The IOT revolution from the principles to the practice

DISI-Cesena// edited by Antonio Natali

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0.1 Industry4.0

Nel contesto del Piano nazionale Impresa 4.0 (Governo) riportiamo qui una elaborazione di Assolombarda:

Il `Piano Nazionale Industria 4.0` identifica come direttrici chiave, da un lato, gli `investimenti` in innovazioni infrastrutturali e, dall'altro, lo `sviluppo delle competenze` ma anche in virtù di una `presa di coscienza` da parte delle imprese. Infatti dopo aver focalizzato i propri sforzi sull'ammodernamento dei processi produttivi in chiave Industry 4.0, le aziende si sono rese conto che la piena valorizzazione di questi investimenti è possibile solo a condizione di sviluppare le competenze necessarie a presidiare le nuove modalità di gestione operativa dei flussi produttivi nel loro complesso.
Considerando il contesto del tessuto produttivo italiano, **fortemente frammentato** e con poche filiere strutturate, il vero elemento attivatore della diffusione delle tecnologie e più in generale del paradigma 4.0 è, infatti, `il capitale umano` su cui è necessario lavorare in maniera assidua e costante per lo sviluppo delle skill necessarie ad adottare e valorizzare al meglio le nuove tecnologie. L'evoluzione digitale, presupposto dei nuovi processi produttivi di 'Industria 4.0', non riguarda solo l'aspetto delle tecnologie ma richiede che ogni impresa avvii una `riflessione strategica` sia per ridisegnare il proprio business model e sia per promuovere in azienda una cultura digitale e una leadership consolidata a supporto dell'evoluzione tecnologica.
Si tratta di una sfida alla quale saranno chiamate le imprese nel prossimo biennio, in particolare le piccole e medie (`PMI`), e che richiede il contributo sinergico di diversi attori. In quest'ottica il compito delle **Associazioni degli Imprenditori** è quello di creare un tessuto connettivo tra le diverse componenti che possono creare le nuove competenze necessarie alle aziende per essere competitive: scuole superiori, `ITS`, università, imprese, istituzioni. Assolombarda, che già da tempo è impegnata sul tema, anche attraverso Ècole, società di servizi dell'Associazione, sta affiancando alcune imprese con percorsi formativi mirati e incentrati sulla formazione on the job, lo scambio di buone pratiche e il confronto con esperti del settore.
Nella maggior parte dei casi non si tratta di sviluppare nuove competenze dal nulla, ma di **rileggere con lenti diverse** i set di competenze tradizionali delle diverse figure professionali, soprattutto nella logica di una maggiore integrazione e di un **graduale allentamento della verticalizzazione delle competenze**. Un passaggio di questa portata non è affatto semplice e implica la necessità di costituire `team di persone` in possesso di competenze diversificate, da utilizzare in relazione alle attività e, soprattutto, alle problematiche che sorgono nel lavoro quotidiano.
Sicuramente la `nuova impostazione organizzativ`a comporta il fatto di dare maggior rilievo a quelle competenze che sono tipiche di un ambiente di lavoro caratterizzato da **complessità e flessibilità**: il problem solving, il pensiero critico, la capacità di coinvolgimento di team di lavoro interfunzionali, la capacità di gestire i processi e i progetti in ottica lean. Per contro, sotto il profilo delle competenze tecnico-professionali, le imprese sono chiamate a sviluppare nei propri collaboratori le **conoscenze necessarie a gestire in modo efficace le tecnologie abilitanti per l'adozione dei nuovi modelli produttivi** e organizzativi, al fine di sfruttare al meglio le potenzialità offerte dalla 'smart manufacturing'.
In questa prospettiva, per le aziende è fondamentale `sistematizzare la relazione tra processi aziendali, capitale umano e competenze`, affinché siano attivati percorsi formativi in linea con le aspettative richieste e non interventi 'spot' di breve termine. Occorre dunque progettare **percorsi di formazione continua** che `coinvolgano le figure professionali centrali per la trasformazione digitale`, così da fornire loro le competenze necessarie per stare al passo con i cambiamenti della fabbrica intelligente.
Un ruolo molto significativo in questo processo sarà svolto anche dalle **metodologie didattiche**, che devono essere radicalmente ripensate e impostate su un paradigma che privilegi prima di tutto la **condivisione di esperienze**, attraverso sessioni formative la cui efficacia e quindi il costo sono valutati sulla base dei **risultati raggiunti** e non del tempo impiegato.
Solo innovando profondamente tutto il processo formativo, a partire dalla **mappatura dei gap di competenze** fino alla **progettazione dei contenuti e alla didattica**, si potranno porre le basi per realizzare quanto da tempo stiamo affermando, cioè che senza investimenti sul capitale umano non si potrà compiere pienamente la trasformazione digitale delle nostre filiere produttive.

