Performance-related aspects in the Big Data Astronomy Era: architects in software optimization

Daniele Tavagnacco - INAF-Observatory of Trieste
on behalf of EUCLID SDC-IT

Design and Optimization

image credits: web

EUCLID mission

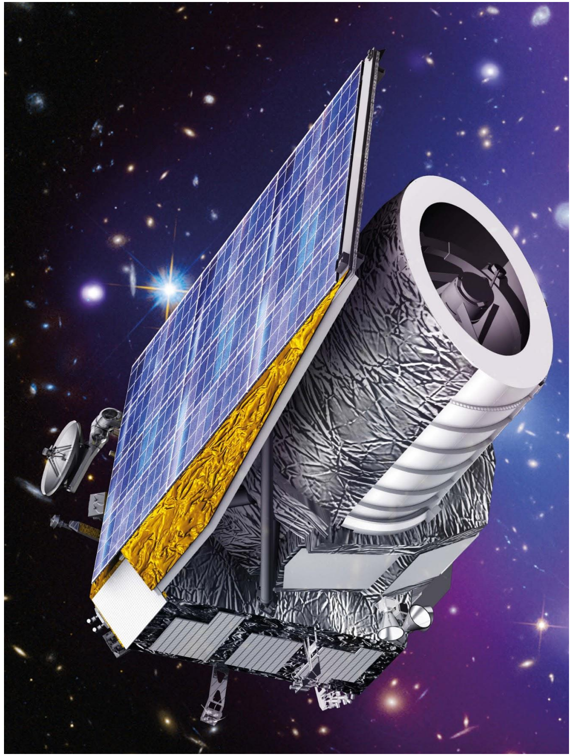


image credits: ESA

- ESA medium class space mission
- Universe expansion, dark energy, dark matter, gravity
- launch 2022
- 15,000 deg^2 survey, 6 years
- 2 instruments: VISible imager, Near Infrared SPectrograph
- ~10^9 observed sources, ~10^6 sources with spectrum
- >15 PB data
- lookback ~10 billion years (z~2)

Design and Big Data

EUCLID : **15 PB** of data to be ~~processed~~ **reduced**

technical only — technical + human: understandable

Big Data: datasets difficult to process in acceptable time frame or cost range

1- Computing power

a) powerful machines

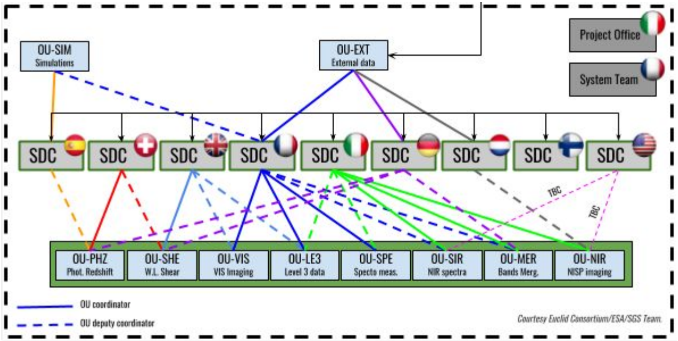
b) parallelize computations

2- Design/optimize algorithms

SDC-IT level3 activities

Euclid computing infrastructure:

- 3 levels: level1 (collect), level2 (prepare), level3 (science)
- distributed infrastructure (--> rules)
    - common environment for sw
    - minimize effort in production and testing
      (common development tools, test tools, ...)



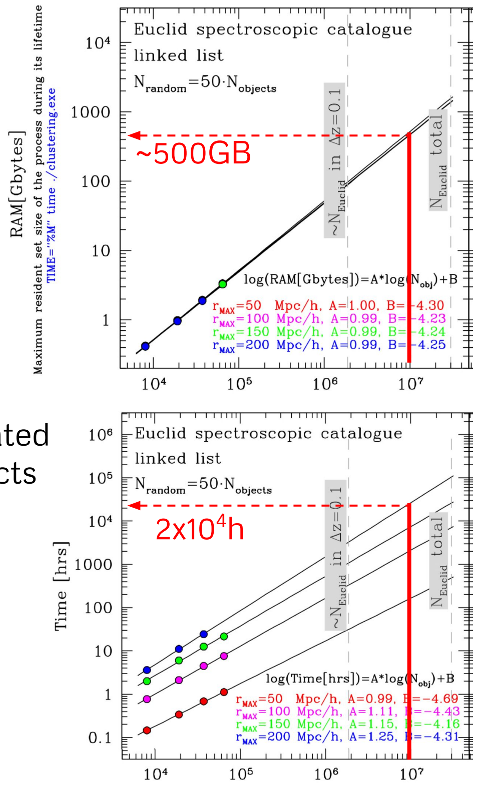
SDC-IT supervise level3 Galaxy Clustering software:

- integration in EC framework
  (C++, Python, 3rd party sw like *swarp*, *sextractor*, *h5py...*)
- software porting in **C++** or Python
- support for refactoring and optimization
- deployment in CI environment

Two Point Correlation Function GC example

Before...

