PhD in Information Technology and Electrical Engineering

Università degli Studi di Napoli Federico II

PhD Student: Jonas Piccinotti

XXIX Cycle

Training and Research Activities Report – Second Year

Tutor: Amedeo Capozzoli

co-Tutor: Angelo Liseno, Claudio Curcio

1. **Information**
   a. **Name Surname, MS title – University**
   Jonas Piccinotti, Master Science Degree in Telecommunications Engineering at Università degli Studi di Napoli Federico II – Full time worker at the Italian Air Force Flight Test Center in Rome.
   b. **XXIX Cycle – ITEE – Università degli Studi di Napoli Federico II**
   Doctorate regarding Computational Electromagnetics.
   c. **Fellowship type**
   University scholarship have been rejected due to personal job salary above the limits imposed by the law.
   d. **Tutor**
   Amedeo Capozzoli
   e. **Co-Tutors**
   Angelo Liseno, Claudio Curcio
2. **Study and Training activities**
   During the Second Year of research activity I had the possibility to attend two external courses.
   a. **Ad hoc Courses**
   No ad hoc courses were attended due to logistics difficulties and job issues.
   b. **Seminars**
   No seminars were attended due to logistics difficulties and job issues.
   c. **External courses**
      1) External course "Operational Test and Evaluation" at National Test Pilot School – Mojave
      The course teaches basic flight test principles, concepts, and processes. Classroom instruction is reinforced by demonstrations and project flights designed to provide "hands-on" experience in flight testing. A final project further reinforces classroom instruction. The final project uses operational requirements/capability documents to plan, flight test, and report on how well an aircraft or system meets mission needs. Previous class projects have included fixed wing, rotary wing, air vehicle and avionics systems evaluations. Duration: 3 weeks.
      2) External course "Missile System Technology Foundation Course" at MBDA Corporation – Rome
      The course is an introduction to all the technologies involved in a missile system, spanning through aerodynamics, propulsion, navigation system and sensors, guidance and control, servos and actuators, seekers and fuzes both EO and RF, lethality and vulnerability, missile test process, human factor and human machine interface. Duration: 1 week.
   d. **Training activity**
   Participation to the nEUROn flight test campaign held by Italian Air Force Flight Test Center at Decimomannu Air Force Base in Sardinia during April and May 2015 (8 weeks).
   nEUROn is the first UCAV (Unmanned Combat Aerial Vehicle) European Technology Demonstrator Program and has been launched as a French initiative with six European Partners. French DGA (Direction Generale de l'Armement) is the Executive Agency and Dassault-Aviation is the Industrial Prime. Italy, the main partner after France, has participated with the leadership, on the Governmental side, of the DAAA (Direzione Armamenti Aeronautici e per l'Aeronavigabilità) and, on the Industrial side, of AleniaAermacchi. Other Partners are Sweden, Spain, Greece and Switzerland.
   During the campaign in Sardinia (the second of the three forecasted campaigns), as part of the program, an operational assessment has been performed, letting the nEUROn fly a representative mission in a realistic scenario. Specific studies regarding the design of minimum RCS profiles and related flight testing were performed. The problem of designing an RCS optimal trajectory has been considered and practically implemented.

e. Credits summary table

	Credits year 1									Credits year 2									Credits year 3		
		1	2	3	4	5	6				1	2	3	4	5	6					
	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary	Check	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary	Check	Estimated	Check	Total
Modules	20	9	0	0	0	0	4	13	20 - 40	10	0	0	0	3	12	0	15	10 - 20	0	0 - 10	28
Seminars	5	0	0	0	0	0	0	0	5 - 10	5	0	0	0	0	0	0	0	5 - 10	0	0 - 10	0
Research	35	8	8	8	8	8	7	47	10 - 35	45	7	7	8	8	8	7	45	30 - 45	60	40 - 60	92
	60	17	8	8	8	8	11	60	60	60	7	7	8	11	20	7	60	60	60		120

Note: Modules credits have been calculated assuming Prof. Riccio's first year directions, namely 0.1 credits per hour for external course, if and only if approved by ITEE PhD Council after reviewing the documentations presented by the student

3. Research activity

a. Title

Fast GPU implementation of a RCS prediction Tool based a GO/PO hybrid algorithm accelerated via NUFFT3 and BVH data structure. Advanced methods for RCS measurements.

b. Study

The scientific field of interest of the research activity is Electromagnetics, both computational and experimental, mainly applied to the aerospace and naval industry. The problem investigated during the activity is Radar Cross Section (RCS) prediction, by means of numerical tools. The biggest Corporations operating in this engineering context have, as a major interest, the prediction of certain electromagnetics features of new platforms under development, such as high performance military aircrafts or ships, with a high degree of accuracy and within commercial convenient times. In facts, "prediction" amounts to the need of implementing, optimizing and speeding up to the limit numerical tools to simulate a very complex scattering electromagnetic problem, involving 3-dimensional arbitrarily shaped surfaces and cavities, of different materials. This long and demanding process goes through modelling CAD, electromagnetics CAD, and anechoic chambers both with mock-ups and real platforms.

