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BRAINS, BOTS AND BUILDERS – MIRNOVA ACADEMY AND ITS "STEM" PROGRAM WITH ROBOTICS SERVING CHALLENGED YOUTH AND CREATIVE MENTORS

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Abstract

This paper presents an overview of a new program in STEM education, teacher training, and integrated application development. Each project, engaging students ranging from pre-high-school classes to post-graduate university levels, is focused strongly upon coupling robotics research and field testing of new devices and algorithms within the context of practical everyday environments, beginning with agriculture and monitoring of chemical, microbiological and crop parameters using UAV and ULV systems.

Keywords: robotics, UAV, drone, agriculture, sensor, monitor, spectroscopy, irrigation, fertilizer, pesticide, insect, crop yield, GIS, education

The pace of new technology development and implementation within the broad sector of commerce and industry, particularly in the domains of robotics and distributed network systems, is extraordinarily rapid. Challenging situations are arising for the general society and its economy, in virtually all countries including the most technologically developed, to keep up with that pace and to accelerate educational proficiency among students and adults who are increasingly faced with both job requirements and opportunities that depend upon knowing more about many new technologies and STEM (science, technology, engineering, mathematics) skill sets. As the variety and complexity of new technologies is increasing, so is the need for people at all levels of usage and engagement to be skilled in systems thinking, project management and the disciplines for working together as teams, often distance-based and remote in locations. This is true and demanding for the research world as well as in applications for conventional business, manufacturing and other uses.

MIRNOVA Academy is a private non-profit institution established in the Russian Federation. It has committed to implementing a novel plan that addresses such problems and also other challenges that face current youth entering into both adolescence and future employment and social frameworks which are characterized by uncertainty, the needs to know more substantial and practical STEM knowledge and skills, and the needs to be adaptive and innovative. A Program has been designed and implemented for conducting projects that involve collaboration between students at multiple levels of knowledge, skill, aptitude and competence, ranging from elementary to high school class levels, and mentors who may be teachers, university or post-graduate students, professors, and experts from industry and the research community.

Unlike many programs worldwide which focused upon short-term projects which will begin and end within the confines of a few months and which are often competitive challenges with specific rules and guidelines, the MIRNOVA Program creates projects are multi-year in nature, intended to involve participants from multiple institutions including schools and universities, and to do so in a manner that is consistent with contemporary project management methods and techniques as practiced in higher education and within industry. There are several reasons for this program architecture, four in particular.

♦ First, such methods (including, for example, AGILE software engineering, and formal project management disciplines, aid in the educational process for students, teachers and mentors alike in training within the pertinent disciplines of product design and commercialization, business and financial development, and entrepreneurial management. This is important for future scientists, engineers and technologists, whether such persons focus their careers in basic research and academics or in the domain of commerce and industry.

♦ Second, the nature of projects that involve multiple technologies and interfaces between systems is such that strongly disciplined project management is a fundamental prerequisite for successful completion. Projects involving distance-based team members operating in not only different time zones but different personal schedules require the structure for scheduling and completing assigned tasks and for arranging real-time interactions using internet-based communications.

♦ Third, the nature of a project such as AgriBrains puts demands upon all team members and all technical components for improved communications between diverse groups. Simply put, the engineering and technical people need to be able to communicate clearly and efficiently with persons who may be experienced in fields such as agriculture, aeronautics, healthcare, environmental testing or public safety and security, in order for complex and complicated systems such as UAVs and other robotic devices to be used in optimal ways for the final applications. This communication pathway is bi-directional; application experts need to understand the potentials and the limits of the hardware and software systems in order to know better what can be done with the technology and in order to ask the right questions and make the right requests for new development.

♦ Fourth, the trends and requirements in both education and "large-scope" research programs – the type of research that typically demands time, diverse-capability teams, extensive experimentation and replication for verification – demand both more adept and experienced work forces, people who will have vocational as well as academic skills and training, and opportunities to do more variety of trials and field-tests, and all with greater economy and reduced costs for such tasks. Examples can be found in fields like "self-driving cars," cooperative robots in space-based engineering (e.g., NEOShield for asteroid impact deterrence), environmental and especially climate-change monitoring, and several aspects of agriculture including pest control and abatement. These needs from the research and commercialization sectors complement the needs for the educational process, beginning at earlier ages and skill levels, to include more opportunity for students to interact, within projects directly, with those engaging in "deep" research. The opportunities include internships and apprenticeships, often enabled or enhanced by today's internet and "virtual reality" capabilities; these opportunities are part of the motivation and the technical basis for MIRNOVA Projects.

Thus, this STEM initiative within MIRNOVA places a strong emphasis upon the development of interaction and communication skills, along with the work on actual electronics, software, and mechanical engineering.