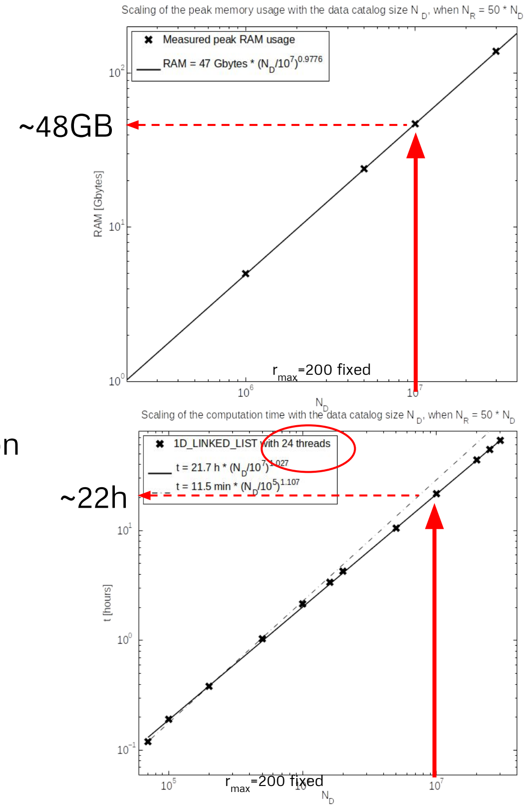
on Euclid estimated size of ~10^7 objects



EC: technical budget note, 2015

...after

measured on simulated catalogs



EC: LE3_GC_2PCF_SDD, 2017

Software design

Activity performed before writing any line of code

Aimed at reducing:

- rigidity - any change affects many parts of the system
- fragility - change breaks unexpected parts of the system
- immobility - code hard to reuse because it cannot be disentangled

Based on:

- **S**ingle Responsibility - each entity has only one responsibility
- **O**pen/Close - entities open for extension, closed for modifications
- **L**iskov's Substitution - Open/Close applied to behaviour
- **I**nterface Segregation - avoid general purpose interfaces
- **D**ependency Inversion - decoupling high-level /low-level modules with interfaces

Scientific software: how good is design?

Software is a collection modules that:

- operate in harmony
- have simple APIs
- hide complexity internally

Requirements change during lifetime:

- extend functionalities
- maintain reliability when extending
- reuse parts of the code

The quantity of data to be reduced is increasing:

- code scalability
- how many data are “big data”

Optimization within Euclid GC

Scientific software:

- has special life cycle
- mainly developed by scientists
- No a priori requirements

Refactoring the code:

- more understandable
- cleaner and tidier
- removing redundacies and unused code
- generalize to allow reuse
- change internal structure
  (smooth flow, avoid nested conditions)
- improve performance

```
void loopVectorA(vector<int> & vec) {

    int c = 0;

    // simple loop
    for (size_t ivec=0; ivec<vec.size(); ivec++) {
        c += vec[ivec];
    }

}

void loopVectorB(vector<int>  vec) {

    int c = 0;

    // optimized loop
    for (vector<int>::iterator it = vec.begin(); it != vec.

        c += *it;
    }

}
```

Optimized code

```
loopVectorA(std::vector<int, std::allocator<int> >&):
  rep ret
loopVectorB(std::vector<int, std::allocator<int> >):
  rep ret
```

Compiler result

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void loopVectorB(vector<int>  vec) {

    int c = 0;

    // optimized loop
    for (vector<int>::iterator it = vec.begin(); it != vec.

        c += *it;
    }

}
```

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```
>>> if (os.path.exists("filename")) :
...       os.remove("filename")
... f = open("filename",'w')

# -------

>>> if not (os.path.exists("dirname")) :
...       os.makedirs("dirname")
```

Python!

```
f = open("filename","w+")

# -------

os.makedirs("dirname")
```

Need to become a code expert?

