ANNEX C
Letters of support of co-PIs and collaborators

SUTD
SINGAPORE UNIVERSITY OF
TECHNOLOGY AND DESIGN

SINGAPORE, October 10th, 2017

Dear Prof. Massimo Alioto,

I am happy to be part of your five-year NRF "CogniVision" CRP proposal as project co-PI. My contribution to the project is on the image sensor and ultra-low power radios, in which area our group has contributed with more than 200 publications, 10 patents, 1 book and over 50 silicon chip fabrications.

On the relevant project tasks, I will collaborate with the PI and the CogniVision team to develop an image sensor with in-situ/in-sensor processing, with fundamental pre-processing steps being performed at very low power consumption before reading out pixels. Through the collaboration with the team, a CMOS image sensor will be demonstrated that generalizes the concept of near-pixel motion detection to a local saliency analysis, limiting read-out and consequent processing only to salient frame regions.

I will also contribute with a novel radio with ultra-low power consumption for cognitive/attentive cameras. The proposed radio will have the capability to continuously receive commands from the cloud, and hence respond to requests that arise from the detection of conditions of interest (e.g., when an event is detected in the neighborhood of an individual camera, and frames or video clips are needed from the cameras in the same area for better understanding of the scene and the context). As another important implication, the radio being investigated in this project also enable the cloud to push appropriate configurations to adjust the cognitive camera configuration (e.g., neural network weights) based on the scene and lighting conditions to enhance the quality of event capture.

My research staff and I commit to participate to the "CogniVision" research activities through regular meetings, as well as regular remote teleconferences.

With this letter, I express my commitment and interest in collaborating on the "CogniVision" proposal. Looking forward to collaborating with the CogniVision team.

Sincerely,

Professor Yeo Kiat Seng
Associate Provost
Graduate Studies & International Relations

Faculty of Engineering

Dep. of Electrical and Computer Engineering

SINGAPORE, Feb. 27th, 2018

Dear Prof. Massimo Alioto,

This letter is to express my interest and commitment in cooperating with the other investigators of the "CogniVision" proposal, which is being submitted to the NRF COMPETITIVE RESEARCH PROGRAMME (CRP) Grant Call.

If the application is successful, I will serve as the leader of the sub-project "Energy-centric machine learning-circuit co-design". In particular, I will contribute to the investigation and development of frameworks and approaches to design energy-aware deep learning algorithms that enable a silicon implementation suitable for tightly energy-constrained silicon systems. Several novel techniques will be investigated as detailed in the proposal, including model compression and attention mechanisms.

Look forward to our collaboration on the CogniVision program. Sincerely,

Jiashi Feng

Assistant Professor

Department of ECE

NUS

DEPARTMENT OF ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

UNIVERSITY OF MICHIGAN

COLLEGE OF ENGINEERING

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Dennis Sylvester
Professor
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Feb 27, 2018

SUBJECT: International Collaborator - NRF "CogniVision" Project

Dear Professor Alioto:

I am happy to be international collaborator in your NRF "CogniVision" proposal on cognitive cameras. I find the proposed research is very compelling and impactful.

I will be glad to contribute to this research with my expertise in ultra-low energy CMOS integrated systems, with focus on imaging systems. Regarding my commitment, I am willing to visit NUS for a few weeks every two years during the period of this project, and have regular remote interaction through teleconferences. I also confirm my interest in co-supervising graduate students working on this project.

Our research collaboration will be focused on the challenges at the boundary between sensing and processing, and on the opportunities to reduce the energy through co-optimization, leveraging our recent research work that was demonstrated at the ISSCC conference. In particular, our collaboration will involve the interaction between the imager and the processing/cognition sub-systems, to create unprecedented opportunities to enable irrelevant activity skipping via inexpensive assessment of their relevance at the lowest abstract level of comprehension, and confining computation within low-energy tasks in the common case (see related sub-projects in the proposal). Our collaboration will also involve spatially selective methods to preserve accuracy in detection/classification/tracking tasks, while ignoring irrelevant portions of the frame.

With this letter, I express my interest and commitment to collaborate on this proposal. I look forward to our collaboration.

Best Regards,

Dennis Sylvester
Professor
Director, Michigan Integrated Circuits Laboratory

School of Electrical & Electronic Engineering

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Feb 27th, 2018

Dear Prof. Massimo Alioto,

I am glad to be part of your five-year NRF "CogniVision" CRP proposal as project collaborator. My contribution to the project is on the image sensor and its interaction with processing, leveraging my expertise as researcher and designer of image sensors, with more than 30 CMOS imagers demonstrated in the last ten years.

