What can Industry 4.0 learn from SE?

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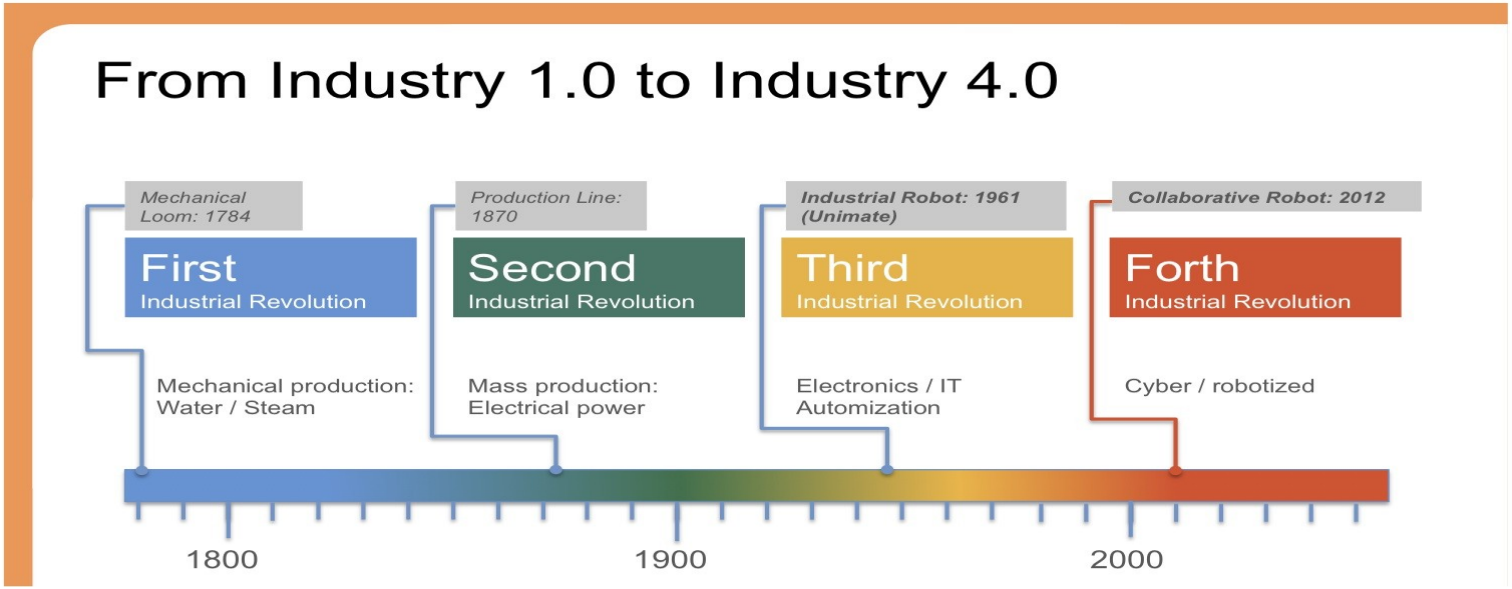
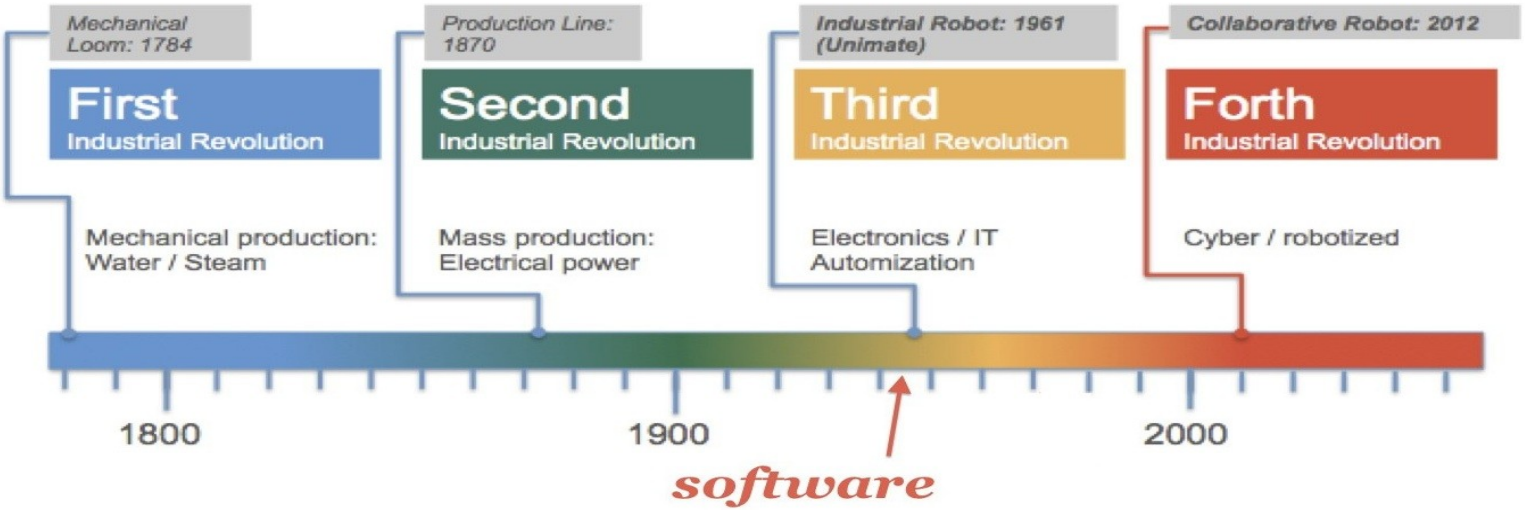
for i = 1 to 4 do {industry (i);}



