and wireless connections are used as communication protocols between different modules and parts of robot. Operator's commands data packet is sent through a 5GHz, 802.11ac wireless network and a bullet M5 from operator's station with a flat panel antenna with a maximum gain of 15 dbi to the same system of communication and an antenna of 8dbi gain on the robot and to the main board; the robot's feedback packet data is sent back to operator, with the same procedure. The goal for the 2-way communication is for the operator to monitor, robot's critical info in order to make the required decisions in times of need. An Axis P7214 video encoder is used to send and receive audio and video datas through its 4 available channels; 4 out of 7 available cameras on robot are selected at one time, which operator can change the active cameras at any time.

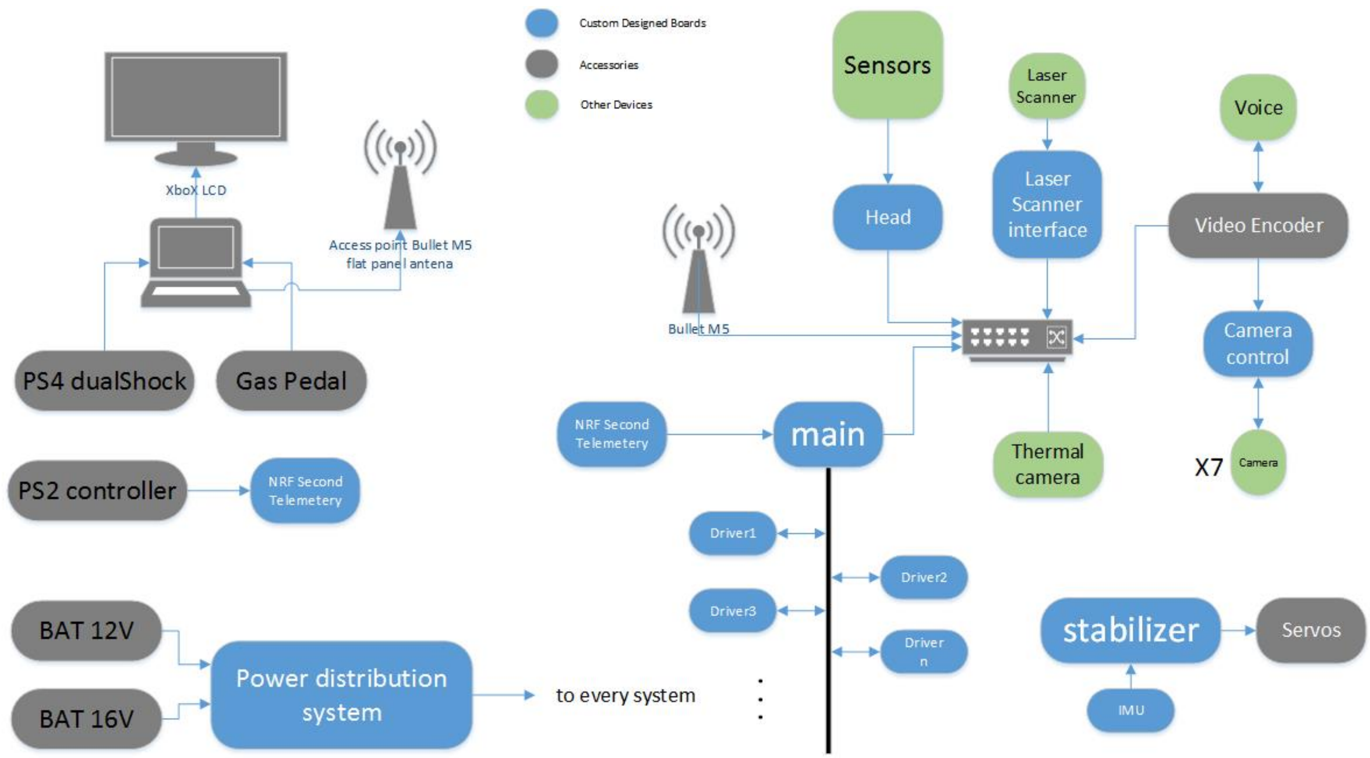

Fig. 9. The electrical and communication systems topology.

D. Human-Robot Interface

Both the robot and all the operator system's parts, such as the monitor, the DS4 controller, laptops and access points have a single power button which initializes all the devices and programs; this minimizes the setup and breakdown time. Also, for faster setup in testing phase, we have a second controller which uses a NRF module to communicate directly with the robot.

III. Application

A. Set-up and Break-Down

Both the robot and all the operator system's parts, such as the monitor, the DS4 controller, laptops and access points have a single power button which initializes all the devices and programs; this minimizes the setup and breakdown time. Also, for faster setup in testing phase, we have a second controller which uses a NRF module to communicate directly with the robot.

