IAPP Project FTK

2-Year Post-Doc Position at Pisa University

Fast Tracker for Hadron Collider Experiments

Fast Tracker for Hadron Collider Experiments (FTK) is a Marie Curie PEOPLE Industry-Academy Partnership and Pathways (IAPP) Research Project funded within the EU seventh framework (http://ec.europa.eu/research/participants/portal/desktop/en/opportunities/fp7/calls/fp7-people-2012-iapp.html).

FTK (http://ftk-iapp.physics.auth.gr) aims to develop an extremely fast but compact processor, with supercomputer performances, for pattern recognition, data reduction, and information extraction in high quality data processing. The proposed hardware prototype features flexibility for potential applications in a wide range of fields, from triggering in high energy physics to simulating human brain functions in experimental psychology or to automating diagnosis by imaging in medical physics.

The first goal consists in demonstrating the system can perform online track reconstruction of full events at the highest rates and luminosities of the Large Hadron Collider (LHC – http://home.web.cern.ch/about/accelerators/large-hadron-collider) and SLHC (http://info-slhc-pp.web.cern.ch/info-slhc-pp) at CERN (http://home.web.cern.ch), beyond the limits of any existent or planned device and despite the overwhelming confusion due to the very high track multiplicity and the exceedingly large event pile-up.

With this goal in mind, we participate to the construction and the test of a high precision real-time tracker built for the ATLAS experiment (http://atlas.ch/): the Fast Tracker processor. FTK can improve the capability of the ATLAS detector to select interesting events reach of heavy leptons or quarks within the huge LHC background. It uses FPGA and ASIC chips to implement real-time complex track-reconstruction algorithms. The particle trajectories are reconstructed in 3D in a few tens of microseconds and the quality of the fit parameters is close to that achievable by offline analysis. The first stage of this reconstruction, consisting in an extremely fast association of the measured points belonging to the same trajectory, is performed by a massively parallel processor called associative memory (AM). AM examines the detector data, *while they are read-out*, and identifies those matching predefined patterns.

The IAPP 324318 "FTK" Project provides a unique opportunity for experienced researchers (e.g. post-docs) to tackle strongly relevant technological problems related to the development of a powerful dedicated processor where parallelism is exploited at the maximum level.

The project consortium is composed by:

(1) Laboratoire de Physique Nucléaire et des Hautes Energies, CNRS, Paris, France;
(2) CERN, European Organization for Nuclear Research, Geneva, Switzerland;
(3) Aristotle University of Thessaloniki, Thessaloniki, Greece;
(4) Prisma Electronics SA, Alexandroupolis, Greece;
(5) CAEN SpA, Costruzioni Apparecchiature Elettroniche Nucleari S.p.A, Viareggio, Italy;
(6) University of Pisa, Pisa, Italy.

This consortium will offer a multinational and multicultural top-level environment to the researcher.

The scientific and technological work of the project is organized into 6 packages.

The first one, "Prototype Production", includes board design, FPGA firmware development, PCB

construction and assembly, and standalone test for a first validation.

The second work package, "Infrastructures and Integration", takes care of the crates, the power supplies, and the space for integrated lab tests.

The third one, "Commissioning", closes the research path described above. After the tests in the laboratory, the new hardware will be moved to the experiment at CERN and will spy real data during normal data taking. Commissioning implies the insertion in the experiment, the development of monitoring and control software compatible with its rules, long tests to validate the system, data taking, and data understanding.

The forth work package is "Architecture Simulation". It consists in producing software that has an important impact on hardware choices. A complex package, FTKsim, has to simulate the hardware on both Monte Carlo and real data. It is used to optimize the hardware design, to specify, build, and test the internal data paths needed for the LHC high luminosity, to determine the optimal size of the system, and to scrutinize the physics case. The simulation is an essential part of all tests since it allows prediction of the hardware output, starting from the inputs, to validate the hardware functionality.

The fifth work package, "Image Processing", is devoted to applications of our technology outside the high energy physics field. We will use our processor to process still images and movies in real time.

The sixth work package is "Silicon Detector R&D". It does not have a direct impact on the other electronics tasks. However, it provides a solid link with the evolution of the ongoing R&D for the silicon sensors and the front-end readout electronics in view of the high-luminosity upgrade of the LHC.

Details can be found at the project web site http://ftk-iapp.physics.auth.gr/.