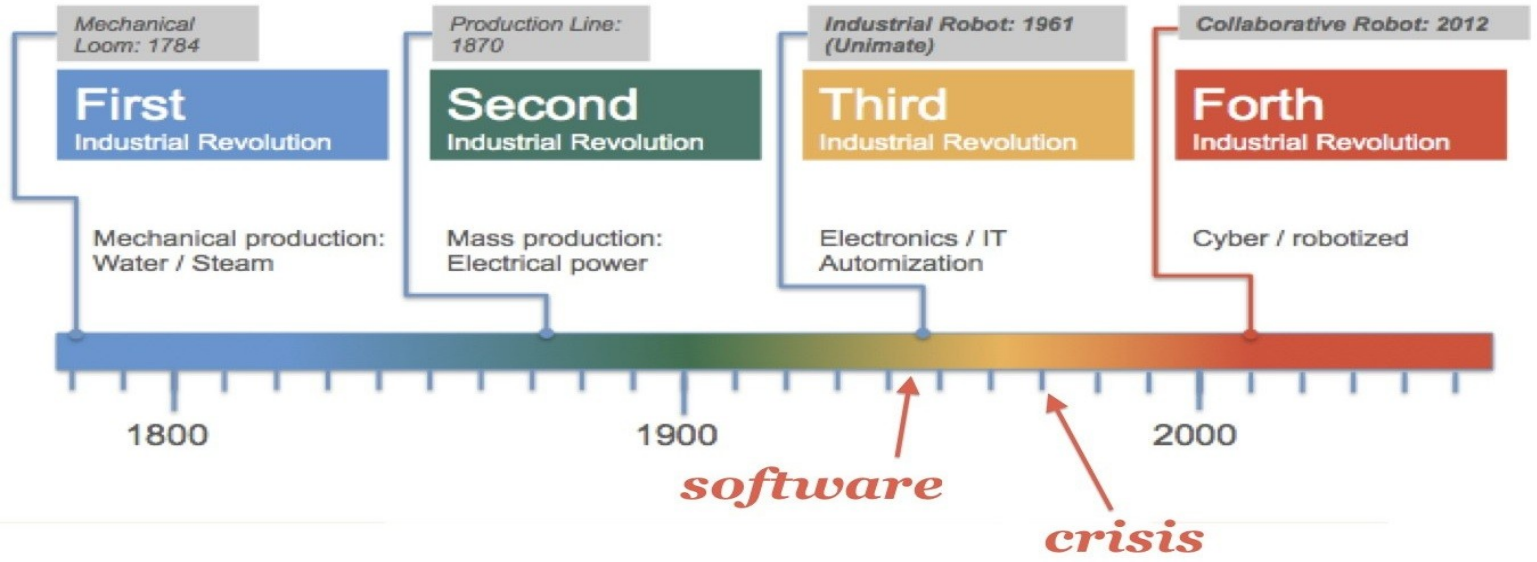
Credit: nelmia Robotics Insight (2015)

