A PROPOSAL TO THE OHIO UNIVERSITY RESEARCH COUNCIL

TITLE OF PROJECT: Machine Learning in the Actuating Internet of Things_ ________

NAME OF APPLICANT: _Julio Arauz_____________________________________

STATUS: __X___ Asst. Prof. _____Assoc. Prof. _____Prof. _____ Administrator

DEPARTMENT: _School of Information and Telecommunications Systems________
CAMPUS ADDRESS: 31 S. Court St. Rm 156______________________________
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RE-SUBMISSION: _X_ YES (Original Submission Date Sep/30/2013)
____ NO

BUDGET: Total Request ___7932.08__________
(May not exceed $8,000)

IRB AND IACUC APPROVAL:
To ensure that the University is in compliance with all federal regulations, complete the checklist below. Note: your proposal can be approved prior to IRB or IACUC approval, but funding will be withheld until notification of approval or exemption.

Yes	***No***	***Office of Research Compliance***	***Policy #***
X		Human Subjects in Research (including surveys, interviews, educational interventions): Institutional Review Board (IRB) Approval #: 13X200 Expiration Date: 9/17/2014	19.052
		Animal Species: Institutional Animal Care & Use Committee (IACUC) Approval #: Expiration Date:	19.049

SIGNATURES:

Applicant's Signature		**Chair/Director's Signature**	
Signature		Signature	[signature]
Name	Dr. Julio Arauz	Name	Mr. Phil Campbell
Dept/School	ITS	Unit	ITS
Date	Jan/21/2014	Date	Jan/21/2014
Dean's Signature			
Name	Dr. Scott Titsworth	Signature	[signature]
College	Communications	Date	1/22/14

√ **Optional:**
If selected for funding, I give permission to the Office of the Vice President for Research and Creative Activity to use my proposal as an example during training and workshop exercises.

Signature: [signature] Date:_Jan/29/2014_______________

Ohio University Research Council Proposal Checklist

Applicants **<u>must</u>** complete and sign the checklist. The checklist should be included as the second page of the application (following the cover page).

✔ Cover Page	use OURC form
✔ Checklist	use OURC form
✔ Abstract*	1 double-spaced page
✔ Introduction *(for resubmissions only)**	1 double-spaced page
☐ New Project Description *(for established applicants only*[†]*)**	1 double-spaced page
✔ Discussion	10 double-spaced pages
✔ Glossary/Definition of Terms* *(not required)*	2 double-spaced pages
✔ Bibliography *(not required)*	3 pages
✔ Biographical information *(applicant(s) and key personnel)*	3 pages per person
✔ Other Support *(applicant(s) and key personnel)*	1 page per person
✔ Budget and Justification	no limit specified
✔ Appended Materials	10 pages; no more than 10 minutes of footage
✔ Recommended Reviewers	5 required
✔ Electronic copy of proposal	Single Acrobat file, containing entire proposal and required signatures

* These sections should be written in language understandable by an informed layperson to assist the committee in its review. Established applicants (*†)* are faculty members who have tenure **and** have been at the university at least three years or administrators who have been at the university at least five years.

****Please note: The committee has the right to return without review any proposals that do not conform to these format requirements.****

Applicant signature: Julio Aráuz S ____________________

3. ABSTRACT

{This project aims at enabling a new and completely different capability of what is known as the Internet of Things (IoT). Today the IoT is largely a collection of Internet connected sensors that gather data for a variety of purposes in areas like home automation or smart energy grids. This project proposes research with a completely different type of device, Internet connected actuators. Contrary to sensors that are passive, actuators carry out tasks that involve physical movement. The use of actuators is quite common in modern industrial environments. Consider for instance the assembly lines in modern factories where robots operate under tightly controlled conditions. These robots are basically a group of interconnected actuators commanded via a reliable communication link. They can follow a previously written script of commands, as the task and the environment in which they operate do not change; thus this application is referred to as a non real time one.

This project is unique in that it proposes looking at the challenges that exist when actuators are used in real time applications. To illustrate the difference, consider the command of an unmanned flying vehicle using a wireless link in an unknown environment. In this scenario tasks cannot be scripted in advanced and the communications link could be unreliable.}

The main goal of this 12-month project is to research techniques that compensate for challenging network conditions when actuators are employed in real-time applications commanded over the IoT. The IoT is a lossy {(e.g. can lose information)} and delay prone environment that complicates their operation by human subjects. The project will make significant contributions to applications in robotics, unmanned rescue vehicles or remote surgery. The outcomes will be reported in peer-reviewed publications along with implementation guidelines from which multiple domains in industry and academia will benefit.

4. INTRODUCTION

This proposal has been revised following the recommendations from the fall cycle committee. The following changes have been introduced.

