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Robot Controlled Six Degree Freedom Camera

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Abstract--- *The Operational System for Inspection, Research, and Instrument Support (OSIRIS) is a remotely operated free-flying camera robot. Designed to fly in air, OSIRIS has full six axis control and can serve as a test platform for several areas of research including attitude control, path planning, inspection tasks, and human-robot interaction. Similar vehicles designed in the past use ducted fans and compressed air for propulsion. OSIRIS implements an alternative propulsion system, the centrifugal pump-jet propulsor. Upon vehicle integration, the system was tested in a micro-gravity environment on board NASA's KC-135 Weightless Wonder V where it had uninhibited motion. The testing was done in conjunction with the Reduced Gravity Student Flight Opportunities Program at Johnson Space Center. These tests were used to measure the functionality and effectiveness of the propulsion system and to determine a preliminary characterization of the vehicle dynamics. Analysis demonstrated that the propulsion system can effectively run a space simulator vehicle in air in a microgravity environment.*

Keywords--- *Freedom Camera, Robot Controlled, Enormous Asset.*

I. NOMENCLATURE

ISS = International Space Station

EVA = Extravehicular Activity

OSIRIS = Operational System for Inspection, Research, and Instrument Support

AERCam = Autonomous EVA Robotic Camera

ABS = acrylonitrile butadiene styrene

A/D = analog to digital

PVC = polyvinyl chloride

II. INTRODUCTION

Before the International Space Station (ISS) is complete, nearly 2000 man-hours of extravehicular activity (EVA) will be performed by astronauts.[1] Every time an astronaut participates in a space walk, he is exposed to risk: risk of collision with a micrometeorite, risk of exposure to dangerous radiation during a solar flare, and risk of a technical malfunction. Although these risks are managed and controlled by careful maneuvering of the space shuttle and monitoring of solar activity, the danger always exists. In an ongoing attempt to reduce the risk to an astronaut, the pertinent technology and methods are continually improved and refined to provide the best security. Currently, fixed cameras are used to help astronauts inspect the exterior of the ISS before, during, and after EVAs.[1] However, fixed cameras cannot provide the most convenient views, and cannot view a single area from all angles.

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By using a free-flying camera robot, inspection and verification of the workspace could be done by focusing in on the desired areas in great detail. A free-flying camera robot will improve the quality and quantity of information available to the astronaut, saving time and increasing efficiency during the EVA. By increasing efficiency, astronauts will spend less time performing EVAs, reducing the time during each mission when they are most vulnerable, a very desirable result.

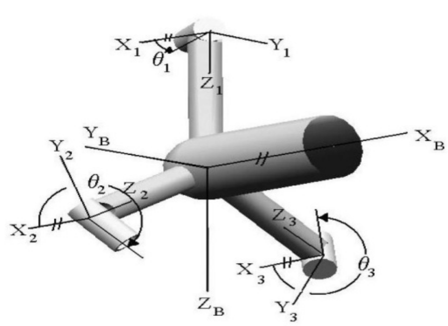
At any given time, the future of the space program depends on successes. It is extremely important that engineers be informed during every step of a given mission to ensure the highest probability of safety and success. For example, take the break-up of the Columbia space shuttle. Since the accident, all space shuttle missions have been grounded, the on-board experiments and equipment delivery postponed, and the future of the United State's involvement in the development of the ISS questioned.[2] A tragedy of this magnitude has an enormous impact and any technology that could have given the engineers any opportunity to fix the problems or reduce the risks prior to re-entry would have been an enormous asset.

The Operational System for Inspection, Research, and Instrument Support (OSIRIS) is a ten-inch diameter spherical free-flying camera robot. Although OSIRIS is designed to fly in air, the information gained as a result of its development will contribute to the development of a space version. OSIRIS has full six-axis control and can serve as a test platform for several areas of research including attitude control, path planning, inspection tasks, and human-robot interaction.

III. Previous Research

The first free flying camera platform to be tested in space was the Autonomous EVA Robotic Camera (AERCam). AERCam is approximately fourteen inches in diameter and uses twelve nitrogen gas-powered thrusters for propulsion. The first vehicle in this series flew on STS-87 in 1998 and demonstrated the usefulness of a small free flying camera.

The OSIRIS vehicle, shown in Fig. 1, represents a new direction for space simulation of camera robots. The primary drawbacks of the SCAMP and SCAMP SSV vehicles are their large size, heavy weight, and inefficient thrusters. OSIRIS was developed with a smaller maximum diameter than AERCam and a total weight of under ten pounds. In addition, an alternative propulsion system with greater potential for down-scaling was integrated. This propulsion system provides full six-axis control authority over the vehicle.