Turning point



(“L’enfant terrible” is born)

Crisis



1st NATO Conference on **Software Engineering**,
Darmstadt, October 1968

Meanwhile (50 years)

Software

Process — 

Product — 

"Traditional" engineering principles apply to **process** but not so well to **product** — *why*?

"L'enfant terrible"

Hardware and other "traditional" industrial **products** fabricated according to the *laws of* ***physics***.

Software not governed by the laws of ***physics***:

- it does not weight / does not smell
- it does not warm up / cool down
- it is chemically neutral ...

Anthony Oettinger (ACM President, 1967):

"(...) the scientific, rigorous component of computing, is more like ***mathematics*** *than it is like* ***physics"***

Software = mathematics in motion

Can one *pretend* that **software production** is not affected by its **special nature** and simply move on?

People have tried to do so, for 50 years, with little success.

Still Oettinger **(already** in 1967):

"It is a matter of **complexity**. *Once you start putting thousands of these instructions together you create a* **monster** *which is* **unintelligible** *to anyone save its creator and, most of the time, unfortunately even to the creator."*

Industry 4.0 and software

Industry 4.0 to rely on highly **sophisticated** software on an **unprecedented scale**.

Billions, not thousands, of lines of code required to

for *all* **do** {*human* := *robot*}

Software **correctness** and **robustness** therefore essential.

What have we learned about software?

Software lives on **abstraction**:

> *"The purpose of* **abstraction** *is not to be* **vague**, *but to create a new semantic level in which one can be* **absolutely precise**." *(E. Dijkstra)*

From a Robot Programming Tutorial:

> *"The fundamental challenge of all* **robotics** *is this: It is impossible to ever know the true state of the* **environment**. *A* **robot** *can* **only guess** *the state of the real world based on measurements returned by its* **sensors**."

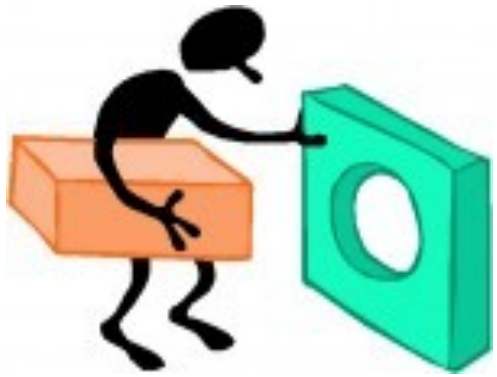
We have developed a sound theory for (safe) **guessing** called **abstract interpretation** — widely used in *program analysis* tools nowadays.

Type oriented programming

Something we've also learned is how important **types** are.

Every computation, piece of data should have a **formal type**.

Types permit (automatic) **checking** before **building**.