Detailed job description – Position details

The researcher, in the proposed post-doc position, will contribute to the work package 5, "Image Processing", at developing high quality applications in fields other than HEP, for which the computing power is still a limiting factor.

For instance, these techniques could be important for real-time diagnosis in 3D high-resolution medical imaging (a memory and computing-power demanding activity), while the patient is under examination.

The possible use of the associative memory processor for neurophysiologic studies of the brain is especially fascinating. Some convincing models, which try to validate hypotheses of brain functioning, have much in common with the FTK architecture developed for HEP.

A multilevel model seems appropriate to describe the brain organization to perform a synthesis that, of course, is much more impressive than those of the HEP triggers. It has been suggested [Del Viva MM, Punzi G, Benedetti D (2013) Information and Perception of Meaningful Patterns; PLoS ONE 8(7): e69154. doi:10.1371/journal.pone.0069154] that the brain dramatically reduces the input information, by selecting those data matching a specific set of memorized patterns: only the matching patterns are sent to higher-level processing and to long-term storage. The double constraint of finite computing power and finite bandwidth determines to a large extent what type of information is defined to be "meaningful" or "relevant" and sent to further processing.

The AM pattern-matching technique has demonstrated to be able to play a key role in high rate filtering/reduction tasks. We now want to test the capability of an AM to emulate the first stage of the brain activity, dedicated to external stimuli pre-processing. Then, the AM-based processor will be used for a real-time hardware implementation of a fast pattern-filtering of the type studied in the above-mentioned models of human vision and other brain functions.

The AM-based processor will be fed with static images and movies in real time. We want to check the capability of the AM to extract the relevant features, from an image or from a movie, and to substantially suppress the non-relevant information. The images have to be formatted in the right way to be sent to the AM system. For static images, groups of 3x3 pixels are extracted from the image and each particular configuration constitutes a 9-bit pattern. In the early stage, called "training" or "learning", the frequency of the matching patterns will be measured by an FPGA controller. The frequency is the crucial feature according to which it is decided whether a pattern is relevant or not. After the learning phase, the relevant patterns are downloaded to the AM bank and the processor will be ready to filter the static images by selecting only about 5% of the input data. For movies, we need to add the time as a third dimension, resulting in 3x3x3 patterns made of 27 bits (128 millions of possible configurations for simple black and white pictures). The AM system will continuously monitor the pattern frequencies, updating the AM bank as the frequency distribution changes.

Important deliverables of work package 5 are two publications, which should show if the AM system can (or cannot) emulate the low-level brain's filtering function for both still and moving images. The corresponding milestones will be considered attained if the results are accepted for publication on peer reviewed journals.

In case of success, we can apply the AM filtering also to medical images and test reconstruction algorithms applied to the filtered pictures, in order to contribute to the development of an automated diagnosis or, at least, a computer-based diagnostic tool. More specifically, we are planning to exploit the computing power of a parallel array of FPGAs (Field Programmable Gate Arrays), used by FTK to find clusters (spots of adjacent fired pixels) in silicon detectors.

The appointed researcher, with specific expertise in the field, will share the responsibility for the setup and use of the AM system for Image Processing.

During the 24-month duration of the grant, the appointed researcher will:

(1) setup a test stand based on an evaluation board; the board is equipped with a large Virtex-6 chip connected to an Associative Memory bank, which, in turn, is organized on a small mezzanine called LAMB (Little Associative Memory Board);

(2) write the software to handle the memory (about 1 or 2 millions of patterns) in order to perform image filtering and contours extraction;

(3) produce the FPGA firmware and software to handle images and movies, namely to perform the training by measuring the pattern frequencies and selecting the relevant ones, to download the found patterns to the AM, and to use the system to filter the images and movies;

(4) participate to publication and dissemination of the results.

The researcher will fully exploit the experimental facilities installed at Dipartimento di Fisica "Enrico Fermi" - Università di Pisa, at INFN - Sezione di Pisa, and at CAEN, where an FTK laboratory is already in operation. She/he will exploit the computing facilities there and will be able to profit of all other FTK laboratories distributed in Europe.

The research will be carried out under the guidance of Prof. Mauro Dell'Orso of the "Enrico Fermi" Department of Physics.

The position will be funded through a 24-month "assegno di ricerca", issued by Università di Pisa according to the rules of Italian law and Pisa University regulations. The grant is planned to start on January 1st 2015.