Source code

```
void Test1(int a, int b, int c, int d) {

    int res = a;
    res += b;
    res += c;
    res += d;

}

void Test2(int a, int b, int c, int d) {

    int res = a + b + c + d;

}
```

```
Test1(int, int, int, int):
  push rbp
  mov rbp, rsp
  mov DWORD PTR [rbp-20], edi
  mov DWORD PTR [rbp-24], esi
  mov DWORD PTR [rbp-28], edx
  mov DWORD PTR [rbp-32], ecx
  mov eax, DWORD PTR [rbp-20]
  mov DWORD PTR [rbp-4], eax
  mov eax, DWORD PTR [rbp-24]
  add DWORD PTR [rbp-4], eax
  mov eax, DWORD PTR [rbp-28]
  add DWORD PTR [rbp-4], eax
  mov eax, DWORD PTR [rbp-32]
  add DWORD PTR [rbp-4], eax
  pop rbp
  ret
Test2(int, int, int, int):
  push rbp
  mov rbp, rsp
  mov DWORD PTR [rbp-20], edi
  mov DWORD PTR [rbp-24], esi
  mov DWORD PTR [rbp-28], edx
  mov DWORD PTR [rbp-32], ecx
  mov eax, DWORD PTR [rbp-24]
  mov edx, DWORD PTR [rbp-20]
  add edx, eax
  mov eax, DWORD PTR [rbp-28]
  add edx, eax
  mov eax, DWORD PTR [rbp-32]
  add eax, edx
  mov DWORD PTR [rbp-4], eax
  pop rbp
  ret
```

Compiled code

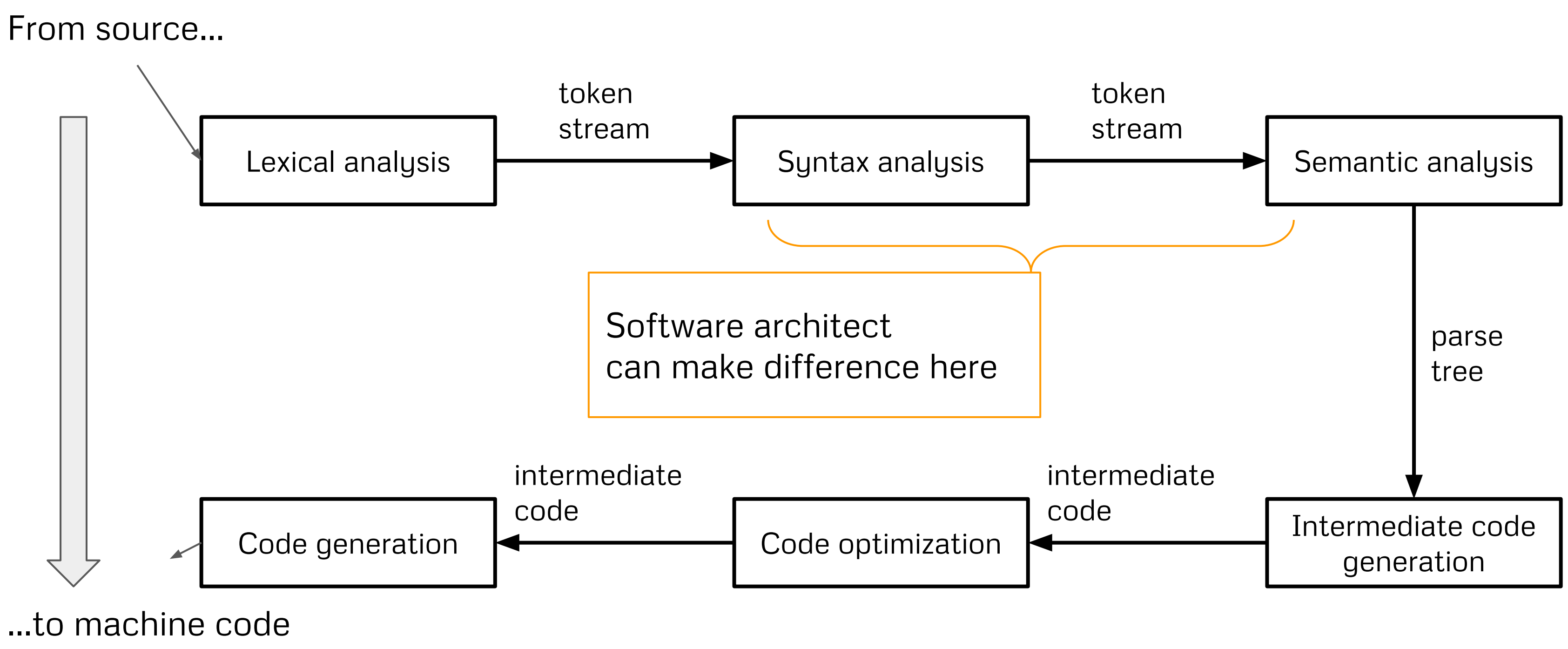
1reg

2reg

Optimized code by compiler

```
Test1(int, int, int, int):
  rep ret
Test2(int, int, int, int):
  rep ret
```

What a compiler does?