First, the title was changed to reflect the correct terminology for the proposed work. As the underlying proposed framework uses machine learning technology; this terminology was used to correctly reflect the proposed work instead of the terms *artificial intelligence*. This correction was made throughout the text.

Second, one consistent example is used throughout the proposal to explain the project goals and tasks. Instead of visiting multiple application examples, the unmanned flying vehicle example is used to explain concepts throughout the document.

Third, the methodology section emphasizes that the work proposed will be based on quantitative analysis. A comment from the reviewing committee expressed concerns regarding the applicability of qualitative analysis for some related applications (e.g. remote surgery). While the comment correctly highlights that limitation, the proposal now emphasizes that previous work in the area looked at qualitative results but the newly proposed work will be geared towards quantitative methods and analysis.

Fourth, intermittent lay language was introduced throughout the proposal following the changes in content and structure suggested by the OURC program coordinator.

Fifth, to comply with formatting requirements, figures were redesigned, the preliminary studies section was subdivided and simplified in order to better explain previous reserach. The text was reformatted accordingly without affecting any main section of the document.

All changes to previously existing text are marked throughout the proposal inside curly brackets (e.g. {}).

5. DISCUSSION

A. SPECIFIC AIMS

{Imagine you are remotely controlling a flying unmanned vehicle over a wireless link. When there are no communication impairments, commanding the vehicle is straightforward. However, once there is no direct line of sight between you and the vehicle it is likely that the commands you send will get lost or corrupted over the air. This greatly hinders your ability to perform maneuvers and degrades the quality of the experience.

In a general way, the unmanned vehicle is just a set of actuators. In this context, the goal of this project is to answer the following main research question for the control of actuating systems operated via lossy links or networks.}

i. How can one compensate for the delay and losses introduced by the intermediate network that degrade the quality of the experience and aid the human operator controlling the actuating system?

The proposed research hypothesizes that if key performance network indicators {(e.g. network delay or packet losses)} along with historical short-term user behavior properties (e.g. speed and direction of movement) are taken into consideration in a software-based {machine-learning} engine, it should be possible to compensate for communication challenges and improve the perceived quality of experience of human operators.

Compensation for these challenges could be achieved by partially or fully hiding the communication {impairments}, introduced by the network, from the human operator. In this research it is assumed that other legacy compensation mechanisms that provide communication reliability {in data networks}, cannot effectively operate in this case. {This project is interested in looking at impairments that} are more common and last longer than those supported by legacy mechanisms employed in data networks.

The project also aims at answering the following secondary research questions.

ii. What are the factors that influence the ability to compensate for network losses?

iii. Can compensating mechanisms be extended from one type of actuating system (e.g robotic arm) to another (e.g. unmanned vehicle)?

iv. How do you determine the dynamic range where a compensating mechanism is effective?

v. How do internal (e.g. network characteristics or compensating model) or external (e.g. type of physical controller) factors influence the dynamic range where the compensating mechanism is effective?

Answering these secondary research questions will help in characterizing the machine learning solution. Additionally, the answers will allow for gaining understanding of the limitations of any compensation mechanism as a function of the type of actuating system and controller.

B. SIGNIFICANCE

The proposed research project lies in an area where multiple modern applications can greatly benefit from its successful completion. To illustrate the importance of the project we will revisit the case of a rescue operation carried out by unmanned vehicles in an emergency situation like the exploration of collapsed buildings after earthquakes. Today in such a scenario, the operator of the system is typically tied to the exploration site via a local wireless link established between a command center and a robot. However, wireless links, due to the nature of the channel, regularly experience quality variations that result in intermittent connectivity and thus a degraded experience during the control of the system. Similar scenarios are common in other applications {already mentioned elsewhere}. Therefore, there is a current need for mechanisms that can enhance the user experience when controlling actuating systems under challenging communication conditions.

Previous research has not looked at any compensation mechanism that can aid in the operation of actuating systems when intermediate links experience short intermittent outages. Existing research has also left unexplored the case where the actuating system is commanded through a packet switched network that may introduce varying delays or losses in the transmission of commands to the system.

The proposed research project seeks {to improve} the quality of experience a human operator perceives when commanding actuating systems under challenging communication circumstances. This improvement can be achieved by incorporating a compensation mechanism near the actuators. An improved quality could be achieved with a mechanism that aids in the execution of tasks that require a finer precision of movement when network conditions are challenging. For such a mechanism, there is wide range of applications that can benefit a very large population of direct and indirect users. As mentioned elsewhere, the successful completion of the project could aid applications related to remote patient examination, remote surgery or unmanned aerial, spatial or submarine vehicle control.

