24th COBEM - 2017

ABCM
Associação Brasileira de Engenharia e Ciências Mecânicas

24th ABCM International Congress of Mechanical Engineering
December 3-8, 2017, Curitiba, PR, Brazil

COBEM-2017-1746
EXPLORER ROBOT: PLATAFORM BASED ON RASPBERRY BOARD

Filipe d' S. Aureliano
Ariellen A. Fidelis Costa
Alexandre Oliveira Lopes
João Mario M. Freitas
University Center of the Southern Minas, Unis Group; Joaquim Camilo Tavares Street, 570
filipe254@hotmail.com; ariellenfideliscosta@gmail.com; alexandre.lopes@unis.edu.br; joao.mario@unis.edu.br

Abstract. *This work presents an explorer rover robot prototype, developed to work in high risk operations and to explore rough environments. Inside this context, the explorer robots have the objective to inspect a given environment and use its sensors to reveal the physical characteristics of the place, usina Raspberry Pi plataform to control its maneuvers, analysis and the manipulation of objects. The project is a mobile robot, attached with a manipulating clar which works integrated to a system with a movement controller, partially autonomous. The camera (RaspCan) allows precise joint operations with the help of a vision system, focusing in a given object so the robot could locate it so the system can inform the robot the position of the object (x and y coordinates). The movement is provided by treadmills, assuring the moving capacities even in irregular grounds. The manipulator is developed in order to allow safe and precise operations. Therefore, all communication uses a wireless conectioon using a C language software to the Wiringpi library, making the environment analysis to be made via the camera attache to the controller, ensuring a real time image transmision. The system can be controlled using cellphones, tablets or notebooks, allowing the operatior to be outside an unsafe area.*

Keywords: *Raspberry PI, explorer robot, vision system, manipulator.*

1. INTRODUCTION

In order to improve and expand the usage of explorer robots, a study about the drawbacks of the existing systems was conducted. However, the common activities are the ones that expose people to many dangerous situations. When analysing the crescent needs of efficiency and safety in these kind of operations, the use of robotics and automation appears as possible options in order to solve this problem.

However, in order that these advances can be used, the applications with the highest financial return should be the priority given the high cost of the equipment. In order for the equipment to be used in any kind of activity, the financial and ethical matters, safety and welfare of the workers, should be studied. In order to comply with safety and cost/benefits needs, it is necessary to produce a versatile and compatible system with the current technologies, with an attractive cost and with the same ability as a worker and, thus, replacing the human presence in hazardous environments.

The mobile robotics studies the development of devices capable of movement in uncontrolled, noisy and unknown environments. A good example of robotics application, according to Barbosa *et al*. (2008) is the construction of terrain explorer vehicles. Another example of the application of robotics is the presence of many robots in Mars, collecting data for scientific studies and a possible attempt of a manned mission to the planet (TERRA, 2012). Other vehicles are currently being developed for terrestrial, aerial and aquatic environments (PAIVA, 2002). These robots have the objective to replace humans in places where access is difficult and can also collect data, such as air quality, soil composition and the presence of water and of living organisms.

The existing mobile robots should have the ability to, for example, recognize a specific object among many. The Artificial Intelligence (AI) is responsible to transform a simple static device that can only repeat a given action into fully autonomous robots capable of making decisions. According to the situation that the robot will operate, the software project becomes more complex, making it possible that the robot had to execute some functions concurrently. The Operational System (OS) used is important, since the programmer will concern only with the program functional aspects. The operational system is responsible for interface between the robot's hardware and software. In order to fulfil these objectives, it is necessary multidisciplinarity between fine mechanics, electric/electronics and computation, so this new and important area has the necessary support (Pazos, 2002).

The present work has, as main characteristic, the operational versatility and safety in applications of this genre.

2. GENERAL DESCRIPTION OF THE MOBILE ROBOT

The prototype structure was constructed with the objective to support the planar platforms (acrylic layers), making it possible for the robot to carry many attached devices and components. The robot structure has 250 mm in length, 200 mm in width and 150 mm high. The prototype components are shown in Figure 1: (1) robot chassis, (2) traction treadmills and pulleys, (3) camera, (4) manipulation claw, (5) flashlight, (6) refrigeration pump, (7) refrigeration reservoir, (8) radiator, (9) Raspberry Pi B+ and its electronic components.