Graphical representation of vehicle body axis

The new physical configuration gives the vehicle the capability for greater maneuverability and ease of control. In addition, the small size is ideal for inspection tasks, allowing OSIRIS to access constricted areas for inspection. The low weight of OSIRIS has no effect on its space simulation capabilities, but makes it easier to manage on Earth during development and testing phases.

IV. PRINCIPLE OF OPERATION

The kinematics for OSIRIS were studied and discussed by David Hart in his Masters' thesis.[4] The propulsion system prototypes were initially created for testing in the Space System Labs' neutral buoyancy tank, so it was unclear whether or not the centrifugal pump-jet propulsor would provide sufficient thrust in an air environment. The final design by Hart was a system that included an intake with an impeller to generate flow to the nozzles. Three diffuser valves are located between the impeller and nozzles to provide additional degrees of freedom to the system. Using the three rotating nozzles and three variable position diffuser valves, OSIRIS has six degrees of freedom. The motor that drives the impeller could be throttled to provide an additional degree of freedom to the system, but this functionally was not included in the current version of vehicle development.

Figure 2 shows a basic graphical description of the geometric properties associated with the vehicle. The X, Y and Z axes with a subscripted B represent the body axes of motion for the vehicle. Each of the θ values around the small cylinders represents the corresponding rotating nozzle which produces the thrust. The larger cylinder along the X_B axis is the vehicle intake.

Geometric analysis of the vehicle proves that this setup is capable of providing sets of nozzle forces and angles that can produce complete six degree of freedom motion to the vehicle. The analysis begins with a set of six equations which are combined into matrix form with a force vector and a state vector. These two vectors contain all of the undetermined variables and trigonometric functions; all the remaining numerical coefficients are stored in a purely numerical matrix. For a complete explanation of the kinematic calculations, see Hart's thesis.

The method used by Hart separates the unknowns and inputted variables from the numerical coefficients, which makes it easier for solving the equations in a computer program. Initially, the forward kinematics were solved to determine the resulting vehicle motion from given nozzle position and force vectors. Unfortunately, this is not a usable calculation; the reverse kinematics are needed to allow a desired motion input and nozzle positions and forces output. This requires a 6x6 numerical coefficient matrix to be inverted, but since all of the trigonometric functions have already been removed into the external vectors, the calculation is simplified. At this stage θ_1,θ_2 and θ_3 can be calculated, but the nozzle forces f_1, f_2 and f_3 have yet to be determined.

The nozzle forces are related to the diffuser valve positions, which in turn are related to the flow resistance. Hart measured flow resistance coefficients based on the diffuser valve positions and determined a relational equation for the water based application of this propulsion system. For simplicity reasons, this equation was used when determining the diffuser valve percentage open in the kinematics for OSIRIS. Finally, after completing all the calculations on a desired thrust vector established by the pilot, the control code can relate the nozzle positions, θ_1,θ_2 and θ_3, and nozzle forces, f_1, f_2 and f_3, to the actual servo positions that will create the desired vehicle motion.

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V. HARDWARE DEVELOPMENT

OSIRIS was designed around the centrifugal pump-jet propulsion system to fully fit within the ten-inch diameter spherical casing. Figure 3 shows the main center assembly, which uses a Pittman 8322 brushed motor and encoder pair linked by an Oldham coupling to a two-inch diameter impeller. The motor bolts into an aluminum mount, which has a side access port that provides the ability to tighten the coupling. The impeller shaft sits in a cylindrical delrin center mount. The shaft is aligned using two ball bearings separated by a spacer. One bearing sits in the aluminum motor mount fore of the coupling connection and the second is press fit intothe aft side of delrin center mount. The motor mount bolts into the back of the center mount.