The creation of machine learning based compensation mechanisms, as mentioned before, is a new unexplored field. It constitutes a new endeavor for the researcher who in the past has dedicated efforts to research in the area of networking, wireless networking and quality of service studies. In addition, this project demands abilities in a wide range of areas that cover applied topics in computer science, electrical engineering and systems control. The researcher has carried out research in all the relevant areas; however, a combination of these skills in one project constitutes a new, challenging direction.

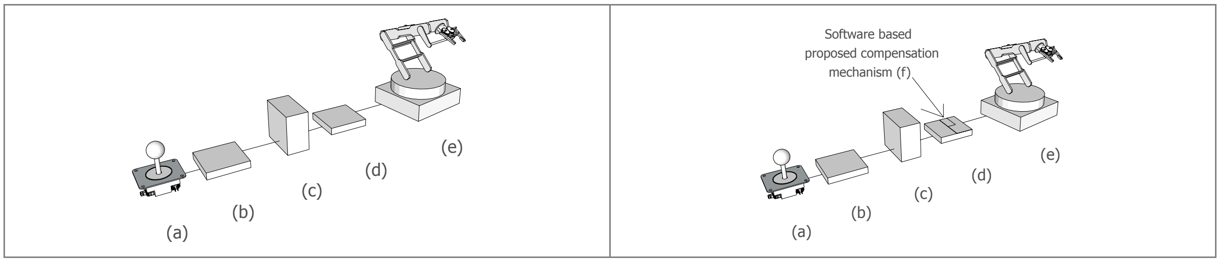

Figure 1. {**Test bed for measuring perceived quality of experience**
Left: Original setup. Right: Setup with future software based compensation module}

{The results from this project will be disseminated via publications within the IoT and Cyberphysical Systems (CPS) research community. The targets for publication will be the IEEE (Institute of Electrical and Electronics Engineers) CPS Week conference. Subsequent publications sponsored by professional organizations (e.g. IEEE and ACM) will be sought thereafter. }

C. PRELIMINARY STUDIES OF THE APPLICANT

Actuating systems were first considered by the researcher in the context of perceived quality of experience (QoE) studies for the IoT [2]. {This study focused on collecting quantitative and qualitative data about the experience when operating actuators via lossy and delay prone links.}

{C.1 Experimental Setup: The **left** section of **Figure 1** illustrates the setup constructed by the researcher for QoE measurements. {This test bed allowed an operator to command a set of actuators (e.g. motors) in a robotic arm. It had five main elements. First, an analog joystick controller (a) was used to command the system. The controller was connected to an electronic board (b), which translated joystick analog commands into digital data packets to be transmitted over a network. To simulate randomly distributed packet losses and delay in a network a link emulator box was used (c). Once data packets were processed by the link emulator (c) they were sent to a second electronic board (d). The only function of this second board was to read the data packets and interpret which motor in the robotic arm (e) should be moved.}

{<u>C.2 Experimental Design and Procedures</u>: To measure quality of experience the following approach was employed. Users were asked to move a dot of light, projected by a small laser attached to the robotic arm's gripper, between a set of marks on the wall as shown in **Figure 2**. Two distinct degrees of freedom configurations were tested; the first one restricted the arm's movement to a horizontal direction (**Fig. 2 -** left), the second allowed movement in both horizontal and vertical directions (**Fig. 2 -** right).}

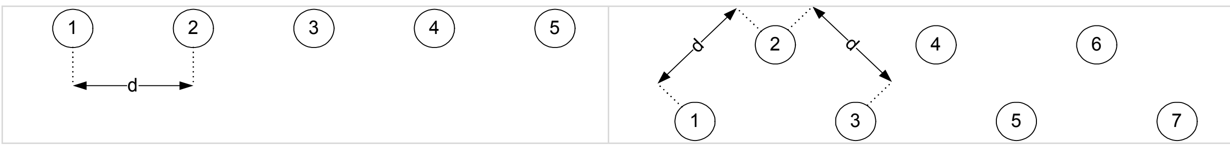

Figure 2. Wall marks for QoE data collection. {**Left: One degree of freedom: horizontal. Right: Two degrees of freedom: horizontal and vertical**}

Qualitative QoE was evaluated by asking a human operator to classify the task completion experience by using an ACR (absolute category rating) scale recommended by the International Telecommunications Union (ITU) for qualitative classifications [3]. This scale assigns a numerical level, known as the mean opinion score (MOS), of five to the best experience and of one to the worst. Quantitative performance was simultaneously studied by recording how fast the operator was able to complete the set of tasks. Each task was {replicated} multiple times and multiple first-time operators were considered.