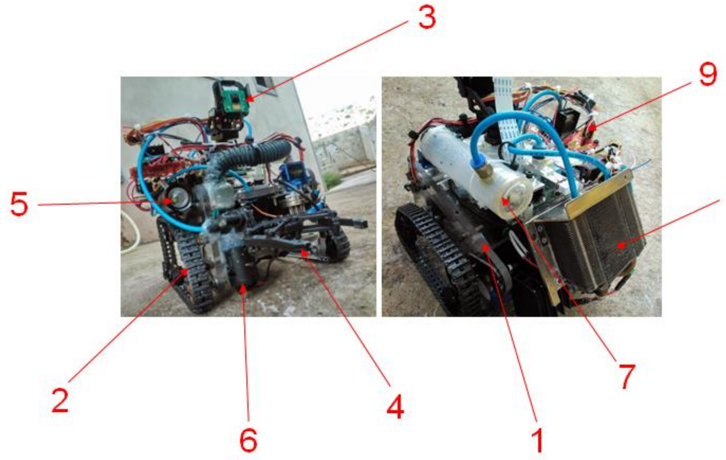
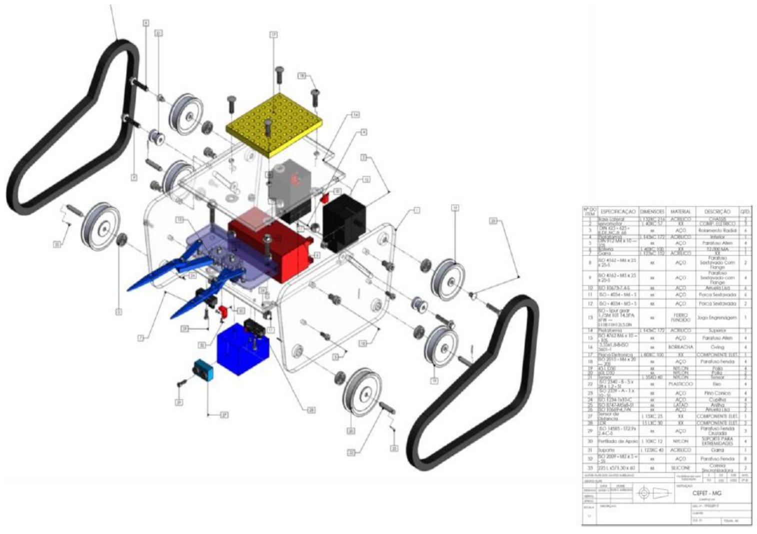


Figure 1. General description of the mobile robot

2.1 Mechanical Project

The initial process of the project the 3D modelling of the prototype was conducted using a CAD tool, as shown in Fig.2, showing the structural parts, which were later used in the mechanical fabrication. The improvements possibilities in the cost/benefit relation can also improve the construction of the prototype in order to show movement.