Salary will be calculated according to EU category standards. A mobility allowance is included, depending on the family situation of the researcher at the time of the recruitment. The total gross annual amounts, including all compulsory social security contributions as well as direct taxes (such

as income tax) are: 62.361,00 EUROS/year for the base salary, 12.792,00 EUROS/year for the mobility allowance to a researcher with family charges, and 8.954,40 EUROS/year for the mobility allowance to a researcher without family charges.

The grant will be paid by the administration in monthly deferred payments.

Eligibility criteria

The candidate should fulfill the eligibility criteria for *Experienced Researchers (ER 4 to 10 years)*, typically equivalent to a post-doc level, according to the EU requirements.

According to the Marie Curie funding scheme, *Experienced Researchers (ER 4-10)* must, at the time of recruitment, **either** be in possession of a doctoral degree, irrespective of the time taken to acquire it, **or** have at least four years of full-time equivalent research experience. This is measured from the date when they obtained the degree which formally allowed them to embark on a doctorate in the country in which the degree was obtained or in the host country (irrespective of whether or not a doctorate was envisaged).

In our case the ER should not have more than 10 years of experience (< 10 years of experience).

Mobility Requirements: to ensure the European character of an IAPP project, researchers to be newly recruited are required to undertake trans-national mobility when taking up their appointment. At the time of recruitment by the host organization, researchers must not have resided or carried out their main activity (work, studies, etc.) in the country of their host organization for more than 12 months in the 3 years immediately prior to their recruitment. Short stays such as holidays and/or compulsory national service are not taken into account. Researchers of any nationality can be recruited within IAPP projects as long as the transnational mobility rule is respected.

She/he must be expert in C++ software and very expert on FPGA technology, design, simulation and implementation. Specific experience in the field of real time image processing will also be an important added value.

She/he must be expert of device simulation and test, as well as of performance measurement.

Selection procedure

Candidates will be selected taking into account their scientific curriculum vitae, with special emphasis to expertise in the specific fields covered by the project, to be evaluated through the training career, scientific publications in peer-reviewed journals, internships, participation in scientific conferences and international schools, etc. Adequate knowledge of the English language is mandatory.

Pre-selection of the candidates, based on the evaluation of their scientific CV, will be done by the Steering Committee of the FTK Project. After shortlisting, the top candidates will be contacted for an interview by a Selection Committee. The interview may take place via videoconference, or similar. The Selection Committee consists of three members appointed by the Scientific Board of the FTK Project among the members of the Steering Committee or of the Scientific Board itself. The final selection will be done by the Scientific Board on the basis of both the CV and the report of the Selection Committee on the interview.

The winner will receive a 24-month grant ("Assegno di Ricerca") with Università di Pisa.

The selection of candidates will be accomplished according to the transparent recruitment strategies recommended by "The European Charter for Researchers" and "The Code of Conduct for the Recruitment of Researchers" (see:
http://ec.europa.eu/euraxess/pdf/brochure_rights/am509774CEE_EN_E4.pdf).
Special care will be taken to the implementation of equal opportunity policies including gender equalities.

How to apply

Candidates must send their application, according to the scheme of Appendix A, by email to ftk@df.unipi.it, using as the subject: "Assegno di Ricerca FTK".
The deadline for the application is November 5th 2014.
The application must contain, as attachments:
(1) the detailed scientific curriculum vitae of the candidate specifying her/his expertise in the fields covered by the project, the fulfillment of the eligibility criteria, the past experience, and the scientific production;
(2) a scanned copy of a valid identity document (e.g. passport).
Candidates may also optionally include one or more letters of reference.

For further information on the position, please contact prof. Mauro Dell'Orso (mauro.dellorso@df.unipi.it).

Il Direttore del Dipartimento di Fisica "E. Fermi"
Firmato
Prof. Francesco Fidecaro

APPENDIX A

To: Dipartimento di Fisica Enrico Fermi

Università di Pisa – Pisa, Italy

Re: call for 2-year post-doc position within the MC-PEOPLE-IAPP Project 324318 "FTK"

APPLICATION (please fill and send it to ftk@df.unipi.it)

Name:

Surname (Family name):

Place and date of birth:

Sex:

Citizenship:

Identity Document (e.g. Passport, Identity Card):

Identity Document Number:

Please, attach to the email:

1. Detailed scientific curriculum vitae, prepared according to the call;
2. A scanned copy of a valid identity document (e.g., passport);
3. (Optionally): one or more letters of references.