Project Charter

for

Spectrum Sensing using USRP

Version 1.0 approved

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Group 5

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"I pledge my honor that I have abided by the Stevens Honor System."

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1. Project Description

The goal of this project is to design and implement a radio frequency scanner that can automatically detect and identify radio signals in a given area. Information about the number of signals present, their modulation type, and their signal strength strength will be displayed to an operator succinctly and clearly. Conversely, by knowing which frequencies are being used, the user or operator will also have an awareness of the radio frequencies that are unused. This process is very important in military and law enforcement operations where having a tactical advantage over the adversary, such as a higher situational awareness or unrestricted communication, is key. The Spectrum Analyzer will leverage Software Defined Radio for quick development time and flexibility. The hardware used for this functionality may also be used for other tasks in addition to the software that will be designed from this project, eliminating the need for an operator to carry multiple single-task devices. The system is primarily intended for and marketed towards military and law enforcement applications, and the MITRE Corporation is funding development by providing equipment and expertise.

2. Business Objectives and Success Criteria

Business objectives of this project span from technical to logistical aspects of the final product. One major objective is to demonstrate to MITRE, which acts within the same interests as the Army, that the capability brought to them by using the group's product would be significantly beneficial to them in their line of work. For the Army, the benefits can be quantified in ways such as lives lost and mission success rates. Another business objective is to complete the project within the timeframe offered by Senior Design and within the budget ($400) offered to the group by Stevens Institute of Technology. Success criteria involves being able to identify the presence of signals with at least an 85% success rate, identify signal types with at least a

70% success rate, and do this in under 10 seconds for a given bandwidth roughly the size of 10% of the center frequency that the operator is interested in. By delivering a final product that meets the defined requirements, in the given timeframe, and under budget, the overall business objective will be satisfied.

3. Stakeholders

The main stakeholder in this project is the military. This product is being designed keeping the military in mind , in conjunction with a company that works in the military's interests. Hardware choice has been impacted the most by the choice to design this product for the military. Initially, commercial, off-the-shelf hardware was chosen. This gives the military maximum availability and low costs. Secondly, the hardware was specifically chosen such that the packaging of the components is lightweight and takes up minimal space compared to previous attempts at solutions to this problem.

By nature of the product, there are other stakeholders involved. Perhaps the second most important stakeholder is the FCC. The spectrum sensing product that we are going to be creating has a main goal of identifying signal presence, and conversely, spectrum availability. This implies the use of the RF spectrum, a very important resource, important to the operation of the modern world. As unlicensed users, the group needs to take extreme caution to ensure that they are not violating any FCC regulations. Failure to follow regulations can result in large fines and potentially more. With the hardware being used in this project it will be possible to read data in the cellular bands, and also to jam FM radio signals, among other things. Unlawful use is prohibited to all members of the group to ensure that the FCC does not have to take legal action; it is for this reason why the FCC is such an important stakeholder.

The third most important stakeholder is the operator of the product to be created. This would likely take shape as a soldier in the military. When thinking from this perspective, there are several ergonomic concerns that appear. A deployed soldier must be able to use the spectrum sensing device in the field, and obtain meaningful data in an easy to read fashion. Failure to keep this stakeholder in mind can result in a product that meets all technical requirements, but is unusable in the real-world; it is for this reason why the operator is such an important stakeholder.

Stakeholder	***Major Benefits***	***Attitudes***	***Win Conditions***	***Constraints***
MITRE	Provide another capability for their customer	A capability they would be very interested in providing	Acquiring the capability	Cannot compete for business with industry
Developers	Acquire industry related skills that can be widely applied	Gain experience in relevant systems	Completing the project successfully.	Are limited in budget and knowledge
Army Corporate (acquisition)	Decreased hardware dependency for signal sensing	Need a product that works and works well	A software based spectrum analyzer that replaces the hardware equivalent	Needs to work well and needs to be deployable on pre-existing computers
Soldier (operator)	Carrying significantly less weight, may be easier to use	Needs to be relatively simple to use and have a very low failure rate	Works when needed	Device cannot operate outside of hardware capabilities
Soldier (maintainer)	Decrease in maintenance time and cost	Another system to maintain, but much simpler than other systems	Low cost, COTS product requiring little maintenance	Minimal due to COTS nature and acquisition process
FCC/other RF regulators	N/A	Needs to not interfere with FCC regulations in the development stage	The product does not interfere with pre-existing regulations	The product can not interfere with pre-existing regulations

4. Mission

The Spectrum Sensing using USRP project will offer the Army the capability to identify RF signals in a given area of the RF spectrum like never before. An increased level of situational awareness, which will be provided by the project, will lead to a significant tactical advantage for its operators. Unlike current systems that are bulky and expensive, our product will use Software Defined Radio and commercial-off-the-shelf technologies to deliver a low cost and reliable solution. This approach will maximize the amount of capabilities that the Army has available to them for the least amount of resources spent. The project will be sponsored by MITRE, lending equipment and technical expertise as necessary. The team will use these resources to develop the project over the course of the Senior Design process.