Nº DO ITEM	ESPECIFICAÇÃO	DIMENSÕES	MATERIAL	DESCRIÇÃO	QTD.
1	Base Lateral	L 132XC 216	ACRILICO	CHASSIS	2
2	Servomotor	L 40XC 57	XX	COMP. ELETRICO	3
3	DIN 625 - 625 - 8LDE,NC,8_68	xx	AÇO	Rolamento Radial	6
4	Plataforma	L 143xC 172	ACRILICO	Inferior	1
5	DIN 912 M4 x 10 --- 10S	xx	AÇO	Parafuso Allen	4
6	Bateria	L 40XC 100	XX	12.000 MA	1
7	Garra	L 123XC 152	ACRILICO	XX	1
8	ISO 4162 - M4 x 25 x 25-S	xx	AÇO	Parafuso Sextavado Com Flange	2
9	ISO 4162 - M5 x 25 x 25-S	xx	AÇO	Parafuso Sextavado com Flange	4
10	ISO 10673-7,4-S	xx	AÇO	Arruela Lisa	6
11	ISO - 4034 - M6 - S	xx	AÇO	Porca Sextavada	6
12	ISO - 4034 - M5 - S	xx	AÇO	Porca Sextavada	2
13	ISO - Spur gear 1.75M 10T 14.5PA 6FW --- [illegible]	xx	FERRO FUNDIDO	Jogo Engrenagem	1
14	Plataforma	L 143xC 172	ACRILICO	Superior	1
15	ISO 4762 M4 x 10 --- 10S	xx	AÇO	Parafuso Allen	4
16	3.33x1.8-B-ISO 3601-1	xx	BORRACHA	O-ring	4
17	Placa Eletronica	L 80XC 100	XX	COMPONENTE ELET.	1
18	ISO 2010 - M4 x 20 --- 20S	xx	AÇO	Parafuso Fenda	4
19	45 L D30	xx	NYLON	Polia	4
20	30 L D30	xx	NYLON	Polia	[illegible]
21	Tensor	L 35XD 40	NYLON	Tensor	2
22	ISO 2340 - B - 5 x 28 x 1.2 - St	xx	PLASTICO	Eixo	4
23	ISO 2339 - A - 1 x 10 - St	xx	AÇO	Pino Conico	4
24	ISO 1234 1x10-C	xx	AÇO	Cupilha	4
25	ISO 8747-M5x6-St	xx	LATAO	Anilha	2
26	ISO 10669-4,7-N	xx	AÇO	Arruela Lisa	2
27	Sensor de Distancia	L 15XC 25	XX	COMPONENTE ELET.	1
28	LDR	15 LXC 30	XX	COMPONENTE ELET.	2
29	ISO 14585 - ST2.9x 2.4-C-S	xx	AÇO	Parafuso Fenda Cruzada	3
30	Perfilado de Apoio	L 10XC 12	NYLON	SUPORTE PARA EXTREMIDADES	4
31	Suporte	L 123XC 45	ACRILICO	Garra	1
32	ISO 2009 - M2 x 5 --- 5S	xx	AÇO	Parafuso Fenda	8
33	225 L x571,30 x 60	xx	SILICONE	Correia Sincronizadora	2

CEFET - MG

Figure 2. Mechanical structure

In order to move the prototype, treadmills were chosen once they can promote a better soil adherence and thus, improving the traction capacity in rough terrain. Also, they help in the prototype's weight to be uniformly distributed on the superficial area of the treadmills. In addition to this, the option of the treadmills allow to the prototype to make turns around its axis, which cannot be achieved using conventional wheels.

2.2 Rapberry Pi B+

The Raspberry Pi is a small, low cost credit, card sized computer designed initial and specifically for education but providing interesting resources for embedded systems. Raspberry Pi Model B+ (Fig. 3) is based around an ARM processor which can run the open source Linux operating system well known as Raspbian which is a Debian-based Linux distribution specifically designed for the Raspberry Pi. Further description, including the specification of the Raspberry Pi B+ board, can be found in (Sachdeva and Katchii, 2014).

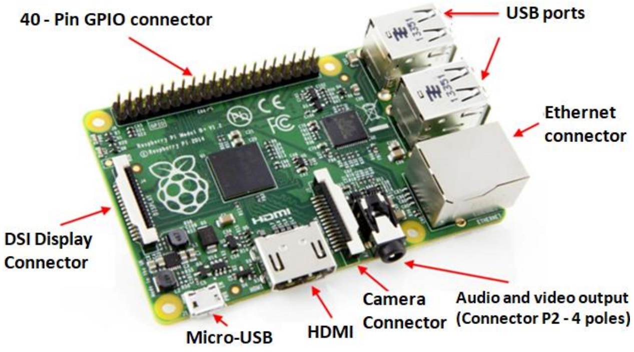


Figure 3. Raspberry Pi B+

2.3 Electronic components Distribution

The electronic parts that compose the rover are better characterized and detailed in Fig. 4. A lead 6V battery is used to power the actuators and a Lipo 11.1V battery powers the Raspberry Pi B hardware, ensuring 3.5 hours of operation without the need to recharge. After the batteries are powerless, an external source is used to recharge them. The CI 74HC14N offers buffers that are able to transform the input signal, well defined, into noiseless output signals where they are connected to actuators and the H bridge which inverts the rotation of the device.