Each project in the overall Program is designed to engage students at multiple levels of their schooling in sequential phases of a multi-year, multi-institution, and also, gradually, a multi-national project that will share in being open-source, readily deployable for experimentation and testing, extensible to new applications, and producing intellectual property and tangible tools that will have demonstrable value for potential commercialization. AgriBrains is the first project within the Program. It has been selected and designed in order to provide the optimum foundations – organizationally, technically, and financially, for conducting future projects, for generating a platform upon which future projects can extend research and provide testing and validation, and for creating sustainability through commercial value. Currently, it is defined as:

Agricultural Productivity Optimization using cooperative robots for sensing, analytics and control.

In its initial work, AgriBrains concentrates upon using individual units and clusters (groups) of UAVs for:

Monitoring of crop conditions for humidity (irrigation), pest control and ripeness.

This project encompasses the following objectives in the subject matter of study, training, experimentation and new research conducted by the project team members:

- Use of robot networks (UAV, ULV, AUV) with both human-assisted and autonomous functionality, employing a diverse array of CBR (chem-bio-rad) and EM (electromagnetic) multi-spectral sensors as well as electromechanical actuators.
- Onboard and mobile, as well as manually-delivered

- Dynamic mobile operation, and static-placed stationary operation
- "Plug-n-play" device independence for all platforms including other non-UAV systems
- Data acquisition and integration with satellite-based and other telemetry and knowledge sources
- Analytics employing human expertise and synthetic (AI, machine-learning) intelligence
- BOINC-based distributed processing for massive computational tasks (open-source, UC-Berkeley)
- Data management and knowledge representation and distribution

This project builds upon extensive and proven prior research by members of the technical and management team within MIRNOVA as well as by other research and development that is accessible to the team. The scope of the project is open-ended and will evolve over time as new participants and stakeholders enter into direct activity and indirect collaboration, making use of the open-source platform created in the first phase.

AgriBrains begins with technical components that are currently "COTS" (commercial-off-the-shelf) – available devices and components including software modules. All of the core technologies and tools, including electronics, software, project management, are currently existing and accessible for this project. Research leading to new designs, both physical and in control systems such as software, will develop after teams have achieved sufficient familiarity and skill levels with system operations. Furthermore, there is much new development in the application areas, using todays' existing UAVs and software. Two major areas within agriculture that are only beginning to receive attention are:

● Fruit crops, in particular orchards, especially high-sensitivity crops such as grapes, cherries, and citrus fruits

● Monitoring and management of livestock including herds of cattle, sheep, goats and even reindeer

Among the UAV systems for use within AgriBrains are devices that have already been introduced successfully into both the agricultural industry and the educational/research sector in China, EU and USA. These include three specialized UAVs already being successfully deployed in agricultural settings. It is significant that these and many other UAVs do not conveniently communicate with one another, either in sharing of data and control parameters, nor in direct cooperative actions. Furthermore, autonomous operations are virtually nonexistent. These tasks constitute part of the focus within the AgriBrains Project as it is currently underway.

Figure 1: eBee SQ drone for spectroscopic surveys

Figure 2: DJI eight-rotor drone with 10-liter capacity

Not every task nor every project team needs to work hands-on with the most sophisticated or expensive equipment. This is a major consideration for being able to offer educational and internship opportunities to a larger and more diverse population of participants and to make project activities be more adaptive and useful to research groups who may have limited mobility, budgets, and who also may desire increased testing of devices (including onboard sensors) without a high learning curve or a high budget for platforms such as the more "industrial level" UAVs. Figure 4 below illustrates two low-cost UAVs, one of which is capable of being produced using low-cost 3D printed structural components, an Arduino or Rasberry Pi motherboard, and about one hour of concentration in an ordinary home or garage environment.

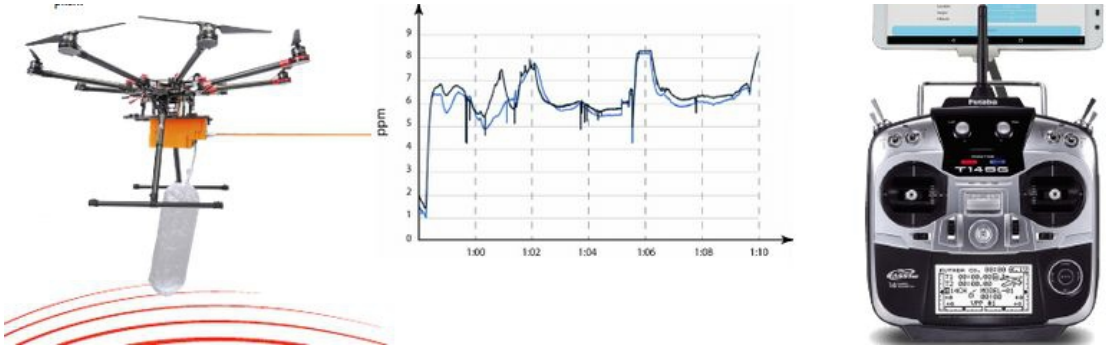

Figure 3: Sentroid UAV illustrating air sampler, analytical results and control unit

Figure 4: CopterExpress UAVs for education and low-end commerce (delivery)

Project Outcomes and Benefits:

The AgriBrains Project delivers first and foremost an Engineering Platform ("Testbed") that can be employed in many future ways by different teams including those who graduate formally and informally from the MIRNOVA Program and from their university programs. This platform is as much one for testing new devices including UAVs, and software, as it is also for new methods in every dimension of agriculture including all types of livestock farming such as cattle, pigs, sheep, and fish in the form of aquaculture.