5. Project Scope

Business Purpose: Introduce a significant improvement to the Army's radio frequency situational awareness by developing the capability for signal identification and modulation classification across a specified spectrum.

Project Goals:

- Time: Complete the project by Spring 2016 (in accordance with Senior Design deadlines)
- Cost: The group will spend under $400 as a hard limit, but more realistically under $50 since the sponsor is providing all necessary hardware for the project.
- Quality: Identify presence of signals with a reasonable SNR (>=25dB) with 80% accuracy and identify modulation type of supported signals of reasonable SNR with 60% accuracy. Scanning a bandwidth spanning 10% of the desired center frequency will take no longer than 10 seconds from start to final output data.
- Use open source software and COTS (Commercial off-the-shelf) hardware.
- Easy to use interfaces - First time user with basic RF knowledge will be able start a scan of a desired spectrum without assistance. Additionally, a user with basic RF knowledge will be able to understand output data without referring to any manuals or documentation for the program; the output will be intuitive.
- Multi-purpose hardware (Laptop and SDR only).
- Will not interfere with any FCC regulations.

Project Work Statement:

- Create a website explaining the scope of this project within the requirements and deadlines of the Senior Design course.
- Decide on a set of standards (development environments, version control of software) to be used throughout the entire project.
- Create a transmitter with one radio along with a set of user configurable signal templates that can be used for transmitting known signal types. This will be used for testing of the receiver.
- Complete GNU radio tutorials to gain a better understanding of the work required for the technical aspects of the project.
- Create signal identification algorithm
    - Understand and implement Automatic Gain Control algorithm to ensure that the system will automatically adjust itself to see the most signals in a given environment in the presence of noise.
    - Understand and implement Fast Fourier Transform (FFT) algorithm to view a frequency domain representation of the spectrum
    - Understand and implement Power Spectral Density (PSD) algorithm to turn the FFT data into raw power measurements.
    - Understand and implement frequency shifting algorithm to be used when scanning bandwidths larger than the largest bandwidth that can be scanned given the group's hardware (sampling frequency determines bandwidth, and sampling frequency is processing dependent).
    - Understand and implement In-Phase and Quadrature (I/Q) data acquisition algorithm. This will be used to data samples on specific signals of interest to be passed on to the signal modulation identification algorithm.
- Create signal modulation identification algorithm for analog modulation types
    - Understand machine learning, specifically using the TensorFlow python library.
    - Work along with MITRE to pick up on their machine learning algorithm and gain best possible understanding to improve upon.
    - Bring machine learning algorithm to a working state as a standalone module.
    - Create interface for machine learning code to allow integration with the signal identification portion of the project.
- Add digital modulation types to the modulation identification algorithm
- Increase operation speed by optimizing existing code created in previous stages of the project

Key Deliverables:

- Senior Design Fall midterm report
- Senior Design Fall final report
- Senior Design Spring midterm report
- Senior Design Spring final report

- Development computer to be used for remote development by group. SSH access must be enabled.
- Senior Design Website
- USRP N210 set up as a transmitter with user configurable transmitting profiles for known signal types
- USRP N210 with signal detection capability (without modulation identification)
- USRP N210 with signal detection and modulation identification capability (no operational time constraint)
- Working prototype (same as above, with operating time constraint within ~100% of target operating time)

Key Milestones:

Key milestones are contained within Section 8. Key Milestones.

Major Constraints:

- The group is limited to hardware of the sponsor's choosing.
- The group has limited experience on machine learning. It was determined before tackling the project that machine learning will be brought to a working state, however extreme accuracy is not required. This will take place once the group has a working prototype and time for refinements, or by MITRE.
- The group does not contain any federally licensed amateur radio users. The group will not break any FCC regulations, regardless of any project requirements that may come up. Abiding by the FCC policy and other governing body rules like for RoHs (Restriction of Hazardous Substance).

Major Assumptions:

Major assumptions are contained in Section 6. Assumptions and Dependencies.

Exclusions:

- The project will only consist of a software program. The hardware is commercial-off-the-shelf (COTS), and property of MITRE, and as such is not under the group's control.
- The project will not include training on basic RF concepts. Users should be aware of basic concepts before using the product.
- The machine learning may be left in a working, but to-be-improved state as agreed upon during project planning; a well-refined machine learning algorithm may not be included.
- The product may be used in violation of FCC regulations; appropriate licensing will not be included with the product. Users are responsible for their own actions while using the product.

- The product will not include a laptop. The prototype will be run on a laptop of the group's choosing, but the main deliverable is a software program to be used on operator's own equipment.

6. Assumptions and Dependencies

AS-1: Upon entering the project it was assumed that MTIRE would be able to provide us with a radio receiver of sufficient quality to accomplish the project.

AS-2: MITRE is acting on behalf of the military, another key stakeholder.