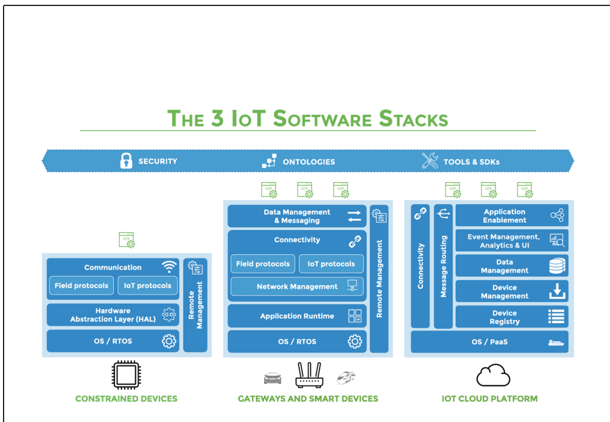
0.2 Overview

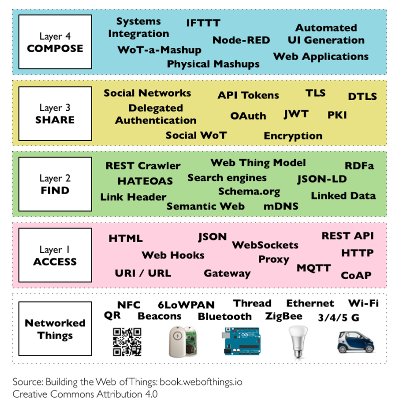
0.2.1 The new industrial revolution .

– The first three industrial revolutions were powered by *steam*, *electric energy*, and *electronics*. Today's Industrial Revolution is powered by data. And that data comes from the Things that fill your factories and supply chains. Sensors, controllers, edge-computing nodes, and devices all talk to one another and to the cloud in order to turn data into insight and insight into action. These Things possess varying levels of processing functionality, ranging from simple sensing and actuating, to control, optimization, and full autonomous operation.

0.2.2 The smart factory .

– All incremental value of a Smart Factory system is based on the ability to accomplish four objectives:
  1. Communicate: communications technologies are necessary to move the data.
  2. Aggregate a broad array of data from your equipment, as well as relevant internal and external systems. Data aggregation is a necessary first step in IIoT (*Indutrial IOT*) implementation, whether from existing PLC, SCADA and *Distributed Control System* (DCS) systems or from newly installed sensors.
  3. Analyse the data to generate information that can be used to inform operational and business decisions.
  4. Act: on your new insight by automating processes, optimizing systems, and informing business strategy.





– A Smart Factory requires collecting, analyzing, transporting, and storing vast amounts of data. The data must be filtered and processed to extract meaning and value, either at the edge or in the cloud. New systems are required to handle the challenges posed by the volume, velocity and variety of these data sets. Solution vendors must either improve data management capacity or develop algorithms that are better at extracting insight from small samples of data. Until this challenge is addressed, the IIoT will be typified by vast data lakes that are siloed, unstructured, and temporary.

