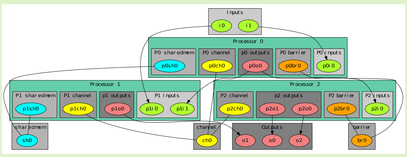
BondMachine, a mouldable computer architecture

UNIVERSITÀ DEGLI STUDI DI PERUGIA

an OS-less approch to reduce the Software/Hardware gap

The BondMachine (BM) is an innovative computer architecture built on two main components: Connecting Processors (CPs) and Shared Objects (SOs). CPs have different Instruction Set Architecture (ISA) and can be connected together sharing resources. The result is a heterogeneous system perfectly fitted to a specific computational problem. The cores are particularly simple (i.e. optimized to execute atomic tasks), and their problem solving potential mainly relies on how they are interconnected. Moreover, in order to use many well-known tools and techniques ranging from languages to compilers, the "register machine" abstraction has been kept.
The BM can be used as a general purpose computer architecture or as an high specialized device perfectly suited to fit specific problems; furthermore the BM is flexible enough to be adopted in different scenarios like Internet of Things (IoT), Cyber Physical System (CPS) and High Performance Computing (HPC).
The flexibility of the BM architecture makes possible the use of evolutionary algorithms that select architectures, processors programs and interconnections.
Currently the BM is implemented by using the Field Programmable Gate Array (FPGA) chips that are the most powerful implementations of reconfigurable hardware nowadays. The implemented EtherBond protocol allows to build distributed systems.
The BM architecture combined with all these technologies results in a brand new computing environment: **The BondMachine Ecosystem**.

The BondMachine architecture



A complete example of the BondMachine architecture. It consists of two inputs and tree outputs interconnected between the input/output registers of the processors. Shared objects, such as memory, Channel and Barrier, are connected among the processors.

The BondMachine architecture consists of interconnections among Connecting Processors and Shared Objects (SOs) built to implement dedicated tasks. The main features of this kind of architecture is the possibility to configure:
- the number of processor cores and their types
- the number of inputs and outputs

Connecting Processor

The CP is the **computing core** of the BondMachine. Several CPs can be configured in arbitrary connection topologies within the BondMachine. They can have different registers, istruction sets, io-registers and still cooperating..

Shared Object

Any kind of component the can be **shared** among CPs. Shared Objects increase the processing capability and the functionality of the BM improving the high-speed **synchronization** and **communication** between tasks running on separate CPs.

Single Multicore

```
package main
import (
        "bondgo"    y
)
func pong(c chan uint8) {
        var ball uint8
        for {
                ball = <-c
                ball++
                c <- ball
        }
}
func main() {
        ball:=uint8(1)
        ch := make(chan uint8)
        go pong(ch)
        for {
                ch <- ball
                ball = <-ch
        }
}
```

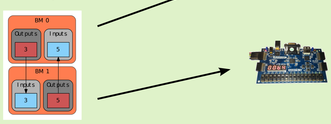
User friendly approch to create your microprocessor

Simple scenario with two CPs exchanging data through a Channel. The Go source code is compiled using the Bondgo Arch-compiler which produces the related architecture.

Simple Interconnected Multicores

```
package main

func test() {

  in0 = bondgo.Make(bondgo.Input, 3)
  out1 = bondgo.Make(bondgo.Output, 7)
  out0 = bondgo.Make(bondgo.Output, 5)
  for {
      bondgo.IOWrite(out0, bondgo.IORead(in0)+1)
  }
}

func main() {
  in0 = bondgo.Make(bondgo.Input, 5)
  in1 = bondgo.Make(bondgo.Input, 8)
  out0 = bondgo.Make(bondgo.Output, 3)

  device_1:
     go test()

  for {
     bondgo.IOWrite(out0, bondgo.IORead(in0)+1)
  }
}
```

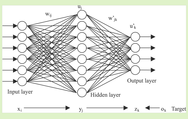
Easy solution to move towards multilayers architectures



This scenario extends the logic to a multi-device environment. A dedicated protocol over ethernet enables the communication among devices.

Complex Multicore Systems

Optimizing a single device to support intricated computational workflows

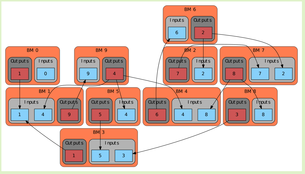


A graphical rappresentation of a multilayer neural network as it is syntetized in the BondMachine ecosystem.

Complex Interconnected Multicores

Extending the very same approch to Enable the "IoT as a service"

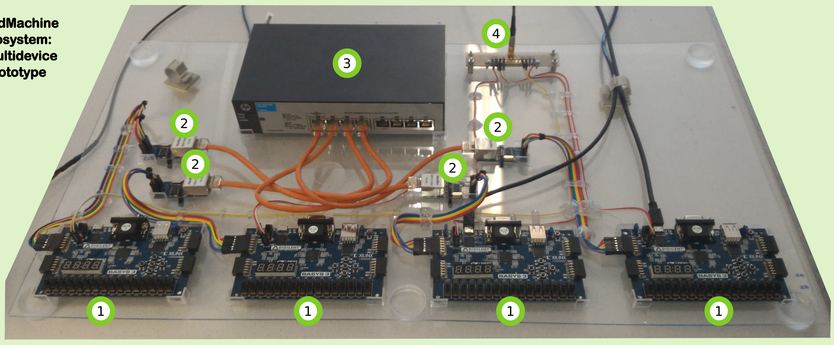
Many distributed devices collaborating as a single system



A graphical rappresentation of how to implement a distributed system of BondMachines. The communication among devices follows the very same approch as the communication among cores in a single device.

The Prototype

BondMachine ecosystem: a multidevice prototype

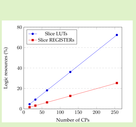


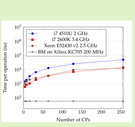
The prototype shown in this picture is composed of 4 FPGA evalution board (1) equiped with SPI ethernet dongles (2) that are connected throught a switch (3). The board are connected to a power supply (4).

Conclusion

We designed and developed an innovative computer architecture prototype, which considerably smooths the allocation of hardware resources, even among multiple devices, and offers an alternative way to solve complex computational problems.
The key aspect of the project is the opportunity to manage the hardware without an operating system allocating the resources by using an high level program (i.e. the Go language). This is what makes the system particularly user-friendly.
The combination of the BM architecture with hardware reconfiguration technologies (FPGA) and a dedicated communication protocol over Ethernet is a strategy aimed at creating a smart ecosystem, with the following selling points:

- **Reusability**: the same object can be recycled as many times as necessary, contributing to an efficient use of resources and offering a solution to the needs of the 4.0 industry;
- **Open source**: the whole architecture is built on lock-free programming;
- **Extensibility**: it can be changed according to the evolving needs of its users, in order to make it suitable for their specific problems;
- **Distributed processing**: the architecture is meant to distribute the processing power among the ecosystem modules;
- **Environmentally friendly**: reducing power and raw material;





Ongoing preliminary performance tests

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