As a platform, AgriBrains is designed to provide reusable toolsets and libraries, both hardware and software, that may be used across different experiments conducted by totally distinct teams. This process is not only about technology but about project management and cooperativity among teams. Here is where AgriBrains, and the MIRNOVA Program as a whole, makes a substantive departure from a dominant tradition of competition and contest-oriented projects within especially the educational domains (e.g., FIRST Robotics, an eminent and pioneering robotics competition, very international in scope – www.firstinspires.org), and other competition-oriented STEM programs (e.g., Intel Science Fair). The primary differentiator is the emphasis upon working on projects that will produce components that others can use – including multi-year participants (e.g., through middle and high school and then into college levels) – and to link project technical activity and success directly with training for internships, apprenticeships, and entrepreneurial business "start-up" initiatives. In the process, those persons who are mentors, advisors and trainers, coming from the research centers of universities and institutes, gain tangible results for their efforts and energies in guiding youth to "find their guiding stars and reach them."

First there are direct, concrete Technical Outcomes and Benefits:

This initial project will enable participating students, teachers, mentors and teams to implement practical technologies, products and services serving the global agricultural industry in the following 12 manners, gradually over a period of months and years:

- CB (chem-bio) sensing and monitoring – focus upon toxins, bacteria and viruses
- Frost control – this is an emerging problem given the trend in non-linear climate change
- Seed planting – focus upon actual planting and follow-up for germination/replanting
- Fertilizer optimization – focus upon reduction of excess use and cost
- Irrigation optimization – focus upon balance in hydration
- Pest control – focus upon emerging insect and micro-fauna due to climate change
- Sugar content – a critical area for fruits and for crops used in beverage production
- Ripeness and harvest readiness – focus upon increasing yield and turn-around
- Tree and bush pruning (management and planning)
- Differentiation and specialization for crop type variants
- Predator control (e.g., birds, foxes, wolves) – focus upon deterrence
- Planting and harvest planning (info ◊maps ◊AI-recommendations)

These technical outcomes from this foundational project are remarkably wide, open-ended and expansive, and this governs the choice of such an area for the Program's Initial Project undertaking. These outcome values extend beyond agriculture into many other application areas, all of which have value for training, education, research, and commercialization.

Next, in principle with the MIRNOVA mission, there are other significant outcomes besides those of technology development. These are also areas of study and new learning for all participants – students in pre-college and university levels, as well as teachers and expert mentors. In essence, the use of "STEM" activity provides the matrix and basis for learning important social and economic principles and skills often missed.

Social Outcomes: Students, including the pre-risk/higher-risk group of students who may initially not be interested in STEM topics will be more attracted to a project that is more visibly connected to more "concrete" and "business-tangible" topics such as food production.

Educational Outcomes: There will be teachers, university students and professors experienced in training teachers and peers for expansion of STEM into all school levels and especially for addressing populations of non-STEM-interest students, especially those who will not be likely to attend university and go into STEM careers. There will be a refined group of students identified as top-choice candidates for employment in companies that are constantly seeking to identify and evaluate their "next generation" of employees.

Financial Outcomes: There is ample evidence, worldwide and especially from studies conducted in USA, Korea and China (2015-2017), that there will be commercially viable intellectual property ("IP") from the AgriBrains Project, and such will be marketable as technology and potentially through entrepreneurial spin-off and startup companies.

Conclusion:

To paraphrase one of the producers of the futuristic film, "Interstellar," regarding our current socioeconomic, educational, and also agricultural climate, "We are not there yet, thankfully, but we could find ourselves there sooner than we think possible." James Cameron's "there" refers to a world where basic farming and agriculture is a major challenge that demands far more daily attention than our highly urbanized and geographically sequestered populations on this planet currently devote to the process of producing what we will eat each day.

The specific AgriBrains project is designed to provide re-usable, reconfigurable software and hardware that can be deployed in other topics (this model derives from the historical successes in many computing systems especially; e.g., object-oriented design, interpretive programming, XML-based scripts). High on the list for extensions of AgriBrains are applications in climate change and ecosystem monitoring as well as corrective

action (use of actuators, not only sensors), experimental field studies in turbulence and non-linearity wind patterns, as well as in energy optimization, water control, and the critical domain of public health (epidemiology of emerging infectious diseases, many deriving from global warming and climate change).

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