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Embedded Reconfigurable Processing for UAV applications

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The unmanned aerial vehicle (UAVs) have been around for many years. UAVs provide invaluable support for military missions particularly for surveillance, terrain mapping, target identification, and more. UAVs can potentially be applied to non military applications such as early forest fire detection, weather situations and others. The UAV technology has improved over the years in terms of materials, engines, aeronautics and controls. This has resulted in dramatically size decrease, improved speed, payload, endurance, operation range and reliability. But more importantly, advances in electronics and computer technology has produced new intelligent UAVs that can perform on board processing, imaging and networking with each other in autonomous group flyers. The key enabling technologies for these developments are: embedded reconfigurable processing, wireless networking and advanced imaging. In this lecture we provide some background for these technologies and also discuss research developments that affect or will affect UAVs in the near term.

On board processing.
There is increasing need for flexible embedded processing on board a variety of aerial vehicles especially UAVs. To perform their mission, UAVs need unconventional on board processing capabilities:
a) Performing multitude of computationally intensive functions
b) Operating autonomously, adapting from one input to another
c) Meeting low power and reliability requirements.
The challenge to on-board processing systems is due to the large volume of data and the complexity of data processing, particularly signal processing and image processing algorithms. Some of these functions e.g. communication protocol adaptation, multichannel CDMA need to be performed simultaneously and in real time. Moreover, on-board systems need to handle communications with other UAV nodes and ground command and control stations;
Thus on-board systems need to operate in multiple roles and moreover, need to be configured dynamically in response to environment changes. However, they need to adapt at a slower pace as mission requirements evolve, and as new signal processing algorithms, network protocols, communication and coding schemes are enhanced or replaced. A key enabling technology to achieve these objectives is adaptable and reconfigurable hardware.
The basic digital system technologies used for on-board are: a) microprocessors, b) digital signal processors (DSPs), c) field programmable logic arrays (FPGAs). Microprocessors are software-controlled systems and hence are very flexible but suffer from two drawbacks: 1) power consumption, 2) minimal hardware adaptability to mission changes. DSPs provide better adaptability and performance especially for signal/image processing, however, they suffer from power consumption. FPGAs are more adaptable than DSPs, however, they also consume much power for on-board processing. Apparently, an ASIC solution would be best for low power consumption but it it also the most inflexible of all.
New system on chip (SOC) technology pulls together ASICs, microprocessors and FPGAs into a single polymorphic chip design. SoC technology is well suited for many new compute-intensive applications such as, signal and image processing, wireless communications and networking. There is an important need for reconfigurable hardware in future SoC applications. For example, future SoC products will be wireless communicating with powerful servers for applications. Optimizing performance while maintaining low power consumption will depend on the SoC ability for quick or

even dynamic reconfiguration. There is a new emerging trend for SOC configurability: Platform SOCs: this scheme integrates microprocessors, ASICs and memory cores but also reconfigurable hardware fabrics. It appears that Platform SOC fabrics are more suitable for implementing embedded on-board systems because they are more flexible, potentially can consume less power and are amenable to dynamic or even autonomous reconfiguration. We shall review in this lecture various schemes and suggestions as to how to build coarse-grain reconfigurable fabrics within an SoC platforms, their advantages and near term prospects for on-board processing.

Networking.

There are several proposals for a hierarchical system architecture to to manage the information flow and inquiries between a Command and Control Central Station and mobile UAVs in real time. The UAVs are organized into a Master-Slave hierarchy, where a Master is associated with a number of autonomous Slave UAVs. The Station communicates with the Master through station-level queries and commands whereas the Master broadcasts master-level queries to the Slaves for detailed sensory data collection and processing.

A key aspect of these system architectures is the adaptation and learning capability which is embedded in both the Master and Slave UAVs.

The Master employs two on board learning mechanisms. The first employs supervised query learning which is applied to the sequence of queries, evaluations and feedback from the Station to the Master. The second mechanism employs supervised and unsupervised training applied to on board processed sensory data with the aim to provide adaptive recognition of target areas of interest. The Slaves employ one learning mechanism which is similar to the lower level adaptive training of the Master, but on more detailed data collected due to proximity. Moreover, the Slaves are equipped with peer communication capability to self evaluate their data prior to reporting to the Master.

The proposed architectures address several defence oriented scenarios for processing and evaluating inquiry information from a Central Command Station to remote target areas, passive or active, in real time.

Advanced Imaging.

Some of the key requirements for on-board advanced image processing in real time are a) adaptive imaging and filtering, b) advanced associative like memory techniques. In this lecture we will review adaptive imaging, transforms and filtering techniques. We will discuss evolution computing and evolvable techniques that apply to imaging and filtering. We will also review bio-inspired associative memory technology, e.g. protein-based memories, that hold much promise for embedded imaging in UAV applications.