B. Experiments

XerXes have gone under heavy field tests to determine it's weaknesses and errors. We've also prepared a somewhat testing ground similar to the competition's environment and tested both our operator's and robot's performance. Aside from this testing ground, we've tested the robot's performance on real sandy and rocky terrains. Needless to say that vulnerable electronic boards or mechanical weaknesses were either replaced or redesigned. XerXes performance has been tested many times. Lab test results were acceptable. We also received multiple RFP from different organizations such as Iran's NDMO; the robot's weight is a bit heavier than standards for practical uses, we intend to resolve this issue in later versions with the hope of presenting an efficient and practical rescue robot to the world.

C. Application in the Field

XerXes have gone under heavy field tests to determine it's weaknesses and errors. We've also prepared a somewhat testing ground similar to the competition's environment and tested both our operator's and robot's performance. Aside from this testing ground, we've tested the robot's performance on real sandy and rocky terrains. Needless to say that vulnerable electronic boards or mechanical weaknesses were either replaced or redesigned. XerXes performance has been tested many times. Lab test results were acceptable. We also received multiple RFP from different organizations such as Iran's NDMO; the robot's weight is a bit heavier than standards for practical uses, we intend to resolve this issue in later versions with the hope of presenting an efficient and practical rescue robot to the world.

IV. Conclusion

Building XerXes is not a simple task, it demanded electronic, control, mechanical and software knowledge and experience, which our team passed these challenges by combining theoretical knowledges learned in university and researches done both online and by asking experienced professors for their guides and the experience gathered during it's years of operating, which involves building the previous robots and

TABLE I
MANIPULATION SYSTEM

Attribute	Value
Name	XerXes
Locomotion	tracked
System Weight	85kg
Weight including transportation case	90kg
Transportation size	0.7 x 0.9 x 0.6 m
Typical operation size	0.6 x 0.7 x 0.5 m
Unpack and assembly time	170 min
Startup time (off to full operation)	5 min
Power consumption (idle/ typical/ max)	30 / 300 / 640 W
Battery endurance (idle/ normal/ heavy load)	300 / 45 / 20 min
Maximum speed (flat/ outdoor/ rubble pile)	0.7 / 0.6 / 0.3 m/s
Payload (typical, maximum)	2/ 5 kg
Arm: maximum operation height	190 cm
Arm: payload at full extend	2kg
Support: set of bat. chargers total weight	4kg
Support: set of bat. chargers power	480W (220V AC)
Support: Charge time batteries (80%/ 100%)	30 / 45 min
Cost	4500 USD

participating in different competitions. We look forward to share these experiences and have an effect on the advancement of robotics science by participating in this year's competition.

APPENDIX A
TEAM MEMBERS AND THEIR CONTRIBUTIONS

- Mohsen Hekmat — Team leader, Electronics design
- Mehrad Ghanbari — Mechanical design
- M.Sina AllahKaram — Electronics and Software design
- Mehrdad Rahimian Aqda — Electronics design
- Mehdi HajiSalmani — Electronics design
- Alireza SharifiKia — Software developer
- M.Reza Mirzaei — Mechanical design
- Ali HedayatiRad — Mechanical design
- Jamal H.Bagheri — Mechanical design
- Prof. Hamid D.Taghirad — Supervisor

APPENDIX B
CAD DRAWING

in figure 10 you can see the CAD modeling of our robot.

APPENDIX C
LISTS

A. Systems List

in table I you can see a list of some important specifications about manipulation system of XerXes. ,table II provides some usefull information about our operator station that named XboX.

B. Hardware Components List

in table III some of important hardware components and accessories shown.

C. Software List

in table IV you can see a list of all softwares used by us in GUI and intelligization algorithms.

TABLE II
OPERATOR STATION

Attribute	Value
Name	XboX
System Weight	10kg
Weight including transportation case	10kg
Transportation size	0.8x 0.5 x 0.2 m
Typical operation size	0.8 x 0.5 x 0.7 m
Unpack and assembly time	1 min
Startup time (off to full operation)	5 min
Power consumption (idle/ typical/ max)	60 / 70 / 75 W
Battery endurance (idle/ normal/ heavy load)	6 / 5 / 4 h
Cost	900 USD

TABLE III
HARDWARE COMPONENTS LIST

Part	Brand & Model	Unit Price	Num.
Drive motors	Buhler gear motor 1.61.113 350W	USD 100	4
Drive gears	with motors	-	4
Drive encoder	with motors	-	4
Motor drivers	custom designed	-	4
DC/DC	custom designed with LM2576	-	3
Battery Management	custom designed	-	1
$Battery_1$	Tattu 10000mAh 3S1P 8C Lipo	USD 50	1
$Battery_2$	Tattu 16000mAh 4S1P 15C Lipo	USD 140	1
Micro controller	STM32f030C8T6	USD 1	15
Computing Unit	XboX laptop	-	1
WiFi Adapter	UBNT Bullet M5	USD 90	2
IMU	custom designed with MPU6050	USD 3	1
Cameras	CCTV camera	USD 20	7
Thermal camera	FLIR Lepton	USD 300	1
CO_2 Sensor	MG811	USD 25	1
Battery Chargers	icharger 306B	USD 170	1
7-axis Robot Arm	custom designed	USD 500	1
Rugged Operator Laptop	ASUS N552VW team member's laptop	-	1

ACKNOWLEDGMENT

Special thanks to prof. Taghirad, prof. Ali Khaki Sedigh and K.N.Toosi University of Technology for their financial and scientific support.

