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 – Third 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 – Flight Test Engineer at the Italian Air Force Flight Test Center (Pratica di Mare, Rome).
   b. **XXIX Cycle – ITEE – Università degli Studi di Napoli Federico II**
   Doctorate in Computational Electromagnetics applied to fast RCS prediction.
   c. **Fellowship type**
   University scholarship was rejected due to the existing salary exceeding the limits imposed by the law.
   d. **Tutor**
   Amedeo Capozzoli
   e. **Co-Tutors**
   Angelo Liseno, Claudio Curcio
2. **Study and Training activities**
   During the Third Year of research activity one long External Course and two Seminars were attended.
   a. **Ad hoc Courses**
   No ad hoc courses were attended due to major logistics complications.
   b. **Seminars**
      1) "31° Corso Basico Tactical Data Link" @ Reparto Addestramento Controllo Spazio Aereo – Aeronautica Militare Italiana, Pratica di Mare, 23-27 MAY 2016. (Duration: 1 week, 30 hrs)
      2) "Test and Evaluation Course for Electro-Optics and Infra-Red Airborne Systems" @ National Test Pilot School, California, USA, 11-15 MAY 2016. (Duration: 1 week, 40 hrs)
   c. **External courses**
      1) "Airborne Systems Test Curriculum" @ United States Naval Test Pilot School, Naval Air Station Patuxent River, Maryland, USA, 25 JUL 2016 – 17 JUN 2017. (Duration: 48 weeks, ~200 hrs - ongoing)
   d. **Training activity**
   Training activity regarding the employment of electromagnetic radiation (RF and optic frequency bands) was extensively conducted during the two external courses. The first course (1 week) was dedicated to a quick overview of the theory, practical implementation, and operational test of Electro-Optics (EO) and Infra-Red (IR) airborne sensors, such as Forward Looking Infra-Red (FLIR) and EO gimballed turrets mounted on several types of military and civilian aircrafts and helicopters. The second course (48 weeks), which is still ongoing at the moment at which this accounting is being written, is dedicated to learning and applying the theory and the Flight Test Techniques (FTT) necessary to understand the working logic and perform test activity on various Airborne Systems as installed on military and civilian aircrafts and helicopters. Several short courses within the 48-week course were specifically dedicated to the following areas: Radar (both Air-to-Ground and Air-to-Air modes, with different implementations: mechanically scanned, PESA, AESA), Electro-Optics and Infra-Red sensors (gimballed turrets, missile seekers, thermal imagers in general), Navigational systems, Electronic Warfare (RCS and low observability considerations, jamming techniques, countermeasures). The mentioned courses encompassed about 200 hours of lesson and about 50 hours of flight test activity. Additionally, huge focus and effort was put into English report writing and oral presentations/briefings techniques.
   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				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	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary	Check	Total	Grand Check
Modules	20	9	0	0	0	0	4	13	20 - 40	10	0	0	0	3	12	0	15	10 - 20	20	0	0	5	5	5	5	20	0 - 10	48	30 - 70
Seminars	5	0	0	0	0	0	0	0	5 - 10	5	0	0	0	0	0	0	0	5 - 10	5	0	7	0	0	0	0	7	0 - 10	7	10 - 30
Research	35	8	8	8	8	8	7	47	10 - 35	45	7	7	8	8	8	7	45	30 - 45	34	7	7	4	4	4	7	33	40 - 60	125	80 - 140
	60	17	8	8	8	8	11	60	60	60	7	7	8	11	20	7	60	60	60	7	14	9	9	9	12	60	60	180	180

Note: * External Courses were accounted as Seminars, so that related credits were assigned based on Professor Riccio's first year directions, namely 0.1 credits per hour, 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 (current radiation) and BVH data structure (ray tracing). Advanced methods for RCS measurements.

b. Study

The Study activity respected the path presented in the Second Year TRAR. During the third year significant focus was put into locating the overall research project and the thesis work in a real-world operational aeronautical scenario. Initially, this was accomplished by means of the Airborne Systems Test Course (@ USNTPS - USA) and thanks to the study conducted using the specific literature employed to introduce the Thesis work. With these premises, the actual prediction tool was influenced by this "real-word scenario" idea, generalizing the applicability of the algorithm going from a monostatic RCS case to a multistatic RCS case. The reason why it was important to locate this type of studies and the overall research activity into a real-word scenario is related to the interested of military aviation towards the RCS subject. In fact, also the Italian Air Force, in the process of acquiring the new stealth fighter F-35 aircraft, is now funding studies oriented to the RCS area. Within this frame of reference, being able to employ a tool that can quickly and precisely predict the monostatic RCS (1° step) and the multistatic RCS (2° step) of an electrically large object is a great capability that private companies or governmental institutions would be interested in. Being employed by the Italian Air Force Test Center, the opportunity of participating in the study and development of such tool with Professor Capozzoli's team was overall an extraordinary achievement for strengthening my professional scientific background.