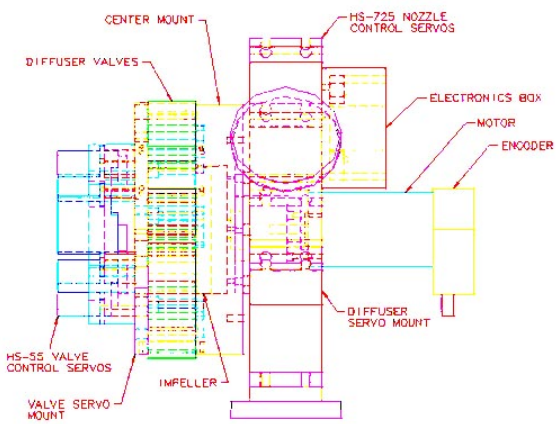

Figure 3: Main Center Assembly

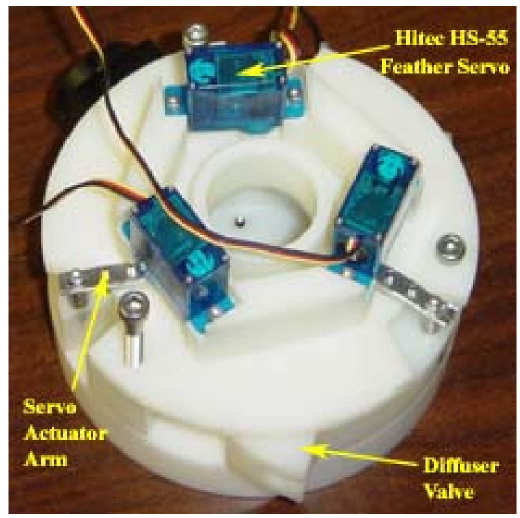

Figure 4: Diffuser Valve Assembly

On the front side of the center mount surrounding the impeller are three diffuser valves. The valves use a living hinge actuated by Hitec HS-55 Economy Feather Servos to change the three outlet areas that pipe out to the nozzles. The servos attach to a top plate that bolts through the diffuser valves into the center mount. An aluminum arm connects to a steel pin that press fits into a hole drilled into each diffuser valve after the living hinge. This allows the motion of the servo arm to rotate the valve to the proper position between fully-open and fully-closed. The full valve assembly is shown in Fig. 4. The section between the back of the diffuser valves and the rotating hinge portion of the adjacent valve frame the outlet area. These edges, capped by the center mount and the servo mount, provide a square outlet, which is then converted to a circular cross-sectional area using an adapter piece,

The nozzles were constructed from acrylonitrile butadiene styrene (ABS) plastic using a Stratasys rapid prototyping machine (see Fig. 5). The exterior of the nozzles fits the surface curvature of the ten-inch diameter sphere. The nozzles have an internal diameter of 0.75 inches, bend at ninety degrees, and taper down to 0.5 inches in diameter. These nozzles attach to the main center assembly by means of an aluminum rotation assembly, illustrated in Fig. 5. The inner aluminum piece press-fits over the of the outlet adapter and then are fixed using 0.0625 inch diameter steel pins spaced at ninety degrees around the exterior. Similarly, the outer aluminum piece press-fits over the nozzle piece and is then glued to the ABS plastic using a cyanoacrylate based adhesive. The two aluminum pieces then rotate around each other using a Teflon® bushing and washer to minimize friction.

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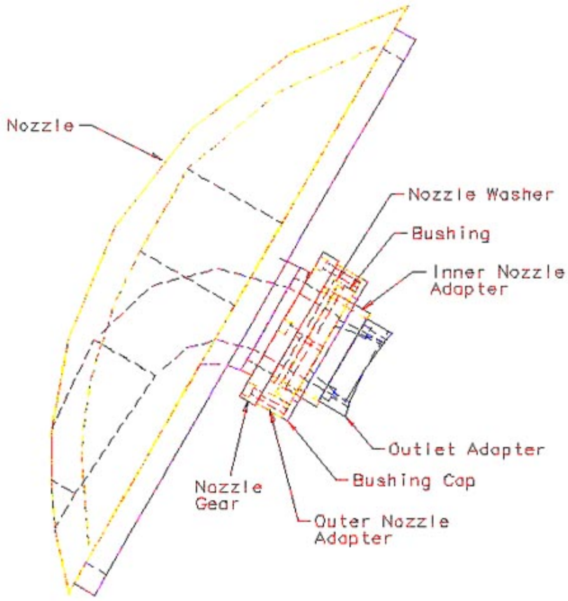

Figure 5: Nozzle assembly

Figure 6: Nozzle gear assembly

The nozzles are controlled using Hitec HS-725BB Sail Winch Servos. These servos provide full 360 degree rotation with potentiometer feedback for position control. A Small Parts GD-4884 delrin spur gear bolts to the outer aluminum piece in the nozzle-adapter assembly. This gear meshes with another gear of the same type and same number of teeth that attaches to the sail winch servo, seen in Figure 6. A single full rotation of the servo gear corresponds to a single full rotation of the nozzle. The three nozzle servos and three diffuser valve servos get commands from a Pontech SV203 servo motor controller board. This board accepts RS232 serial data from a ground based computer and outputs a pulse width modulated signal to control up to eight servos. This board allows position control of the servos and vehicle.