Therefore, a prediction tool such as the one described above should calculate the RCS of an electrically large and arbitrarily shaped object within reasonable times, an operation nearly impossible, if not properly managed. In addition, such algorithms, are extremely helpful during the antenna placement phase or, in general, when studying the effects of external stores on the radar signature of the object: as a good example, recall the F-35 recent radar signature degradation issues related to external missiles/bombs and skin imperfection due to intensive flying activity.

c. Research description

The tool mentioned above is being developed choosing an asymptotic approach (Vs full-wave approach) consisting in the hybridization of GO (Geometrical Optics) and PO (Physical Optics). Operationally this hybrid algorithm consists in two main steps:

1) Predicting the equivalent current densities induced on the scatter surface;

2) Calculating the far field radiated by such equivalent currents.

The activity of the first year has been focused on the first step, namely the GO part: rays launching and induced current calculation by means of the proven ultra-fast BVH data structure. The second year, instead, has been oriented to the acceleration of the PO integrals, which consist in 3D Fourier Transform. The FT is numerically implemented by the

know algorithm Fast Fourier Transform (FFT), but, in this particular case, due to the complex arbitrarily 3D shape, a non-uniform discretizing lattice is required in the spatial domain. Besides, considering the fact that we can be interested only in a certain region only of transformed space, a non-uniform discretizing lattice is required in the spectral domain too. This yields to the use of the 3D NUFFT of the 3rd kind. The only available existing formulation, which is the one by Lee and Greengard, involves Gaussian interpolating windows, which need to be finely tuned by an accurate parameters choice.
The second year research activity has thus been focused on the code implementation: the programming effort has been directed on the Lee-Greengard algorithm, starting from a MatLab version, going through a C++ version, reaching in the end a CUDA version for GPU application. This particular algorithm will be embedded in the much larger algorithm, the one aimed to actually predict the RCS via the GO/PO hybridization mentioned in the beginning. The approach used for this programming work has been a buildup one: the MatLab code, in fact, is the simplest to manage and it has been implemented firstly in a 1-D version, then a 2-D and then a 3-D final version. The same has been realized in the C++ and the CUDA. As for the present day, all the different version of the code have been developed and tested but one: 1-D, 2-D, 3-D for MatLab are complete; 1-D, 2D, 3-D for C++ are complete; 1-D, 2-D for CUDA are complete and the only one still under development is the CUDA 3-D.
The initial code was realized in MatLab, user friendly, high level language, which permits a simple and quick manipulation of the variables during debugging. The code has been organized according to the Lee-Greengard, which is made of 6 steps:
1) Setting the precision and convolutions parameters;
2) Convolution in the spatial domain (spatial Gaussian window);
3) Compensation in the spatial domain (for the spectral Gaussian window);
4) Standard 3D Fast Fourier Transform;
5) Convolution in the transformed domain (spectral Gaussian window);
6) Compensation in the transformed domain (for the spatial Gaussian window).
Going straight to CUDA could have been quite demanding (besides debugging in CUDA is very problematic when accessing the variables which reside on the device), so and intermediate C++ version of the code has been realized. Both C++ and CUDA codes are realized as MatLab “mex functions”, namely functions written in some other language (Fortran, C, C++, CUDA) which can be recalled inside a MatLab session. Both the C++ and CUDA codes are similar: the major difference is that the C++ code is completely serial and executed only by one CPU, while the CUDA executes the 6 steps serially, but each step is internally parallelized.

d. Collaborations

IDS Corporation – Ingegneria dei Sistemi (Pisa)
Flight Test Center – Italian Air Force (Roma)

4. Products

a. Publications

“nEUROn UCAV: development and operational assessment campaign” submitted to “NATO Systems Concepts and Integration (SCI) Panel SCI-269 Symposium on Flight Testing of Unmanned Aerial Systems (UAS)” - Ottawa, Canada, 12th - 15th May 2015.

b. Patents

No patents were obtained.

5. Conferences and Seminars

1) NATO Systems Concepts and Integration (SCI) Panel SCI-269 Symposium on Flight Testing of Unmanned Aerial Systems (UAS) - Ottawa, Canada, 12th - 15th May 2015.

6. Activity abroad

1) 1 week in Canada (Ottawa) for the above mentioned SCI-269 Symposium
2) 3 weeks in USA (Mojave Desert - California) for the above mentioned OT&E course

7. Tutorship

1) Participation in developing and revising Lt. Errico Damiano’s M61/256 Master Science Degree in Electronic Engineering LM-29 entitled “Stima di RCS per applicazioni di autoprotezione passive”