- Standards play a key role in the rate of technology adoption. Standards are required to allow smart connected products, machines, and assets to interact in a transparent fashion. This goes beyond the simple communication protocols, and involves the creation of standard semantics and mechanisms that will allow smart devices to discover each other and interoperate. Standards exist in this area but they are incomplete and do not cover all aspects of manufacturing.
  Standard protocols will allow even the smallest manufacturer to see benefits from IIoT. The key point to understanding how this will happen is to realize IIoT movement is not about the 'things' themselves; **it's about the data**.
  A great example of this can be seen in what's happening with fieldbus networks. These legacy networks are fast, efficient, reliable, incredibly robust and widely adopted. However, there is a growing trend in the marketplace to migrate away from fieldbuses and toward industrial Ethernet (e.g. `Profinet`). The reason behind this move is clear: data access. One can easily envision a system where the `Profinet` protocol is employed for control and data access, and protocols like OPC-UA are employed for information.
- The Smart Factory will rely heavily on data handling, software and communications standards like these to make the connection from machine to cloud as direct as possible, delivering consistent and accurate decision making information in a timely manner. Network performance will need to be maintained as node counts and IIoT data volumes increase. Today, networks are typically separated into machine control (highly synchronized), cell or line control and data handling via `Ethernet TCP/IP`.
- The systems that impact your Smart Factory will not all be internal. External systems from weather networks, suppliers, logistics partners, and technology providers share data with internal systems to drive insight and to coordinate action. System linkages rely on standardized Internet and network protocols that enable secure access to information over cloud and fog platforms. Systems that do not communicate in a standardized language cannot share data to create business value.

0.2.3 The integrated factory .

- The ability to aggregate, analyse, and act on data requires one or more IoT data management and analytic platforms to be integrated with enterprise systems and external solutions via an IoT integration and orchestration platform. A key selection criterion for any IoT platform is out of the box integration with existing IT and OT systems. "Plug and play" integration will dramatically accelerate implementation and reduce the required investment.
- As physical devices are becoming "smart," there is an increasing trend toward IT/OT convergence. Wireless connectivity has provided administrators in charge of operational technology with better monitoring systems and the ability to control physical devices remotely.
- IoT technologies do not impact factories in isolation. They also impact customers, suppliers, value chain partners, competitors, and employees. Software programming tools and Internet-based services make it easy to launch new global software-powered start-ups in many industries – without the need to invest in new infrastructure and train new employees
- Collaborative Manufacturing and Collaborative Development Environments gain importance especially for *Small and Medium Enterprises* (SME) with limited resources. Within a collaborative network, risks can be balanced and combined resources can expand the range of perceivable market opportunities. Companies in collaborative

networks can adapt to volatile markets and shortened product lifecycles with high agility. In contrast to the many benefits, the decoupling and spatial separation of production processes whilst integrating comprehensive production data from multiple production-sites has drastically increased the need for `coordination`.

0.2.4 The technology .

- No technology in itself will disrupt an industry. But the `combination of existing and new technologies` has created the foundation for significant technology innovation.
- `Software is eating the world`. More and more major businesses and industries are being run on software and delivered as online services[1]. Many people around the world lack the education and skills required to participate in the great new companies coming out of the software revolution. There's no way through this problem other than `education`, and we have a long way to go.
- `Understanding` the different business and technical drivers behind `OT` and `IT` is essential to creating a `best practices security framework` that will benefit industrial enterprises. Each element of the production line, including all connected internal or outsourced modules, should be secured. The most vulnerable component in the chain are the endpoints such as computers, embedded devices, `PLC`s, and sensors that are collecting, processing, or producing data. By embracing "`Security by Design`", some vendors are embedding security technology directly in their new generations of `IoT` boards, gateways, modules, and systems. Hardware secure elements, in which encryption keys are safely stored, become an intrinsic part of the architecture and are easy to adopt when retrofitting existing production systems or building new greenfield sites.

[1] Perhaps the single most dramatic example of this phenomenon of software eating a traditional business is the suicide of Borders and corresponding rise of Amazon. In 2001, Borders agreed to hand over its online business to Amazon under the theory that online book sales were non-strategic and unimportant. Now even the books themselves are software.

1 The age of DATA

Traditional client/server computing and enterprise applications usually operate on moderate amounts of `structured data`. Most of the time and effort was spent developing and executing *consistent business logic* on these `relatively modest data sets`. The primary value was not in the data but in the application business logic itself.