The intake,was also constructed on the rapid prototype machine from ABS plastic. It press-fits into the feather servo mounting plate and is held in place by the front fairing. The front of the intake includes a mounting point for a small camera box and a wire pass through one of the stators for internal wiring access. The front fairing fits over the intake and the front half of the nozzles and then bolts to the rear fairing. The rear fairing has a small bulge feature in the back that facilitates fitting the full motor length of the Pittman 8322. In addition, the rear fairing has a nine-pin D-submarine shell connector that bolts to the back. The tether from the control station plugs directly into the back, feeding power lines and signal lines to the vehicle. The two fairings bolt together around the nozzle, intake, and center assemblies to provide a protective shell around the vehicle.

VI. CONTROL SETUP

The OSIRIS control software ran on a Diamond Systems Prometheus PC-104 computer stack. These computers are commonly used as embedded systems for robotics control. The computer runs the QNX real-time operating system, which supports multi-threaded processes. Each process can support separate functionalities of the control system. Both a keyboard and the Flock of Birds control system were used for providing pilot input to the vehicle.

Since this was the first iteration of the project, the control system was completely open-loop control and simply used for basic control functions. Two separate programs were used for controlling the vehicle – the first program allowed for pilot input to select a specific degree of freedom which aligned the vehicle servos appropriately, and the second program used the Flock of Birds controller to provide rotational input while still using the keyboard for incremental translational motion.

1. Keyboard Control Program

OSIRIS was first tested using the keyboard control program. This program runs off three separate threads spawned from the main process. The first thread is executed almost immediately in the main process and it is used to monitor the motor encoder data and rate gyro data from the onboard systems. The other two threads are spawned as needed for diffuser valve servo motion and nozzle servo motion separately. Overall control is gained from looping through a control script in the main process with a menu driven interface. The pilot user interface is simplistic and easy to use; the exact commands used to provide control to OSIRIS are discussed in the test procedure section.

The main process begins by initializing the serial port communications with the servo controller board. It then runs through a script designed to align the sail winch servos that control the nozzle positions. Due to the inherent instabilities and inaccuracies with these servos this was necessary to ensure that the given commands would align the nozzles appropriately. With the servo board used in this experiment, values of 0-255 are sent via serial in a string to tell a specific servo to move to the desired position. The alignment script asked the pilot to enter a positive or negative incremental value to spin the nozzle to the desired aligned position marked by white tape on the fairing.

After the nozzle servos are aligned, the program continues on by initializing the analog to digital (A/D) converter which monitors the data recorded by the rate gyro. The Prometheus PC-104 board has built-in A/D channels of which only one was used for this project – the OUT channel from the onboard rate gyro was connected to channel 0 of the A/D converter. The thread that controls the motor encoder data collection also monitors channel 0 and records the current rate gyro data to a separate file. Data is collected at 40Hz, so this thread is constantly monitoring and recording the data outputted from the vehicle.

Once all of initialization is complete and the data collection thread has been started, the program presents the pilot with the user interface that allows for selection of a specific degree of freedom. The user interface will be described in the test procedure section, but the inner workings are as follows. After the pilot has entered all the commands necessary to describe the desired vehicle motion, a thrust vector is sent to a function. This function calculates the required servo positions for both the diffuser valve servos and nozzle positioning servos as determined from the previously described kinematics.

Subsequent to calculating the geometric kinematics of the vehicle, both of the servo motion threads are spawned. These threads call separate functions from the servo board driver which positions all six servos appropriately. To determine the corresponding servo positions, each servo was tested separately to establish the minimum and maximum positions associated with the two servo types. The physical time necessary for the servos to reach their final position is less than a second, and then the control returns to the pilot to select a new thrust profile, degree of freedom, or to quit the control program entirely.

2. Flock of Birds Control Program

Flock of Birds is a motion detector sensors designed by Ascension Technologies which provides data describing the relative position of a small controller to a larger transmitter.[5] The whole system consists of three main parts: the base, the transmitter, and the bird. The base is where each of the other components connects to and an RS232 serial cable is run to the PC-104 stack. The transmitter was mounted to the control station and the bird was mounted to the pilot's hand. When the pilot began the Flock of Birds control program data was constantly sent from Flock of Birds describing the position of the bird relative to the transmitter.