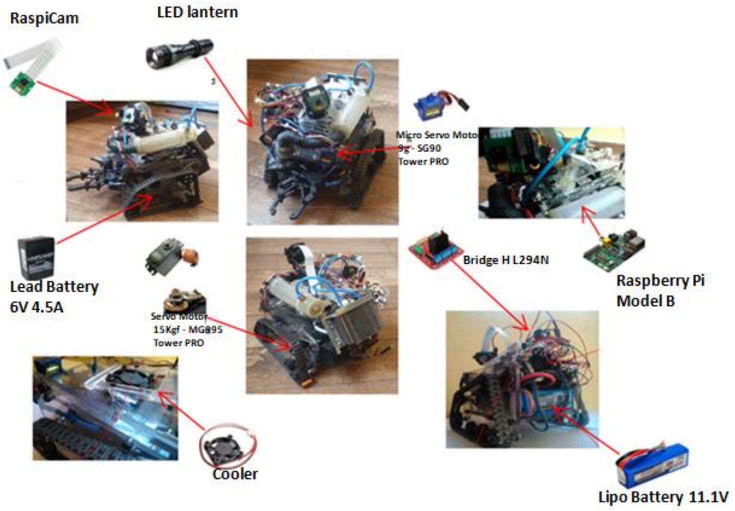


Figure 4. Electronic distribution

2.4 Communication Interface

The control system embedded on the Raspberry platform have a camera included, a wire connection to manipulation and a faster response of speed to the other existing controls once the robot uses robotic vision which include: inspection, classification, navigation, recognition and manipulation. Using the communication interface Secure Shell (SSH), the robot's navigation uses the Operational System Raspibian (GNU Linux), a software application which uses the C language of the WiringPI library in order to control the movements, to analyse the environment and the manipulation of objects. The communication topology is better characterized as shown on Fig.5, which demonstrate its control flow.

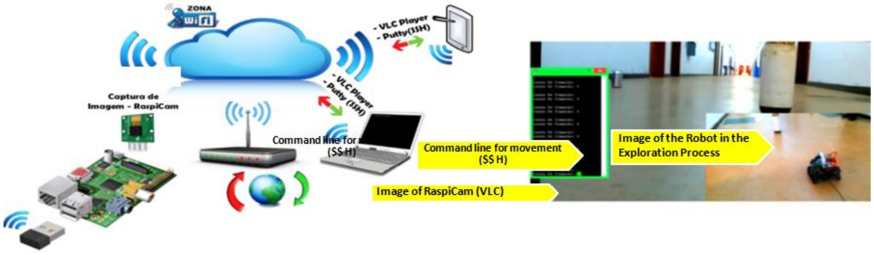

ZONA wi fi
- VLC Player
- Putty(SSH)
- VLC Player
- Putty (SSH)
Captura de Imagem - RaspiCam
Command line for movement ($$ H)
Command line for movement ($$ H)
Image of the Robot in the Exploration Process
Image of RaspiCam (VLC)

Figure 5. Communication Interface

2.5 Image Processing

The image processing is a very important step, once the grey image is filtered and transformed into a mask, a binary black and white image, where the object is white and the background is black, as shown in Fig. 6.

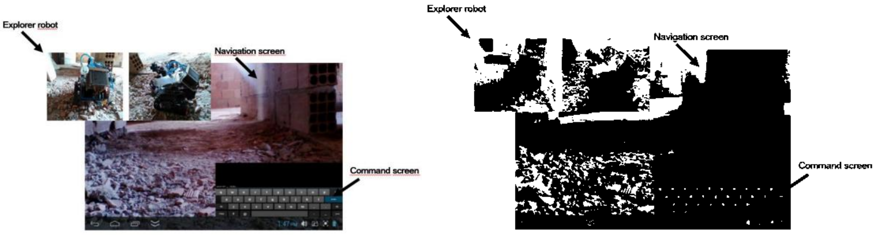


Figure 6. Binary Image

In order to process the camera's real time image, the OpenCV (Open Source Computer Vision Library) tool was used.

In order to put into practice the robot vision concepts and to demonstrate a possible application in the mobile robotic field, a recognition system was developed in order to recognize a predefined object in an image generated by a camera which commands the rover to follow it.