During the past decade, data has grown phenomenally, and an overwhelming amount of the world's data is `unstructured data`. In this growing world of data-centric computing, `the primary value is not in the business logic but in the data itself`. As data has grown so has the size and scale of infrastructure required to handle these large and growing data sets. As data scales beyond petabytes, simply ingesting, storing, retrieving, and processing data becomes challenging using traditional server and application architectures.

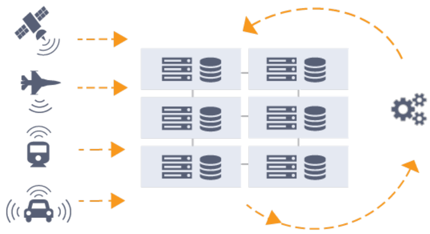
In modern `Distributed architectures`, a large number of similar systems working in concert. The way to coordinate software running on a large number of similar systems is to ensure that each individual system is stateless and communication between them is `REST`ful. State is persisted on a stable storage (hard drives, flash, etc.) using `REST APIs` (Amazon's S3, Google's BigTable, and Microsoft's Azure Active Directory). This API-driven approach abstracts the applications from the details of underlying infrastructure.

Growing data sets are best processed as they arrive as opposed to in batch. This pattern of transitioning from batch processing to stream processing is what is driving the move from now traditional batch processing tools like `Hadoop MapReduce` toward stream processing tools like `Apache Spark`.

Triggers allowed the database engine to execute custom code (stored procedures) on certain database events, simplifying application development. Hyperscale public cloud providers have introduced the equivalent of database triggers to the world of unstructured data. Examples include `Lambda` from Amazon Web Services and `Cloud Functions` from Google Cloud Platform and Microsoft Azure.

As the value of applications moves from monolithic business logic to the data itself, `microservices` allow small pieces of code to surround the data rather than the other way around. The ecosystem surrounding `AWS` Lambda provides a good example of microservices realized.

As the size of data grows, the cost of moving data around becomes prohibitive. We must employ distributed intelligence to `bring computation to the data`. The effort of setting up scalable server, storage and networking infrastructure required to even get started far exceeds the effort to actually process the data and derive value from it.



Next-generation systems will minimize data in motion: new infrastructure and application concepts are now emerging to address these problems of `data-centric computing`. Data-centric computing is poised to change the nature of computing and storage as profoundly as the changes caused by the shift from mainframe to client/server, or from the shift from client/server to Web.

"Computing" is required at all levels of the system's hierarchy by introducing active system elements such as network, memory and elastic storage. The architecture will also need to be composable, based on modular and upgradeable hardware design, and scalable from sub-rack to hundreds of racks. Finally, it must be on an open platform (e.g. `OpenPOWER`) which allows deep innovation by partners at all levels of the ecosystem.

In this world, data is ingested via `HTTP` (ubiquitously accessible) into an intelligent platform that automatically adds relevant `metadata` and executes snippets of code (*microservices*) to inspect and classify the incoming data on the fly. Processed and curated data is API-accessible by users and machines. Developers can realize all of this without the tedium of building, monitoring and managing complex compute, networking and storage infrastructure.

If we can't move the data to the public cloud, it only makes sense to bring the cloud to the data. The next and natural stage in the evolution of cloud services lies with platforms that bring the attributes of public cloud infrastructure to where data is generated and curated.

2 Case studies

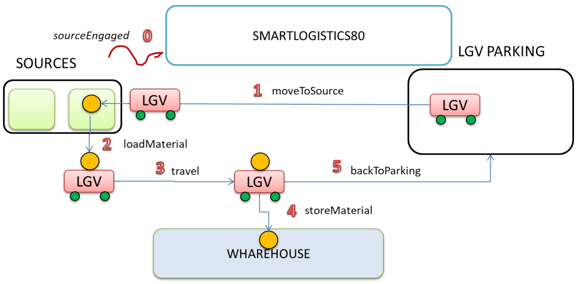
2.1 MMON

See docs/MMONV2a.docx in project aLabDemoIot on `https://github.com/anatali/IotUniboDemo`.