On the related project task, I will collaborate with the PI and the co-PIs to develop an image sensor with in-sensor processing, to enable major pre-processing steps at very low power consumption before performing further data conversion, compression and encoding. The main idea is to generalize the concept of near-pixel motion detection to a local saliency analysis to confine data conversion and successive processing steps only portions of the frame that are meaningful. In particular, I will collaborate to demonstrate an ultra-low power (<100uW) CMOS image sensor, with VGA (640x480) resolution and 30 frame/s, equipped with spatially selective saliency detection for surveillance and security applications, among the others. The sensor will also feature dynamic resolution, triggered by the amount of activities in the scene. I will also collaborate on the investigation of the interaction between the image sensor and the sensemaking, and will support optical and electrical characterization of the sensor (e.g., dynamic range, fixed pattern noise, and spectral response).

I commit to participate to the "CogniVision" research activities through visits and in-person interaction with the team for various weeks on a yearly basis, as well as regular remote teleconferences.

With this letter, I express my commitment and interest in collaborating on the "CogniVision" proposal. Looking forward to collaborating with the CogniVision team. Sincerely,

Dr. Chen Shoushun

School of EEE, NTU
Email: eechenss@ntu.edu.sg

Zurich, Feb 27, 2018

SUBJECT: International Collaborator - NRF "CogniVision" Project

Dear Professor Alioto:

with this letter, I express my interest and availability to be international collaborator in your NRF "CogniVision" proposal on cognitive cameras. I find the related research program very interesting, and it addresses an important challenge with potentially strong impact.

If the research program is funded, I will contribute with my expertise in energy-efficient architectures for machine learning and deep learning, with emphasis on real-time video processing. I am willing to visit NUS during the period of this project and host Prof. Alioto, and interact through remote meetings on a regular basis. I am also interested in co-supervising graduate students in Singapore working on the project.

The research collaboration will involve the architectural aspects of low-energy on-chip accelerators for machine learning, and in particular deep learning. I will interact with the CogniVision team at the interface between the algorithm and the architecture, as well as between the architecture and the circuit level. In the research collaboration, we will leverage our expertise and the numerous demonstrations of architectures of deep learning on-chip accelerators and integrated systems for video processing. The approach will be aligned with the unique research directions pursued in the CogniVision project, and in particular 1) irrelevant activity skipping via early assessment of the of visual tasks at the lowest level of semantic understanding, 2) mostly limiting computation to low-level and low-energy tasks in the common case, 3) spatially selective methods to limit the need for sensing and processing to the regions of potential interest.

In conclusion, I express my interest and commitment to collaborate on this proposal. I look forward to our collaboration.

Best Regards,

Prof. Luca Benini
Chair of Digital Circuits and Systems

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Letters of support of local industry and governmental agencies

Panasonic

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Panasonic is a leading worldwide company in a wide range of applications and markets, including the broad technology area of smart homes and smart cities. Panasonic in Singapore is performing R&D on artificial intelligence technologies that can be applied to perform real-time and continuous monitoring of the scene through tethered cameras. The "CogniVision" research program on Cognitive Cameras is very interesting in the area of smart cities, as low-power smart cameras can be potentially deployed on a large scale to improve safety of public spaces and efficiency of public infrastructures.

The intended research on "CogniVision" and Cognitive Cameras is highly relevant to the current and prospective technological scenario where sensors are distributed ubiquitously, including vision sensors, and has strong potential to disrupt the related applications. Indeed, cognitive cameras and the related ultra-low power hardware technologies represent a new capability that is not available in the current state of the art, as they are enabled to be fully unwired while achieving very long lifetime thanks to their small power consumption.

Such new capabilities that will be demonstrated by the successful completion of the "CogniVision" CRP program are very important in the applications that we are focused on. Indeed, they introduce the unprecedented capability of being massively distributed, always on, and connected to the cloud to enable both local and global context awareness. The on-chip processing of Cognitive Cameras also helps solve the key challenge of reducing the communication bandwidth between the cameras and the cloud, which is a critical aspect in existing applications and technologies.

If the "CogniVision" proposal will be accepted, we are very interested in being involved in the execution of the research project in various ways. First, we are willing to sharing our expertise on applications related to distributed vision systems, video analytics, real-time visual event monitoring and situational awareness through regular technical meetings with our teams. We will also provide our perspective to help focus the research effort towards solutions that is well aligned with market needs, and the technology ecosystem.
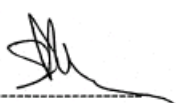
We are also willing to tangibly support the research program with the following contributions:

- FPGA ASIC emulation system (Inrevium ASIC Development Test Platform) for accelerated chip verification, with commercial value of SGD$60,000
- consultation time through regular meetings with our engineers, with expertise ranging from hardware to data analytics and system solutions, with equivalent value of SGD$192,000 ($200/manhour for 16-hour/month x 12months x 5year)
- privileged access to private GPU cluster for accelerated neural network training (Deep Learning GPU cluster) with commercial value of SGD$400,000

We will also be glad to be part of the Advisory Board of the project.