Research description

With respect to the research description provided in the Second Year TRAR, the third year activity was mainly focused on the development and application of the Non-Uniform FFT 3rd Type 3D code using C++ and CUDA programming languages (the MatLab version was completed during the second year). In the following, the frame within the NUFFT was employed is recapped.

The tool uses 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 first year activity was 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 was oriented to the acceleration of the PO integrals, which consisted in developing 3D Fourier Transform. The FT is numerically implemented by the known algorithm Fast Fourier Transform (FFT), but, in this particular case, due to the complex arbitrarily 3D shape, a non-uniform discretizing lattice was required in the spatial domain (i.e. "non-transformed domain"). Similarly, since we were interested in determining the radiation only in certain directions of the transformed space, a non-uniform discretizing lattice was required in the spectral domain too (i.e. "transformed domain"). This was achieved

employing the 3-Dimensional Non-Uniform FFT of the 3rd type. In literature, the only available existing formulation was provided by Lee and Greengard and involves Gaussian interpolating windows, which needed to be finely tuned by accurate parameters choice.
Thus, the second year activity was 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, and reaching a final CUDA version for GPU application (see second year TRAR for further details).
Concluding, the third year activity was initially dedicated to completing the NUFFT algorithm, with respect to the C++ and CUDA codes (the MatLab version was in fact completed during the second year). Once completed, the codes were confronted against the original MatLab version, leading to promising results when employed in notional examples. Additionally, a specific routine called “pruned FFT” was developed to even further optimized the FFT computation in the transformed domain. The second and conclusive part of the third year (which is still ongoing, hence the necessity of the extension till October 2017), is being used to run the algorithm applied to more practical examples: the radiation of currents embedded in a 2D volume (cylindrical geometry infinitely extending in the z-direction) was tested and reported with astounding results when compared to existing commercial codes (speeding-up in the order 2/3 orders of magnitude when compared to FEKO and IDS proprietary codes). The next step will see the currents radiating just from the surface (i.e. PEC object) of the same 2D volume: even though it may appear easier, this case is actually more complicated than the volume one since it requires the “domain decomposition” technique to define the initial non-transformed domain, in order to really optimize and speed-up the code. The final step, which will likely not be accomplished within the time limits set by the PhD regulations, will use a real 3D object of arbitrary shape, making the currents radiate firstly from the volume and secondly, again, just from the surface.
Reaching this final step would mean being able to predict the multistatic RCS of an electrically large object of arbitrary shape with: 1) machine accuracy 2) extremely short time requirements (vs present literature) 3) very affordable commercial hardware (vs present work-stations). Overall that would represent an applicable unprecedented result in computational electromagnetics.

c. Collaborations

Ingegneria dei Sistemi IDS Corporation, Pisa.
Italian Air Force Flight Test Center, Pratica di Mare, Roma.

4. Products

a. Publications

1) “Italian Air Force interest in RCS studies and Low Observability features for airborne assets” - Mercurio, Piccinotti - Oral presentation supported by slides @ AMTA European Regional Event 2016 – Naples - 23 MAY 2016.
2) “Efficient Computing of Far-Field Radiation in 2D” - Capozzoli, Curcio, Liseno, Piccinotti – Letter for the IEEE Antennas and Wireless Propagation Letters - 21 FEB 2017.

b. Patents

No patents were obtained.

5. Conferences and Seminars

1) AMTA European Regional Event 2016, Naples, 23 MAY 2016.

6. Activity abroad

1) 1 week for “Test and Evaluation Course for Electro-Optics and Infra-Red Airborne Systems” @ National Test Pilot School, California, USA, 11-15 MAY 2016.
2) 48 weeks for the “Airborne Systems Test Curriculum” @ United States Naval Test Pilot School, Naval Air Station Patuxent River, Maryland, USA, 25 JUL 2016 – 17 JUN 2017 (ongoing).

7. Tutorship

N.A.