{<u>Factors and levels considered for the study:</u>} Three factors were considered in the study; these being packet delay, packet loss and number of degrees of freedom. A wide range of levels was chosen for the packet delay and loss factors introduced by the network link emulator {(see device (c) in **Figure 1**)}.

{<u>C.3 Results and Analysis</u>: The researcher studied the quality of the experience through two variables. The first variable referred to as "mean opinion score" (MOS), was based on a qualitative rating given to the experience and, as explained before, its analysis uses the methodology and scale recommended by the ITU for quality ratings [3]. Human subjects assigned these scores after performing the tasks under varied network conditions. The scores from all participants and all runs were averaged to obtain the MOS for different network delays, packet losses and degrees of freedom conditions.

The researcher also studied the quality of experience through the “mean task completion time” variable. The task completion time corresponds to the amount of time it takes a human subject to complete several the tasks illustrated in **Figure 2**. All the completion times were averaged grouping them accordingly in the same way as with the MOS. The results for both variables are presented in **Figure 3**. The left subfigures show the MOS and the right subfigures illustrate the mean task completion time for different network conditions and degrees of freedom.

Regarding the MOS results, notice that as expected the reported value decreases as network conditions deteriorate or the number of degrees of freedom increases. Beyond this expected trend, *the results allowed learning of crucial information about the corresponding magnitude of network delay and packet losses that human subjects rate as having high or low MOS*. This information has never been analyzed in the past and is extremely useful for future experiments as it indicates the regions of operation that should be of interest. In particular, for the future work described in this proposal the regions where quality deteriorates but tasks can still be completed under certain MOS targets are of particular interest. For example, the delay region between 200 and 300 milliseconds with packet losses between 5% and 10% correspond to areas where the MOS is above a value of 2 and is an initial target for the evaluation of the compensation mechanism proposed in this document.

Regarding the mean task completion time the researcher observed similar trends. However, *insight was learned about several interesting effects*. First, notice how some mean completion

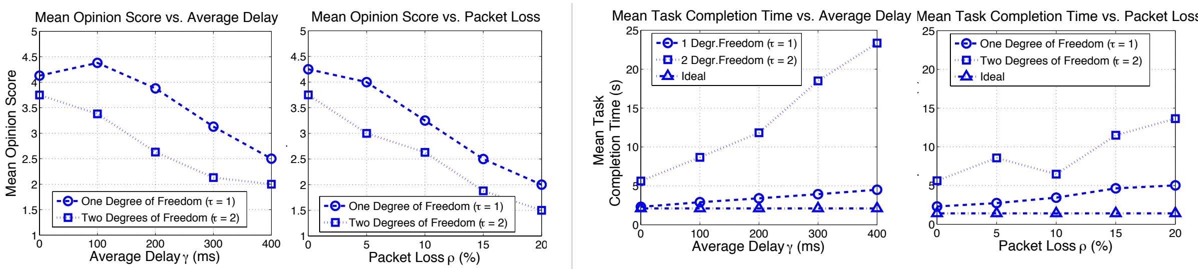

Figure 3. {**Results under different network conditions and for one and two degrees of freedom. Left:Mean opinion scores. Right:Mean task completion times. (See [2] for tabulated confidence levels)**}

times tend to be lower than the expected trend values (see 10% packet loss with two degrees of freedom). From further analysis of the results the researcher learned that under some conditions human subjects gained experience on how to use the system after several trials and thus performed better. Second, the experiment allowed learning how different in magnitude the completion times were from the ideal values. Under ideal conditions (no delay, or losses) we can compute the task times as the actuators move at a known speed and the distance *d* between marks (see **Figure 2**) is also known. The magnitude of the difference will allow performance evaluation of the future compensation mechanism proposed in this document.}

D. Methods

To answer the questions proposed in **Section 5A** {the researcher proposes the design of a compensation mechanism located adjacent to the actuating system as shown in the right section of **Figure 1** in device **e** with the added software module **f**. The new envisioned mechanism enhances device **e** by using machine learning to gain knowledge of the human operator's past movements and network conditions. The mechanism then aids the operator when communication challenges occur. To be successful this project will demand higher quality devices to replace the current ones shown in the test bed from **Figure 1**.}

This project will utilize a methodology similar to that employed for the creation of compensation mechanisms in related domains. In particular, this project will use the principles employed in the creation of compensation and evaluation models for packetized voice and human computer interaction applications [4][5]. These past studies based their methodologies on experiments similar to those described in the previous subsection to carry out {quantitative and qualitative characterizations of the QoE. *However, this project will be geared towards quantitative results and their analysis*}. The procedural methodological steps are detailed next.