With this letter, we express our interest in the project and its importance to our company branch in Singapore. We look forward to having fruitful interaction with Prof. Alioto and his team. Sincerely

(2018 Feb 28, Panasonic R&D Center Singapore, 202 Bedok South Avenue 1 #02)

Shen Shengmei, Jane

Assistant Managing Director

Panasonic R&D Center Singapore

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Date: 27 February 2018

To Whom It May Concern

RE: Letter of Support --- 'Cognitive Cameras' Research

MediaTek is a pioneering fabless semiconductor company, and a market leader in cutting-edge Systems-on-Chip for wireless communications and connectivity, HDTV, DVD and Blu-ray. Mediatek Singapore is currently focused on the design of low-energy integrated systems for mobile platforms, and more recently for the Internet of Things (IoT).

We find the prospective research on "CogniVision" and cognitive cameras very compelling and potentially disruptive in terms of both technological and market impact.

Indeed, there is no available solution for energy-autonomous cameras with long battery lifetime, and current sense making techniques are mostly confined into the cloud, rather than being embedded at the edge of the Internet of Things.

The "CogniVision" proposal enables both capabilities, and is hence expected to open many new opportunities and novel large-scale applications, and to generate a strong industrial interest for the manufacturing, commercialization and integration of this technology into the IoT ecosystem.

We will be glad to be involved in the execution of the research project, sharing our perspective on related applications, the currently growing IoT ecosystem, recent and up-coming technological / application trends, and large-scale manufacturability, among the others.

We will be happy to provide our perspective as a major semiconductor company with global impact on the field, and help directing the research effort towards a manufacturable and commercializable system that fits the existing semiconductor ecosystem, while adding the above unprecedented capabilities.

During the execution of the "CogniVision" projects, we are willing to have regular meetings with the research team to discuss and advice on strategic decisions, on aspects that are important for the applicability and the integration of cognitive cameras in the IoT semiconductor ecosystem.

We shall make available our existing 40nm CMOS Multi-Project-Wafer (MPW) IC design platform to the research team, where each MPW IC tape-out is worth about $50K. We are also willing to host research staff and students at our R&D laboratories for prototype testing and evaluation.

We look forward to the interaction with Prof. Alioto and the "CogniVision" team.

Thank you.
Yours truly,

Dr. Tan Khen Sang
Senior Advisor
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Ref: MHA/158/29/032

Date : 6 Oct 2017

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Associate Professor Massimo Alioto
Department of Electrical and Computer Engineering
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Dear Prof Alioto,

RE: Support for NUS' Proposal to NRF for the Translational R&D for Application to Smart Nation (TRANS) Call for Proposals

I am writing in support of your proposal to the National Research Foundation for its Translational R&D for Application to Smart Nation (TRANS) grant.

The Office of the Chief Science and Technology Officer (OCSTO), is the Science and Technology authority in the Ministry of Home Affairs (MHA), and it leads the Ministry in all Science and Technology related issues, with the aim to elevate MHA's departments' operational effectiveness by harnessing S&T proficiently, develop game-changing solutions leading to improvements and advancements in Home Team operations, and to provide strategic scientific counsel to the Senior Management of MHA and the Home Team.

With reference to your prospective research on "CogniVision" and cognitive cameras, the new capabilities that will be enabled by the successful completion of the related CRP program are very relevant and important to the applications that our Ministry is developing and considering. The capability of deploying ultra-miniaturized and untethered cameras with built-in intelligence for scene sensemaking is indeed very interesting to us, as they create unprecedented opportunities to enable massively distributed vision for context and

situational awareness, object and human recognition, occupancy and crowd monitoring, human activity monitoring, among the others.

Compared to existing imaging technologies that are available from the market and research, cognitive cameras enable continuous vision with a spatial granularity that is much finer as they are untethered and energy autonomous. Their very low power consumption prolongs the battery lifetime and reduces the camera size and weight, which is critical in most of the applications we are focused on.

If the "CogniVision" proposal will be accepted, we are willing to be involved in the execution of the research project by sharing our expertise on applications related to homeland security. We are also available to share highly relevant use cases to help the team maximize the impact of the "CogniVision" project, and to provide real-world benchmarks and visual materials to calibrate and assess their computer vision system.

MHA-OCSTO is keen to collaborate with NUS to trial Cognivision and cognitive cameras in the following areas:

- Rapid mass deployment for surveillance and security in areas not covered by CCTVs
- Mobile analytics worn by frontliners
- Unmanned systems surveillance
- Complementing indoor location tracking with visual imaging

With this letter, we express our interest in the project and assert its relevance to our Office of the MHA in Singapore and the applications we are focused on. We look forward to having fruitful interaction with you and your team. Sincerely

Yours sincerely,

Dr Lee Fook Kay
Chief Science and Technology Officer
Ministry of Home Affairs