The control program that utilizes the Flock of Birds controller makes use of many of the same algorithms used in the keyboard control program. It begins by initializing the serial communications and running the nozzle servo zeroing script. The same data collection thread as used in the keyboard control program is also used in the Flock of Birds control program. After that, the control programs diverge and allow for completely different control methods. Since Flock of Birds uses relative position control, the program actually allows for direct piloting control.

The first step the program takes is to zero the data used for the kinematic calculations. This is required because the position where the pilot is holding the bird relative to the transmitter will usually be an arbitrary combination of the roll, pitch and yaw angles. When the pilot zeros the input, that position of the bird will transmit data to the kinematic calculations which ideally will result in no angular motion of the vehicle. Since the bird was mounted on the hand of the pilot, the program is designed to scale the angular input from ±90 degrees to the desired thrust vector required by the kinematic calculation function to determine servo positioning.

An additional thread is used in this control program which reads in and normalizes the Flock of Birds data to the thrust vector needed by the calculations. Originally the thread was going to average every three data points, but problems arose with reading in the keyboard input since the program was constantly stuck in a loop. Due to this issue the program was changed to update the servo positions after each data point was read in with internal consistency error checking to weed out faulty data from Flock of Birds. For instance, if the unit is located in close proximity with metal then some of the data points transmitted will contain inaccurate data. Once initial testing is completed and quantitative data is gained on how well the control system works, more intense error checking and data processing techniques will be implemented.

The other three threads in the Flock of Birds control program are functionally the same as the three threads in the keyboard control program. Many of the functions that perform the actual calculations and communications with the vehicle remain the same between the control programs to allow for transition to object-oriented control with a single control program with a graphical user interface.

VII. First Flight

During the first flight, problems were encountered when the computer tried to initialize serial communication with the vehicle. Both programs were attempted, but due to the communication problems, the vehicle was unable to be controlled by the pilot. Because of the structure of the control algorithm, the rate gyro information was taken after the serial communication was initialized. However, in this case, serial communication was never established, making it impossible to collect data from the rate gyro. Also, during the flight it was noticed that the motor was receiving inconsistent voltages. Although it set to a DC voltage of thirty volts, it would only stay on a limited time even though the batteries were fully charged. After the flight, the problems were attributed to ground wiring errors and potential corruption of the servo board. To resolve the problems before the second flight, the servo board was replaced with a spare, and with the assistance of a staff electrical engineer some minor wiring modifications were made to attempt to correct the ground issues

VIII. Second Flight

During the second flight, the problems that plagued the first flight again proved to be an issue. Due to limited resources and time, it was impossible to fully diagnose the problem and test the solutions prior to flight. Because of the serial communication problems, the computer could not tell the servos how to orient the diffuser valves and nozzles. These communication problems forced the computer programs to be ineffective, so the computer was disconnected mid-flight. The motor was still behaving in an inconsistent manner, so the voltage was downgraded to twelve volts in an attempt to resolve the observed problems. Unfortunately, twelve volts driving the motor did not provide sufficient thrust for the vehicle. Again, the voltage level was changed back to thirty volts, which now that the computer was disconnected, appeared to function properly. Once the motor was functioning, the nozzles were oriented manually in known basic configurations for a translational test and a rotational test. These actions finally demonstrated that sufficient thrust in air could be generated by the use of a centrifugal pump-jet propulsor. The actions that were taken in flight allowed useful qualitative data to be observed.

IX. Conclusion

The most significant result to come from the testing was that the propulsion system was capable of controlling the vehicle in the zero-g air environment. The air environment had been a cause of concern because the propulsion system had been designed for water.

For a first generation vehicle, the testing of OSIRIS was successful by showing both weaknesses and strengths that can be used when modifying the vehicle in the next generation. Although the onboard sensors were unable to record quantitative data, the demonstration that sufficient thrust could be produced in air using the centrifugal pump jet propulsor proves that the idea is one worth pursuing. Unfamiliarity with the test environment and the inability to fully test in 1-g were unfortunate detractors from the results. However, with the experience gained during the two flights and the planned improvements, the same problems should not be encountered in the future. Future flight team will draw from the experiences of these two flights and be better prepared for the potential difficulties inherent in a complex experimental system in an unfamiliar environment.