a. In the execution of the project it is first necessary to select a machine learning mechanism suitable for the problem. While there are numerous machine learning mechanisms that are applicable to this challenge, for this project the researcher will first consider probabilistic graphical models (PGMs) as the framework. In recent, though unrelated, work the researcher has successfully employed these models to characterize both network and human behavior [6][7]; other research has also shown its suitability to model mobile human actions [8]. PGMs are Bayesian networks that allow a graphical representation of random variables and their influence in graphs. An advantage of these models is their simplicity in construction and straightforward characterization [9]. The *machine learning* framework requires the creation of a basic compensation model. Inputs to the model should mainly consider historical user behavior and network performance indicators. Outputs should indicate whether a particular behavior can be compensated or not and {if necessary what the compensating action should be}. For the creation of this first basic model the researcher will take into account as random variables the network quality indicators and the variables that characterize user movement (e.g. speed, direction, historical variations of speed and direction). Thereafter, it will be necessary to evaluate numerous configurations of influence flow between the variables and selection of possible outputs.

While there is no known methodology to determine optimal or sub-optimal probabilistic influence flow in PGMs, it should be possible to base the design on previous work in other domains [6][7]. For example, based on the experimental data previously obtained by the researcher; the output of the compensation mechanism should determine if movement is or is not allowed during short communication interruptions. Thus, the decision could be probabilistically heavily influenced by packet loss probability and lightly influenced by packet delays [2]. In addition, the decision could also be influenced by historical information on how fast, where, and how often the operator moves the actuating system. Finally, the model could also consider a dynamic operation where system and operator behavior change over time.

b. A first characterization of the probability values required in the model will be performed based on a heuristic approach. This type of approach assigns coarsely estimated values to PGMs parameters based on basic knowledge of the physics of the experiment.

c. Once the first model is characterized an *alpha* test will be carried out with a small group of users. Typically *alpha* testing involves the researcher and other assistants involved in or loosely related to the project. Based on previous experience the *alpha* test group will be approximately ten individuals. The *alpha* test will be designed in a similar way to that followed in previous evaluations of QoE [2]. Tasks similar to those shown in **Figure 2** but for two different types of actuating systems (e.g. robotic arm and small scale unmanned vehicle) will be designed and evaluated. This will provide a first insight into the answers to the secondary *research questions ii* and *iii* (see Section 5A).

d. The results from the *alpha* test will be used as feedback for evaluating changes in the model. Recommendations for changes or improvements will be based on a statistical analysis of the differences between the task completion times with and without the compensation mechanism. It is expected that changes will mainly consist in revisiting probabilistic influence assignments and parameterization.

e. Once a second improved model is created a *beta* testing phase will be carried out. This phase will involve similar tasks but will include a larger human operator set of 50 individuals.

f. The large data set obtained from the *beta* testing phase will be employed as feedback for incorporating improvements in the model and the creation of *version 1.0* of the compensating system. This version will be tested with a group also consisting of 50 human operators. Data from both the *beta* and *version 1.0* testing phases will be analyzed to answer the secondary research questions *iv* and *v.* To find the dynamic range (see section 5A) the researcher is planning to employ statistical analysis of the task completion times and factorial design as in [2].

TABLE 1. DETAILED EXECUTION TIMELINE OVER A 12-MONTH PERIOD

TASK (R=RESEARCHR., GA = ASSISTN.)	RESOURCES	1	2	3	4	5	6	7	8	9	10	11	12
Design of compens. mechanism	R	X	X	X	X								
Test bed construction	R	X	X	X	X								
First characterization	R					X	X						
Alpha testing	R						X						
Analysis of results and tuning	R + GA							X					
Beta testing	R + GA								X	X			
Version 1.0 testing	R + GA										X		
Report & guidelines preparation	R + GA										X	X	X

E. COLLABORATIONS

This project will not include collaboration with researchers from outside Ohio University. It will only involve the main researcher and a graduate student assistant (to be selected). The duties of the graduate student will include support in creation of new electronic control mechanisms and software for the test bed. Additionally, the graduate student will be in charge of collecting data during all phases of testing and in the early stages of preparation of public and institutional reports. Overall it is expected the graduate student to dedicate not more than 15 hours of work per week for one semester.

5. BIBLIOGRAPHY

[1] M. Branicky, M. Cenk Cavusoglu, V. Liberatore, “Multi-Disciplinary Challenges and Directions in Networked Cyber-Physical Systems”, National Science Foundation Workshop on Cyber-Physical Systems, 2006, Austin, USA.

[2] J. Aráuz , T. Fynn-Cudjoe, “Actuator Quality in the Internet of Things”, IEEE Workshop on Internet-of-Things Networking and Control (IoT-NC), in conjunction with IEEE SECON, New Orleans, 2013, USA.