Using the camera's image, the computer start the object's search process, using a digital reference as its basis. The process, which is repeated on every frame, follows the steps described as following:

1. Get the image from the câmera.
2. Smooth the image from the camera in order to reduce the noise.
3. Convert the colored image into a black and white image (grey scale)
4. Thresholds application, generating binary images (black and white only) so the searched symbol can be recognized despite light conditions.
5. Shape detection routine application in the whole image
6. Get the candidate square regions again in the form of image.
7. Search for the quadrant with highest amount of white pixels in every region of the previous item.
8. Rotate the images so they follow the reference orientation, based on the whitest quadrant and the formed angle between the inferior line of the shape and the image horizontal axis.
9. Using the results from the previous item, calculate the binary image's moments. The moments used are the order in X plus the order in Y be less or equal 3, with X and Y positives.
10. A grade is composed by the square of the diference between the momento of each reference order and the candidate image. This is summed to ten times the difference between the amount of remaining figures in the reference and in the candidate, being an image any black portion wrapped in white and vice-versa.
11. The lowest grade region, which is above an experimental stablished level, is considered a valid match. The level can be altered during the program execution, in order to change its tolerance. The control is made via a sliding bar.
12. If any match is detected, the central point (square's center) is considered to the evaluation of the position. If it's located in the first 30% of the image, on the left side, the robot is commanded to turn left. If it is located in the 70%, on the right side, a command is sent so the robot turn left. In order to determine the distance between the robot and the object, the external square area is used. If it is less than 5% of the image, the robot should advance, if it's more than 12%, he should walk back and put some distance. All those parameters can be changed in execution time.
13. With the robot repositioned, return no step 1.

The whole process is detailed in Fig.7 and Fig.8:

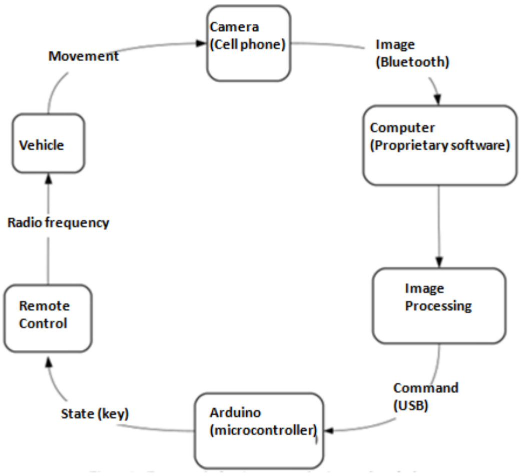
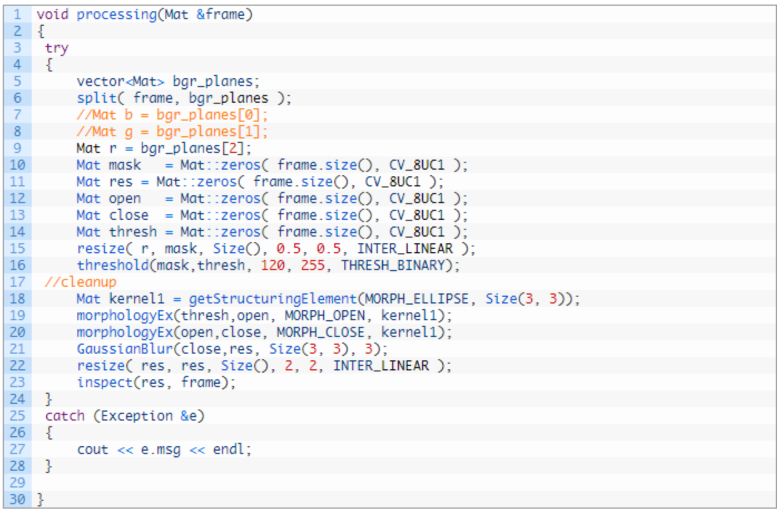


Figure 7. Schematic of Vehicle System Operation



```
void processing(Mat &frame)
{
 try
 {
     vector<Mat> bgr_planes;
     split( frame, bgr_planes );
     //Mat b = bgr_planes[0];
     //Mat g = bgr_planes[1];
     Mat r = bgr_planes[2];
     Mat mask   = Mat::zeros( frame.size(), CV_8UC1 );
     Mat res = Mat::zeros( frame.size(), CV_8UC1 );
     Mat open   = Mat::zeros( frame.size(), CV_8UC1 );
     Mat close  = Mat::zeros( frame.size(), CV_8UC1 );
     Mat thresh = Mat::zeros( frame.size(), CV_8UC1 );
     resize( r, mask, Size(), 0.5, 0.5, INTER_LINEAR );
     threshold(mask,thresh, 120, 255, THRESH_BINARY);
 //cleanup
     Mat kernel1 = getStructuringElement(MORPH_ELLIPSE, Size(3, 3));
     morphologyEx(thresh,open, MORPH_OPEN, kernel1);
     morphologyEx(open,close, MORPH_CLOSE, kernel1);
     GaussianBlur(close,res, Size(3, 3), 3);
     resize( res, res, Size(), 2, 2, INTER_LINEAR );
     inspect(res, frame);
 }
 catch (Exception &e)
 {
     cout << e.msg << endl;
 }

}
```