Finally, there were aspects of the experimentation that were not anticipated until they were experienced during the flight. Because zero gravity and twice gravity are both regimes for which little intuition existed prior to flight, several aspects of the experiment could be improved based on experience. Some of the mechanical components were strained during twice gravity. This problem would be solved by getting more powerful components and by making sure that these components could easily handle the two-g loading. Also, as the plane goes through the zero gravity portion of the flight, there is a momentum that causes floating items to drift towards the rear of the plane. This effect should be taken into account when designing future testing.

OSIRIS is the first generation of a six degree-of-freedom camera robot. The experimentation done in conjunction with the Reduced Gravity Student Flight Opportunities Program served as a proof of concept on which to base future testing. The results gained during the microgravity flight, although quantitative in nature, were sufficient to justify a future research investment.

References

[1] Thooyamani, K.P., Khanaa, V., & Udayakumar, R. (2014). Virtual instrumentation based process of agriculture by automation. *Middle-East Journal of Scientific Research*, *20*(12): 2604-2612.
[2] Udayakumar, R., Kaliyamurthie, K.P., & Khanaa, T.K. (2014). Data mining a boon: Predictive system for university topper women in academia. *World Applied Sciences Journal*, *29*(14): 86-90.
[3] Anbuselvi, S., Rebecca, L.J., Kumar, M.S., & Senthilvelan, T. (2012). GC-MS study of phytochemicals in black gram using two different organic manures. *J Chem Pharm Res*., *4*, 1246-1250.
[4] Subramanian, A.P., Jaganathan, S.K., Manikandan, A., Pandiaraj, K.N., Gomathi, N., & Supriyanto, E. (2016). Recent trends in nano-based drug delivery systems for efficient delivery of phytochemicals in chemotherapy. *RSC Advances*, *6*(54), 48294-48314.
[5] Thooyamani, K.P., Khanaa, V., & Udayakumar, R. (2014). Partial encryption and partial inference control based disclosure in effective cost cloud. *Middle-East Journal of Scientific Research,* 20(12), 2456-2459.
[6] Lingeswaran, K., Prasad Karamcheti, S.S., Gopikrishnan, M., & Ramu, G. (2014). Preparation and characterization of chemical bath deposited cds thin film for solar cell. *Middle-East Journal of Scientific Research*, *20*(7), 812-814.
[7] Maruthamani, D., Vadivel, S., Kumaravel, M., Saravanakumar, B., Paul, B., Dhar, S.S., Manikandan, A., & Ramadoss, G. (2017). Fine cutting edge shaped Bi2O3rods/reduced graphene oxide (RGO) composite for supercapacitor and visible-light photocatalytic applications. *Journal of colloid and interface science*, *498*, 449-459.
[8] Gopalakrishnan, K., Sundeep Aanand, J., & Udayakumar, R. (2014). Electrical properties of doped azopolyester. *Middle-East Journal of Scientific Research, 20*(11). 1402-1412.
[9] Subhashree, A.R., Parameaswari, P.J., Shanthi, B., Revathy, C., & Parijatham, B.O. (2012). The reference intervals for the haematological parameters in healthy adult population of chennai, southern India. *Journal of Clinical and Diagnostic Research: JCDR*, *6*(10), 1675-1680.
[10] Niranjan, U., Subramanyam, R.B.V., & Khanaa, V. (2010, September). Developing a web recommendation system based on closed sequential patterns. In *International Conference on Advances in Information and Communication Technologies, 101,* 171-179. Springer, Berlin, Heidelberg.
[11] Slimani, Y., Baykal, A., & Manikandan, A. (2018). Effect of Cr3+ substitution on AC susceptibility of Ba hexaferrite nanoparticles. *Journal of Magnetism and Magnetic Materials*, *458*, 204-212.
[12] Premkumar, S., Ramu, G., Gunasekaran, S., & Baskar, D. (2014). Solar industrial process heating associated with thermal energy storage for feed water heating. *Middle East Journal of Scientific Research*, *20*(11), 1686-1688.
[13] Kumar, S.S., Karrunakaran, C.M., Rao, M.R.K., & Balasubramanian, M.P. (2011). Inhibitory effects of Indigofera aspalathoides on 20-methylcholanthrene-induced chemical carcinogenesis in rats. *Journal of carcinogenesis*, *10*.

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[14] Beula Devamalar, P.M., Thulasi Bai, V., & Srivatsa, S.K. (2009). Design and architecture of real time web-centric tele health diabetes diagnosis expert system. *International Journal of Medical Engineering and Informatics*, *1*(3), 307-317.