2.2 Logistics

Our company must build a software system (named `SMARTLOGISTICS80`) that must store in automatic way physical material put on one of its material sources into a proper cell of a Warehouse. More specifically the system must:

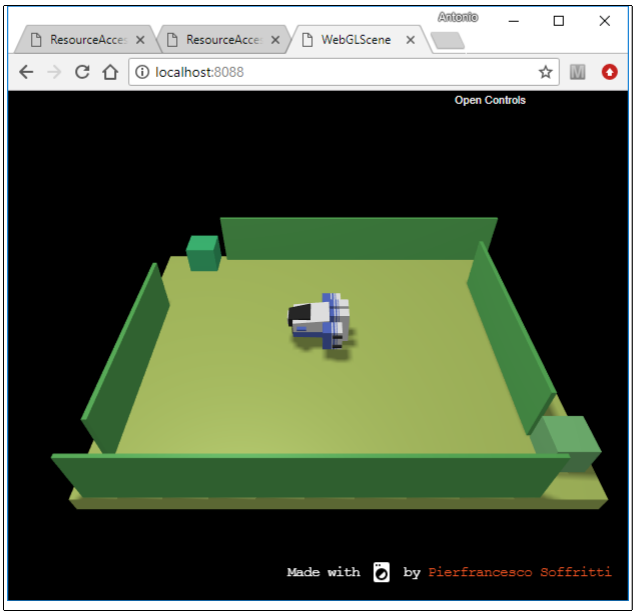
- R0) detect the presence of new material on a source and select a free `LGV` (`LASER GUIDED VEHICLE`) in the parking area
- R1) move the selected `LGV` from the parking area to the source
- R2) check when the material is loaded on the `LGV`
- R3) select a cell in the Warehouse and drive the `LGV` from the source to the Warehouse
- R4) check when the material is stored in the selected cell of the Warehouse
- R5) move the `LGV` from the Warehouse to the parking area



2.3 DDR Robots

In a home of a given city (e.g. Bologna), a `ddr` robot is used to clean the floor of a room (`R-FloorClean`).

The floor in the room is a flat floor of solid material and is equipped with two *sonars*, named `sonar1` and `sonar2` as shown in the picture (`sonar1` is that at the top). The initial position (`start-point`) of the robot is detected by `sonar1`, while the final position (`end-point`) is detected by `sonar2`.



The robot works under the following conditions:

1. `R-Start`: an `authorized user` has sent a `START` command by using a human `GUI` interface (`console`) running on a conventional `PC` or on a smart device (`Android`).
2. `R-TempOk`: the value temperature of the city is not higher than a prefixed value (e.g. `25` degrees Celsius).
3. `R-TimeOk`: the current clock time is within a given interval (e.g. between `7` a.m and `10` a.m)

While the robot is working:

- it must blink a `Led` put on it, if the robot is a `real` robot (`R-BlinkLed`).
- it must blink a Led Hue Lamp available in the house, if the robot is a `virtual` robot (`R-BlinkHue`).
- it must avoid fixed obstacles (e.g. furniture) present in the room (`R-AvoidFix`) and/or mobile obstacles like balls, cats, etc. (`R-AvoidMobile`).

Moreover, the robot must stop its activity when one of the following conditions apply:

1. `R-Stop`: an `authorized user` has sent a `STOP` command by using the `console`.
2. `R-TempKo`: the value temperature of the city becomes higher than the prefixed value.
3. `R-TimeKo`: the current clock time is beyond the given interval.
4. `R-Obstacle`: the robot has found an obstacle that it is unable to avoid.
5. `R-End`: the robot has finished its work.

During its work, the robot can optionally:

- `R-Map`: build a map of the room floor with the position of the fixed obstacles. Once built, this map can be used to define a plan for an (optimal) path form the `start-point` to the `end-point`.

Other requirements:

1. The work can be done by a team composed of `NT` people, with `1<=NT<=4`.
2. If `NT>1`, the team must explicitly indicate the work done by each component.
3. If `NT==4`, the requirement `R-Map` is mandatory.