Figure 8. Vehicle system programming

3. EXPERIMENTAL RESULTS

With the development of the research, it as possible the construction of a functional prototype, which behaved as predicted in simulation, where the operator needs only a cellphone or a computer in order to manipulate the rover's distance in order to explore rough environments without being exposed directly to hazardous situations. While capturing images from the explored environment, the information were converted, as predicted, the information being extended by the operational system, allowing the environment reconnaissance and defining which action the robot should take based in patterns found on the captured images.

The development of the system already shows a preliminary feasibility in many fields, on different applications. However, it is still needed to demonstrate in a more effective way the real viability of the project.

A practical test was conducted, as it is shown in Fig. 9, showing the exploration in rough terrain service execution feasibility, maneuvering the rover using a cellphone connected to a wireless network. The rover's access is granted via its IP address in a real physical system simulation. The demonstration was helpful in order to prove the developed controls efficiency, which act in a friendly and intuitively form even in delicate tasks such as exploration.

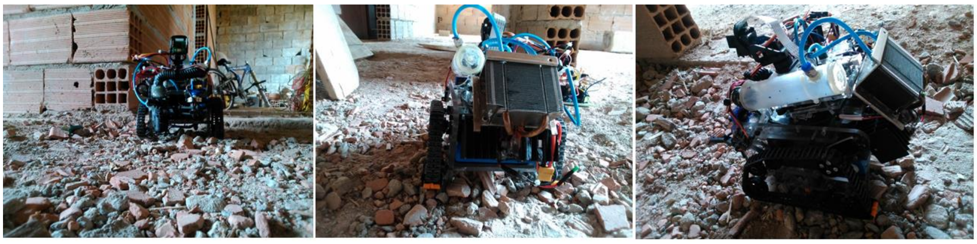


Figure 9. Real physical system simulation

4. CONCLUSIONS

This study presents the Rover robot prototype, in order to explore environments with poor access. Real time images are transmitted using a rotating camera to the operator. The robot can inspect confined spaces or radioactive surroundings, such as a damaged nuclear reactor that has hazardous conditions to people. At last, the device's structure allow for manipulation of small objects using a claw and, thus, allowing flexibility in the operation.

Even though the device is a simple innovation, its implementation could improve significantly the work environment safety and in could expand the range of exploration of rough environments once it allows a riskless operation. The invention could save workers that have to expose themselves to dangerous conditions and, eventually, save lives.

5. REFERENCES

Barbosa, L.F. Wiltgen, et al. Robô explorador multifunções tipo OFF-ROAD. 2008 XI Encontro Latino Americano de Iniciação Científica e VII Encontro Latino Americano de Pós-Graduação – Universidade do Vale do Paraíba. 10 Feb. 2017 <http://www.inicepg.univap.br/cd/INIC_2008/anais/arqui vosINIC/INIC0336_01_O.pdf>.

Paiva, Ely Carneiro de. Veículos robóticos semi-autônomos. 30 de setembro de 2002. 15 Apr. 2017 <http://www.bv.fapesp.br/pt/auxilios/3843/veiculosroboticos-semi-autonomos/>.

Pazos, F. (2002). Automação de Sistemas e Robótica. Editora Axcel.

SACHDEVA, P. and KATCHII, S., 2014. "A Review Paper on Raspberry Pi". Journal of Current Engineering and Technology, Vol. 4, No.6, p.3818-3819 – INPRESSCO2014.

Terra notícias. Robô Opportunity completa oito anos de missão em Marte. 24 de Janeiro de 2012. 20 Apr. 2017 <http://noticias.terra.com.br/ciencia/espaco/roboopportunity-completa-8-anos-de-missaoemmarte>

6. RESPONSIBILITY NOTICE

The authors are the only responsible for the printed material included in this paper.