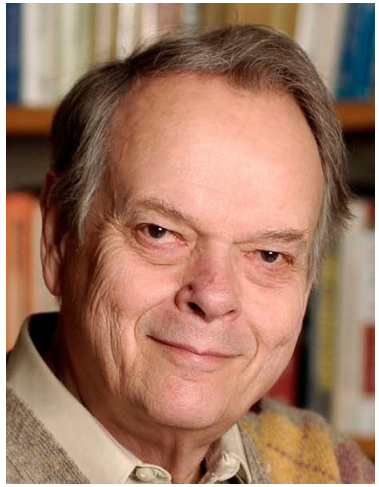
*Doing software without types is like doing **biology** without a post-Linnaean **taxonomy** …*

Beware: most of the software running today is (still) **untyped** or too **weakly typed** (!)

Parametricity and scalability

We also learned to appreciate **generic** (parametric) programs which automatically **instantiate** to specific needs.

Polymorphic types do this - nice theory called **parametric polymorphism** (John Reynolds, CMU).

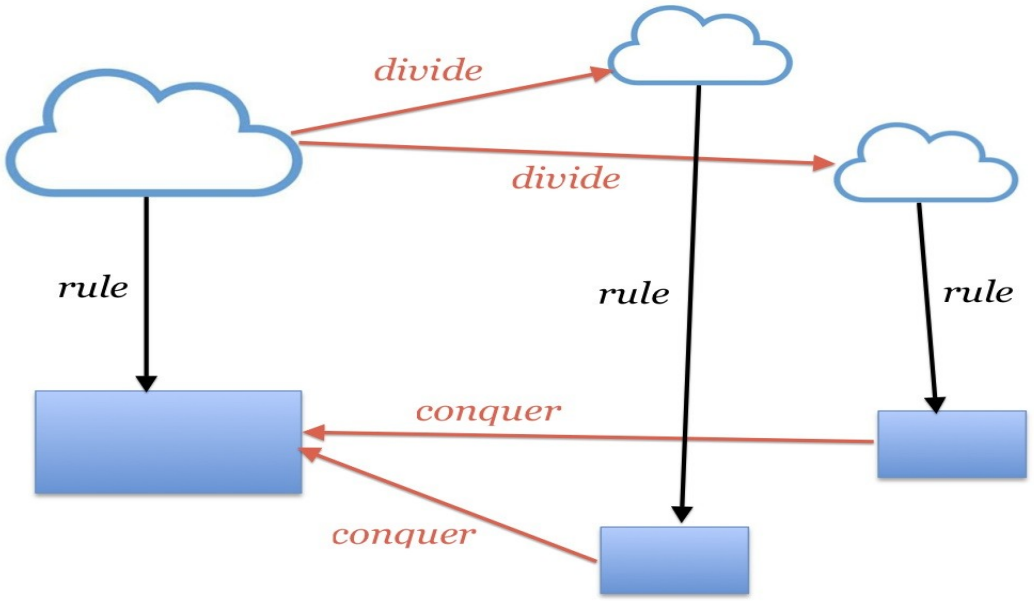


So nice that one derives **properties** of programs **before** even **writing them** — very helpful in **correctness** arguments.

Thanks to techniques like "lazy programming" our **generic** programs have also become **scalable**.

Divide & conquer metaphor

We have learned to better understand and take advantage of this '*quinta essentia*' of **programming**.



Thanks to **D&C** our programs have become **parallel**. Think of **Google**, **cloud** computing, ...

Cyber-security

Surely the **most critical** problem ahead.

> **for** *some* **do** {*human* := *intruder*}

We are learning how to use **number** theory and **automata** theory to build software that is **provably** secure.

Contract-oriented programming

We have also learned that, as in the regular functioning of any **society**, programming should be based on **formal contracts** validated using the underlying **maths**.

Contracts ensure **safety** and **security** essential to **safety-critical** equipment operation.

What can I4.0 learn from SE?

Level of **sophistication** and **safety** needed in **I4.0** incompatible with **ad hoc** software development.

I4.0 should invest on **high-assurance**, **parametric** software **components** developed on a grand scale.

Opportunity for developing widely available, certified **cyber physical component** (CPC) libraries.