AS-3: Hardware provided by MITRE is attainable by the military and can be used if the project goal was to be met.

AS-4: Machine learning is capable of determining modulation types with sufficient speed and accuracy.

AS-5: Researching about the tools of machine learning, the Tensorflow library was assumed to be the best signal identification and modulation tool to be implemented in the scope of this project.

AS-6: The group will be able to to test our product in an environment similar to one that the military operates in (from a radio frequency point of view).

AS-7: What we are developing is still a technology that the military needs and has not already developed.

AS-8: A product can be developed which achieves sufficient speed and accuracy while only using a standard laptop and the hardware found on the radio receiver.

DE-1: Testing of the project is currently entirely dependent on continued access to the radio receiver from MITRE.

DE-2: Continued access to a computer and software which can be used to develop and test the product as well as save the work to an online repository.

7. Constraints

Dimension	*Constraint (state limits)*	*Driver (state objective)*	*Degree of Freedom (state allowable range)*
Features	There are many types of modulation and the group will not have time to account for all of them	Identify modulation types of RF signals	Must be able to identify and demodulate basic signals (AM, FM, several digital signals) at a minimum
Quality	There is no perfect for speed or accuracy, it can only be improved	Have high accuracy in prediction as well as high speed in detection	Must be able to finish tasks in under 5 seconds with at least 75% accuracy
Cost	There are no costs to testing or improving the product	Stay under the $400 budget	Spending beyond $400 is absorbed by the group members
Schedule	Project needs to be finished by May	Have a version at any speed and accuracy by 1/15, have a finished product by the Senior Design exposition	Minimum goals need to be completed by May, improvements beyond this are optional
Staff	Group is a set size and can only get limited help from MITRE	Have every member of the group gain sufficient technical knowledge to do effective work on the project	The group can seek outside assistance from professors and staff as needed

8. Milestones

Event or Deliverable	*Target Date*	*Responsibility*
Senior Design Fall midterm report	Oct 18	Joe
Senior Design Fall final report	Dec 15	Kunal
Senior Design Spring midterm report	TBD	Vijay
Senior Design Spring final report	TBD	Andrew
Development computer networked	Oct 15	Scott
Senior Design Website	Nov 1	Vijay
USRP N210 set up at transmitter	Dec 1	Kunal
USRP N210 with signal detection capability (without modulation identification)	Jan 18	Joe
USRP N210 with signal detection and modulation identification capability (no operational time constraint)	Feb 1	Andrew
Working prototype (same as above, with operating time within 100% of target operating time)	March 30	Scott

9. Project Risks

Risk	*Probability (1-5)*	*Impact (1-5)*	*Mitigation*
An identical product becomes available before ours	1	4	Ensure we are working on the most aggressive timeline possible
Effort estimate is low	2	2	Follow project management best practices in planning
Stakeholder conflict over expected outcomes	1	3	Maintain frequent communication with stakeholders and obtain regular feedback
Project architecture is infeasible	2	2	Treat architecture as a living model to allow for design flexibility
Tool documentation is minimal or obscure	3	3	Refer to examples and request technical help from sponsor

10. Resources

Resource	*Description and Source*
Development Team	5 engineering students from Stevens; signal processing, machine learning, algorithm development
Employees at MITRE	Technical assistance for the project
Adviser	Gives advice and checks up on the status of the project, professor at Stevens
Ettus Research USRP N210	Software defined radio to be used in project, provided by MITRE
COTS Laptop	Will provide processing for software defined radio, provided by development team
Spectrum Analyzer	Used to test performance as the system is being developed, provided by Stevens
MITRE Corporation	Sponsor for the project, provides hardware the system will utilize
GNURadio	Open source library of signal processing blocks
TensorFlow	Open source library for machine learning
Boesch Lab	Laboratory at Stevens Institute of Technology used for team meetings and technical lab work

Approvals

The undersigned acknowledge they have reviewed the Spectrum Sensing with USRP Project Charter and authorize Spectrum Sensing with USRP project. Changes to this Spectrum Sensing with USRP Project Charter will be coordinated with and approved by the undersigned or their designated representatives.

Approval Decision:

- □ Approved, development of detailed project plan is authorized
- □ Approved, project execution is authorized
- □ Approved, but project is on hold until future notice
- □ Revise charter and resubmit for approval
- □ Charter and project proposal are rejected

Role or Title	*Name and Signature*	*Date*
TG Professor	Paul Wojnicki	
Advisor and Professor	Bruce McNair	
MITRE Sponsor	Ryan Nilsen	

Revision History

Name	*Date*	*Reason For Changes*	*Version*
Andrew Guthrie, Joseph Pang, Kunal Patel, Vijay Raja, Thomas Wright	9/26/16	First Draft and added sections 1 and 4	1.0
Andrew Guthrie, Joseph Pang, Kunal Patel, Vijay Raja, Thomas Wright	12/9/16	Revised sections 1 and 4 Added sections 2, 3, 5, 6, 7, 8, 9	1.1