[3] ITU-T, “Recommendation P.800, Methods for subjective determination of transmission quality,” August 1996.

[4] R. G. Cole and J. H. Rosenbluth, “Voice Over IP Performance Monitoring,” SIGCOMM Comput. Commun. Rev., vol. 31, no. 2, pp. 9–24, Apr. 2001. [Online]. Available: http://doi.acm.org/10.1145/505666.505669.

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[6] J. Aráuz, “Estimating Hidden Information for Self-Organization and Self-Healing in Modern Wireless Networks”, MIST Complex Adaptive Systems, 2013, Baltimore, USA.

[7] J. Aráuz, “Self-Organizing Evolving Education”, MIST Complex Adaptive Systems, 2013, Baltimore, USA.

[8] T. Huang, D. Koller, J. Malik, G. Ogasawara, B. Rao, S. Russell and J. Weber, “Automatic Symbolic Traffic Scene Analysis Using Belief Networks”, In Proceedings of the 12th National Conference on Artificial Intelligence, 1994.

[9] D. Koller and N. Friedman, Probabilistic Graphical Models, MIT Press, (2009).

6. Biographical Information

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Education

University of Pittsburgh
School of Information Sciences
Ph.D in Information Sciences - concentration in Telecommunications, 2004
Dissertation: "Markov Modeling of WLAN Channels"

University of Pittsburgh
School of Information Sciences
Master of Science in Telecommunications, 2000

National Polytechnic School
College of Electrical Engineering, Quito, Ecuador
Electronics and Telecommunications Engineering, 1996

Professional Experience

Ohio University
Assistant Professor
J. Warren McClure School of Information
and Telecommunication Systems, 2009 – present.

NEC Network Laboratories
Heidelberg, Germany
Research Scientist for the Mobile Wireless Network Division, 2006- 2009.

Universidad San Francisco de Quito - Ecuador
School of Sciences and Engineering
Full-Time Teaching Appointment, 2004-2006.

University of Pittsburgh
School of Information Sciences
Teaching Fellow, 2003
Graduate Student Researcher, 2001-2004.

IBM of Ecuador
Solutions and Services Division
Project Leader, Banco Popular Outsourcing Project – Services Division
Telecommunications Manager, Customs Systems Integration Project, 1996-1998.

Abaco Constructors
Network Manager, 1995.

Patents

Method for Processing of Downlink Data Frames at Base Stations of WiMAX Systems, X. Costa, J. Aráuz, D. Camps-Mur, applied for in several countries in 2007, granted in Japan in 2012.

Method for Assembling Frames in an Orthogonal Frequency Division Multiple Access (OFDMA) -Based Communication System, A. Zubow, J. Aráuz, X. Costa, P. Favaro, D. Camps-Mur, applied for in several countries, 2007.

RELEVANT PUBLICATIONS PAST FIVE YEARS (ALL PEER-REVIEWED)

Aráuz J., Sánchez A., "Self-Organized Clustering for Improved Interference Mitigation in White Spaces", International Journal of Ad Hoc and Ubiquitous Computing, 2013 (submitted for review – indexed journal).

Shyirambere A., Snow A.P., Aráuz J. and Weckman G., "A Reliability and Survivability Analysis of US Local Telecommunication Switches", Journal On Advances in Telecommunications, v 6 n 3&4 2013. (submitted for review – indexed journal).

Aráuz J., "Estimating Hidden Information for Self-Organization and Self-Healing in Modern Wireless Networks", MIST Complex Adaptive Systems, 2013, Baltimore, USA.

Aráuz J., "Self-Organizing Evolving Education", MIST Complex Adaptive Systems, 2013, Baltimore, USA.

Aráuz J., "PGM Structures for Self Organized Healing in Small Cell Networks", IEEE MoWNet 2013, Montreal, Canada.

Aráuz J., Fynn-Cudjoe T., "Actuator Quality in the Internet of Things", IEEE Workshop on Internet-of-Things Networking and Control (IoT-NC), in conjunction with IEEE SECON, New Orleans, 2013, USA.

Miller Z., Aráuz J., "Self-Coexistence with Autonomous Target Variable Selection for White Space Devices", ITERA 2013, Cincinnati, USA. (Best undergraduate paper award).

Aráuz J., Miller Z., Sanchez A., "Self-organized Distributed Cooperative Control of Interference in Femtocell Networks", International Conference on Selected Topics in Mobile and Wireless Networking (ICOST), 2012, Avignon, France.

Aráuz J., Miller Z., "Self-coexistence in the Dense Case for White Spaces", Proceedings of the Wireless Days 2012 Conference, 2012, Dublin, Ireland.