[15] Ravichandran, A.T., Srinivas, J., Karthick, R., Manikandan, A., & Baykal, A. (2018). Facile combustion synthesis, structural, morphological, optical and antibacterial studies of Bi1− xAlxFeO3 (0.0≤ x≤ 0.15) nanoparticles. *Ceramics International*, *44*(11), 13247-13252.

[16] Thovhogi, N., Park, E., Manikandan, E., Maaza, M., & Gurib-Fakim, A. (2016). Physical properties of CdO nanoparticles synthesized by green chemistry via Hibiscus Sabdariffa flower extract. *Journal of Alloys and Compounds*, *655*, 314-320.

[17] Thooyamani, K.P., Khanaa, V., & Udayakumar, R. (2014). Wide area wireless networks-IETF. *Middle-East Journal of Scientific Research*, *20*(12), 2042-2046.

[18] Sundar Raj, M., Saravanan, T., & Srinivasan, V. (2014). Design of silicon-carbide based cascaded multilevel inverter. *Middle-East Journal of Scientific Research*, *20*(12), 1785- 1791.

[19] Achudhan, M., Jayakumar M.P. (2014). Mathematical modeling and control of an electrically-heated catalyst. *International Journal of Applied Engineering Research*, *9*(23), 23013.

[20] Thooyamani, K.P., Khanaa, V., & Udayakumar, R. (2013). Application of pattern recognition for farsi license plate recognition. *Middle-East Journal of Scientific Research*, *18*(12), 1768-1774.

[21] Jebaraj, S., Iniyan S. (2006). Renewable energy programmes in India. *International Journal of Global Energy Issues, 26*(43528), 232-257.

[22] Sharmila, S., & Jeyanthi Rebecca, L. (2013). Md Saduzzaman., Biodegradation of domestic effluent using different solvent extracts of Murraya koenigii. *J Chem and Pharm Res*, *5*(2), 279-282.

[23] Asiri, S., Sertkol, M., Guner, S., Gungunes, H., Batoo, K.M., Saleh, T.A., Manikandan A., & Baykal, A. (2018). Hydrothermal synthesis of CoyZnyMn1-2yFe2O4 nanoferrites: magneto-optical investigation. *Ceramics International*, *44*(5), 5751-5759.

[24] Rani, A.J., & Mythili, S.V. (2014). Study on total antioxidant status in relation to oxidative stress in type 2 diabetes mellitus. *Journal of clinical and diagnostic research: JCDR*, *8*(3), 108-110.

[25] Karthik, B. (2014). Arulselvi, Noise removal using mixtures of projected gaussian scale mixtures. *Middle-East Journal of Scientific Research*, *20*(12), 2335-2340.

[26] Karthik, B., Arulselvi, & Selvaraj, A. (2014). Test data compression architecture for low power VLSI testing. *Middle - East Journal of Scientific Research, 20*(12), 2331-2334.

[27] Vijayaragavan, S.P., Karthik, B., & Kiran Kumar, T.V.U. (2014). Privacy conscious screening framework for frequently moving objects. *Middle-East Journal of Scientific Research*, *20*(8), 1000-1005.

[28] Kaliyamurthie, K.P., Parameswari, D., & Udayakumar, R. (2013). QOS aware privacy preserving location monitoring in wireless sensor network. *Indian Journal of Science and Technology*, *6*(5), 4648-4652.

[29] Silambarasu, A., Manikandan, A., & Balakrishnan, K. (2017). Room-temperature superparamagnetism and enhanced photocatalytic activity of magnetically reusable spinel ZnFe 2 O 4 nanocatalysts. *Journal of Superconductivity and Novel Magnetism, 30*(9), 2631-2640.

[30] Jasmin, M., Vigneshwaran, T., & Beulah Hemalatha, S. (2015). Design of power aware on chip embedded memory based FSM encoding in FPGA. *International Journal of Applied Engineering Research*, *10*(2), 4487-4496.

[31] Philomina, S., & Karthik, B. (2014). Wi-Fi energy meter implementation using embedded linux in ARM 9. *Middle-East Journal of Scientific Research*, *20*, 2434-2438.

[32] Vijayaragavan, S.P., Karthik, B., & Kiran Kumar, T.V.U. (2014). A DFIG based wind generation system with unbalanced stator and grid condition. *Middle-East Journal of Scientific Research*, *20*(8), 913-917.