REFERENCES

[1] P. Viola and M. Jones, "Rapid object detection using a boosted cascade of simple features," in *Computer Vision and Pattern Recognition, 2001. CVPR 2001. Proceedings of the 2001 IEEE Computer Society Conference on*, vol. 1, 2001, pp. I–511–I–518 vol.1.

[2] S. Kohlbrecher, J. Meyer, O. von Stryk, and U. Klingauf, "A flexible and scalable slam system with full 3d motion estimation," in *Proc. IEEE International Symposium on Safety, Security and Rescue Robotics (SSRR)*. IEEE, November 2011.

TABLE IV
SOFTWARE LIST

Name	Version	License	Usage
Ubuntu	14.04	open	
ROS	indigo	BSD	
OpenCV [1]	2.4.8	BSD	Victim and motion detection
basicOCR	2.4.8	BSD	Hazmat detection
Hector SLAM [2]	0.3.4	BSD	2D SLAM

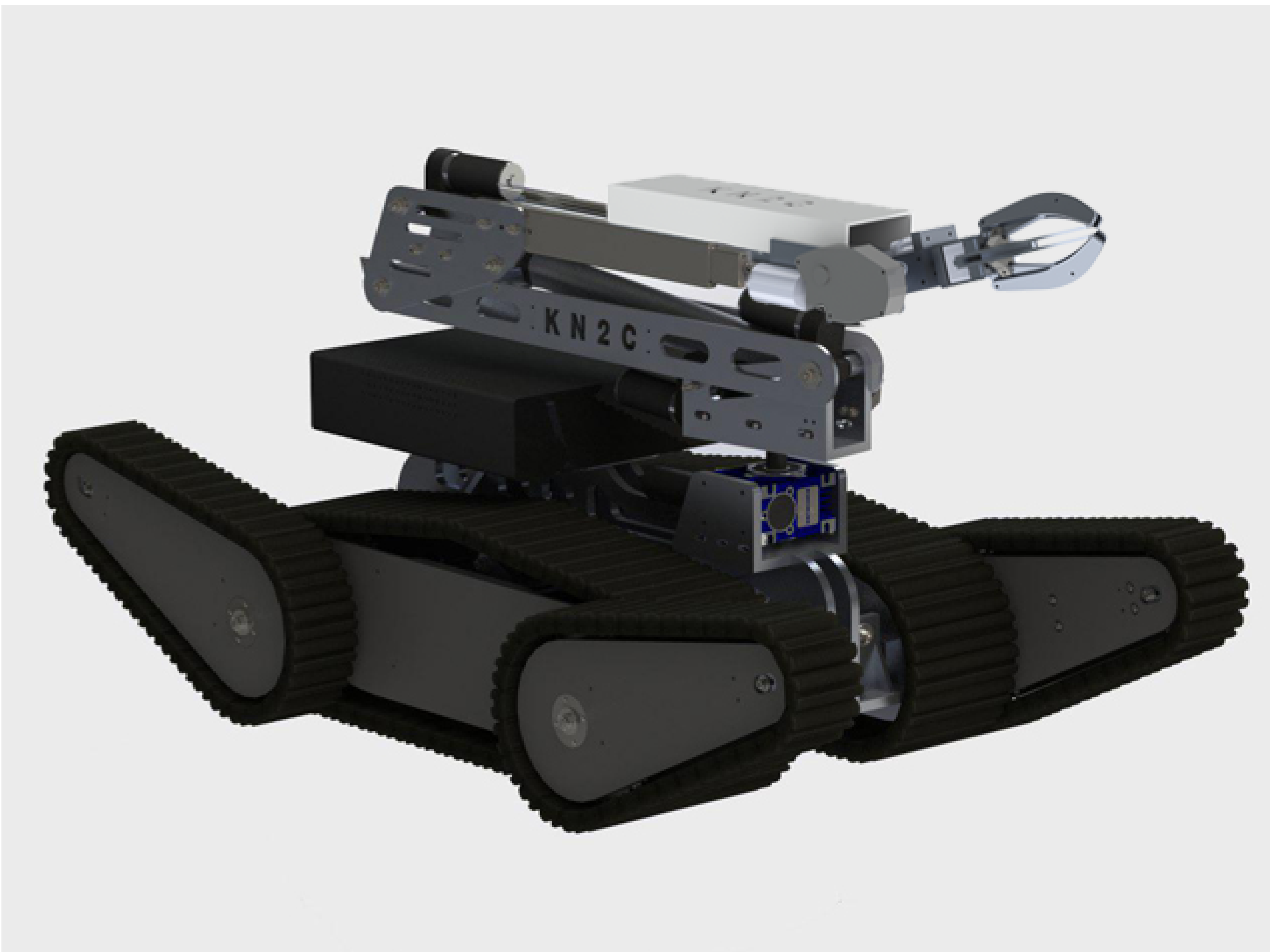

Fig. 10. CAD modeling of XerXes with 7-DOF manipulator system.