Snow A., Aráuz J., Weckman G., Shyirambere A., "A Reliability and Survivability Analysis of Local Transmission Switches Suffering Frequent Outages", approved for publication in the proceedings of the International Conference on Networks, ICN 2013, Seville, Spain.

Costa X., Mezzavilla M., De Marca J., Aráuz. J., "E-Diophantine, An Admission Control Algorithm for WiMAX Networks", IEEE Wireless Communications and Networking Conference, Sidney, Australia, April, 2010.

Costa X., Favaro P., Zubow A., Aráuz J., "On the Challenges for the Maximization of Radio Resources Usage in WiMAX Networks", Proceedings of the 2nd. IEEE Broadband and Wireless Access Workshop, February, 2008.

AWARDS

Association of Computing Machinery (ACM)
SIGCOMM 2005 Junior Faculty Travel Award Grant 2005.

Honors Convocation Honoree, University of Pittsburgh, 2002.

Fritz Froechlich Award, University of Pittsburgh, 2001.

Fulbright Scholarship for graduate studies, Fulbright Commission,1998.

IBM Excellence in Leadership Award, IBM of Ecuador, 1996 and 1997.

7. OTHER SUPPORT

A. PREVIOUS UNIVERSITY FUNDING

The researcher has received no previous funding for the new research direction proposed in this document. Previous basic studies in the area were carried out in early 2013 [2]. Those studies required the creation of a basic test bed for perceived QoE measurements. The test bed was acquired with remaining funds from the researcher 2009 startup funds (25,000 USD). Approximately 500 USD were invested in the purchase of actuators and controllers. Those funds are no longer available as the account was depleted and closed in December 2012. Personal funds were also used for small testbed component purchases. Results from this first project were presented in a peer-review article presented at the IEEE Workshop on Internet-of-Things Networking and Control (IoT-NC) in New Orleans in early 2013. Funding for attending the conference was provided by the endowment fund of the J. Warren McClure School of Information and Telecommunication Systems. The support from this fund was approximately 1,200 USD. This endowment account has limited funds and generally supports traveling to one conference a year per faculty member of the ITS school.

B. EXTERNAL FUNDING

No external funding has been requested for this project.

The researcher prepared two proposals for external funding for other unrelated projects during the past three years. These proposals were not funded and are detailed next.

i. "Towards the Application of Distributed Collaborative Control Principles in Wireless Networks", February 2011, presented as a proposal to the Innovation Research Program from Hewlett-Packard Laboratories; total amount requested 56,198 USD. Not funded.

ii. "Quality of Experience in Immersive Environments", January 2012, presented as a proposal to the Innovation Research Program from Hewlett-Packard Laboratories; total amount requested 12,729 USD. Not funded.

7. BUDGET

The total budget required to execute the project is 7,932.08 USD; the itemized details are shown in **Table 2**.

Table 2. Budget

ITEM #	DESCRIPTION	QUANTITY REQUIRED	UNIT AMOUNT (USD)	TOTAL (USD)
1	Graduate student stipend for one semester	1	3,935.00	3,935.00
2	Fringe benefits (worker's compensation)	1	29.08	29.08
3	Human subject study compensation	100	20.00	2,000.00
4	Lynxmotion servo erector set v1.1	1	1,000.00	1,000.00
5	Dagu 6WD chassis	1	250.00	250.00
6	Arduino Uno Ethernet	4	65.00	260.00
7	Embedded PI board STM32	2	39.00	78.00
8	Arduino WiFi shield	2	85.00	170.00
9	RGB LCD shield	2	25.00	50.00
10	Arduino motor shield	2	30.00	60.00
11	Shipping charges	1	100.00	100.00
			TOTAL (USD)	**7,932.08**

The project includes the participation of a graduate student assistant. The student is expected to work a maximum of 15 hours a week for one semester. A stipend and fringe benefits are included in the budget (Items 1 and 2). The stipend amount is based on the current graduate student stipend at ITS. The graduate student will provide assistance in general research and construction of the compensation mechanisms and the construction of the experimental testbeds. Additionally, the student will be in charge of preparation of experiments, collection of data, processing results and collaborate as co-author in publications. The student will participate in the project during one semester and contribute with no more than 15 hours of work per week.

The project includes budget for a compensated human subject based research for which IRB authorization has already been obtained for one researcher (see documents in the Appendix). Should the project be funded, IRB authorization for the graduate student to participate will also be requested. The project will carry out a maximum of 100 tests with human operators. Subjects will be compensated with a one-time payment of 20 USD for their participation. Subjects will not be allowed to participate more than once in any of the experimental phases.