[33] Rajakumari, S.B., & Nalini, C. (2014). An efficient data mining dataset preparation using aggregation in relational database. *Indian Journal of Science and Technology*, *7*, 44-46.

[34] Karthik, B., Kiran Kumar, T.V.U., Vijayaragavan, P., & Bharath Kumaran, E. (2013). Design of a digital PLL using 0.35 Î¼m CMOS technology. *Middle-East Journal of Scientific Research, 18*(12), 1803-1806.

[35] Sudhakara, P., Jagadeesh, D., Wang, Y., Prasad, C.V., Devi, A.K., Balakrishnan, G., Kim B.S., & Song, J.I. (2013). Fabrication of Borassus fruit lignocellulose fiber/PP composites and comparison with jute, sisal and coir fibers. *Carbohydrate polymers*, *98*(1), 1002-1010.

[36] Kanniga, E., & Sundararajan, M. (2011). Modelling and characterization of DCO using pass transistors. In *Future Intelligent Information Systems*, 86(1), 451-457. Springer, Berlin, Heidelberg.

[37] Sachithanandam, P., Meikandaan, T.P., & Srividya, T. Steel framed multi storey residential building analysis and design. *International Journal of Applied Engineering Research*, *9*(22), 5527-5529.

[38] Kaliyamurthie, K.P., Udayakumar, R., Parameswari, D., & Mugunthan, S.N. (2013). Highly secured online voting system over network. *Indian Journal of Science and Technology*, *6*(S6), 4831-4836.

[39] Sathyaseelan, B., Manikandan, E., Lakshmanan, V., Baskaran, I., Sivakumar, K., Ladchumananandasivam, R., Kennedy, J., & Maaza, M. (2016). Structural, optical and morphological properties of post-growth calcined TiO2 nanopowder for opto-electronic device application: Ex-situ studies. *Journal of Alloys and Compounds*, *671*, 486-492.

[40] Saravanan, T., Sundar Raj M., & Gopalakrishnan K. (2014). SMES technology, SMES and facts system, applications, advantages and technical limitations. *Middle - East Journal of Scientific Research, 20*(11), 1353-1358.

[41] Ayeblo, Y.N., & Faraahi, A. (2015). A Survey of the Solutions to Detect and Deal with File Injection Attacks in Web Sites through Access to Web Server Shared Resources. *International Academic Journal of Science and Engineering, 2*(9), 37-51.

[42] Shanthi, C., & Revathi, V. (2015). DiMAVE, Object Sharing in Distributed Multi Agent Volunteer Environment. *International Scientific Journal on Science Engineering & Technology, 18*(6), 184-186.

[43] Dr. Sujatha, P., & K. Kavitha (2015). Proficient Data Mining Approach for Search Engine Optimization. *International Scientific Journal on Science Engineering & Technology, 18*(6), 190-194.

[44] Dharani Priya, M., & Perumal, S. (2015), Simultaneously Reducing Latency and Power Consumption in Open Flow Switches. *International Scientific Journal on Science Engineering & Technology, 18*(6), 195-199.

[45] Padmaja, S., & Uma Maheswari, J. (2015). A Light Weight Approach to Online Detection and Classification of Interference in 802.15.4-Based Sensor Networks. *International Scientific Journal on Science Engineering & Technology, 18*(6), 200-204.

[46] Kulworawanichpong, T., & Punpaisarn, S. (2014). Computer Mediated Problem based Learning and Higher Order Thinking Skill - A Preliminary Study. *The SIJ Transactions on Advances in Space Research & Earth Exploration, 2*(4), 65-69.

[47] Dr. Ada, M.W.W., & Dr. Chun, W.M. (2014). Simulating Bipedal Character Motions for Kinect Games. *The SIJ Transactions on Advances in Space Research & Earth Exploration, 2*(4), 70-75.

[48] Chamuchi, M.N., Sigey, J.K., Okello, J.A., & Okwoyo, J.M. (2014). The Ideal Computing System Framework –A Novel Security Paradigm. *The SIJ Transactions on Advances in Space Research & Earth Exploration, 2*(4), 94-103.

[49] Creado, O.M., Srinivasan, B., Le, P.D., & Tan, J. (2014). A Privacy-Preserving Unpadded RSA based-Third Party Auditing Protocol for Cloud Storage Secure. *The SIJ Transactions on Advances in Space Research & Earth Exploration, 2*(5), 1-6.