The test bed employed by the researcher in his early study [2] will be updated with better quality, research grade elements using an actuator kit from Lynxmotion (Item #4). This kit also incorporates the required elements for completing the unmanned vehicle construction that will be based on a Dagu 6WD chassis (Item #5). All the necessary control electronics (Item 6 through 10) are based on the open source platform Arduino. Notice that all physical elements are not consumables but, based on the experience gained in the previous study, they will be subjected to extensive use resulting in heavy degradation. All the pricing for the physical items is based on information available on www.robotshop.com as of September 30, 2013.

8. Appended Materials

This section includes a copy of the IRB approval form for research with human subjects, the informed consent form and the data collection instrument to be employed during the experimental data collection phases.

OHIO UNIVERSITY
Office of the Vice President for Research

13X200

Office of Research Compliance
RTEC 117
Athens, OH 45701-2979

T: 740.593.0664
F: 740.593.9838
www.research.ohiou.edu

The following research study has been approved by the Institutional Review Board at Ohio University for the period listed below. This review was conducted through an expedited review procedure as defined in the federal regulations as Category(ies):
7

Project Title: Software Aided Control of Cyberphysical Systems

Primary Investigator: Julio N. Arauz
Co-Investigator(s):

Faculty Advisor:
(if applicable)

Department: Information and Telecommunication

Rebecca Cale
Rebecca Cale, AAB, CIP
Office of Research Compliance

9/17/13
Approval Date

9/16/14
Expiration Date

This approval is valid until expiration date listed above. If you wish to continue beyond expiration date, you must submit a periodic review application and obtain approval prior to continuation.

Adverse events must be reported to the IRB promptly, within 5 working days of the occurrence.

The approval remains in effect provided the study is conducted exactly as described in your application for review. Any additions or modifications to the project must be approved by the IRB (as an amendment) prior to implementation.

Ohio University Consent Form

Title of Research: Controlling Cyberphysical systems
Researcher: Dr. Julio Arauz

You are being asked to participate in research. For you to be able to decide whether you want to participate in this project, you should understand what the project is about, as well as the possible risks and benefits in order to make an informed decision. This process is known as informed consent. This form describes the purpose, procedures, possible benefits, and risks. It also explains how your personal information will be used and protected. Once you have read this form and your questions about the study are answered, you will be asked to sign it. This will allow your participation in this study. You should receive a copy of this document to take with you.

Explanation of Study

This study is being done to measure how well an artificial intelligence solution can aid a user control a cyberphysical system. In this research the cyberphysical system will be a small robotic arm and a small remote control car that you will command using a joystick via a wireless link.

If you agree to participate, you will be asked to perform a series of 10 tasks. Each task involves moving the robotic arm or the remote control car among a series of premarked places around the room. You will be given instructions on how to use the joystick to command the systems and 3 minutes to practice its use before you start. The researcher will anonymously record your time to complete each task.

Your participation in the study will last between 30 and 45 minutes.

Risks and Discomforts

No risks or discomforts are anticipated.

Benefits

This study will help develop artificial intelligence models to control systems that in the future will be useful to command devices that range from robots on a different planet to robots that perform rescue operations.

You may not benefit, personally by participating in this study.

Confidentiality and Records

Your study information will be kept confidential. The researcher will only register the different times to complete tasks. No video, still images or audio of your participation will be recorded. You will be asked to provide your first name, last name, full address, social security number and signature on a separate form before you receive any monetary compensation. This information will be provided to Ohio University's Finance department.

Additionally, while every effort will be made to keep your study-related information confidential, there may be circumstances where this information must be shared with:

* Federal agencies, for example the Office of Human Research Protections, whose responsibility is to protect human subjects in research;
* Representatives of Ohio University (OU), including the Institutional Review Board, a committee that oversees the research at OU;

Compensation

As compensation for your time you will receive a payment of **$20.**

Contact Information

If you have any questions regarding this study, please contact ***Dr. Julio Arauz (arauz@ohio.edu) phone: 740 593 4917***

If you have any questions regarding your rights as a research participant, please contact Jo Ellen

Sherow, Director of Research Compliance, Ohio University, (740)593-0664.

By signing below, you are agreeing that:

- you have read this consent form (or it has been read to you) and have been given the opportunity to ask questions and have them answered
- you have been informed of potential risks and they have been explained to your satisfaction.
- you understand Ohio University has no funds set aside for any injuries you might receive as a result of participating in this study
- you are 18 years of age or older
- your participation in this research is completely voluntary
- you may leave the study at any time. If you decide to stop participating in the study, there will be no penalty to you and you will not lose any benefits to which you are otherwise entitled.

Signature____ Date______________________

Printed Name____

Table for Control of Cyperphysical systems:

Task	Time
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	