Maintaining the code

Revisit the code adopting new features provided by language evolution

```
// Sum first 1000 numbers
int sum1() {

    // set counter to 0
    int sum = 0;

    // loop 1000 numbers adding to result
    for (int i=0; i<=1000; ++i) {

        sum +=i;
    }

    // return number
    return sum;
}


// ------------------------- //


// Sum first 1000 numbers
int sum2() {

    // set last number of the sum
    int last = 1000;

    // use series sum
    int sum = last*(last + 1)/2;

    // return result

    return sum;
}
```

code

```
sum1():
  push rbp
  mov rbp, rsp
  mov DWORD PTR [rbp-4], 0
  mov DWORD PTR [rbp-8], 0
  jmp .L2
.L3:
  mov eax, DWORD PTR [rbp-8]
  add DWORD PTR [rbp-4], eax
  add DWORD PTR [rbp-8], 1
.L2:
  cmp DWORD PTR [rbp-8], 1000
  jle .L3
  mov eax, DWORD PTR [rbp-4]
  pop rbp
  ret
sum2():
  push rbp
  mov rbp, rsp
  mov DWORD PTR [rbp-4], 1000
  mov eax, DWORD PTR [rbp-4]
  add eax, 1
  imul eax, DWORD PTR [rbp-4]
  mov edx, eax
  shr edx, 31
  add eax, edx
  sar eax
  mov DWORD PTR [rbp-8], eax
  mov eax, DWORD PTR [rbp-8]
  pop rbp
  ret
```

compiled

```
sum1():
  xor edx, edx
  xor eax, eax
.L3:
  add eax, edx
  add edx, 1
  cmp edx, 1001
  jne .L3
  rep ret
sum2():
  mov eax, 500500
  ret
```

optimized C++11

```
sum1():
  mov eax, 500500
  ret
sum2():
  mov eax, 500500
  ret
```

optimized C++14

The role of human (scientist) architect

Design code ***properly*** (scalability, maintenance, extension,…)

Consider performance when ***designing code*** and ***picking algorithms***

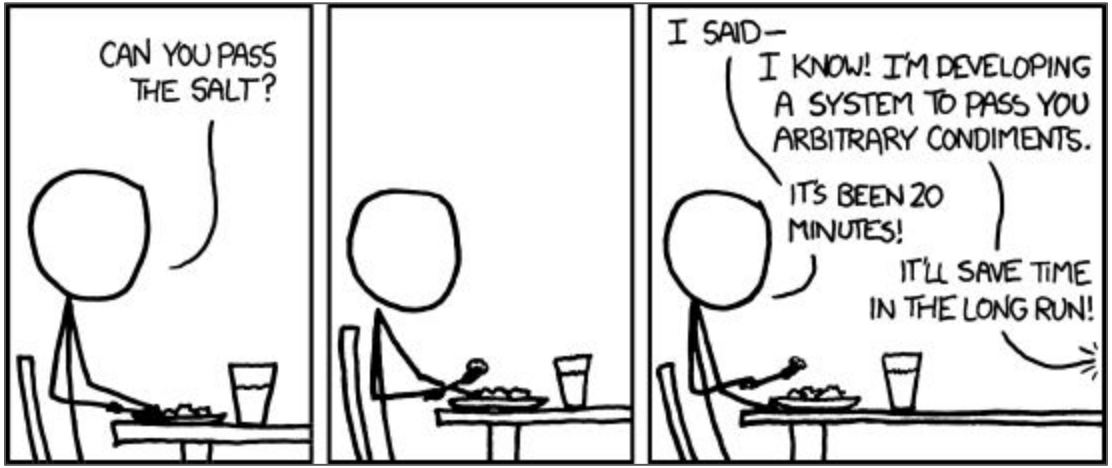
Adopt ***optimized*** features provided by language evolution

Know the **tool**: C++ is not Fortran, Python is not IDL

When optimize don't rely only on "tips&tricks"

If you use C++, trust the compiler, it contains 45 years of improvements…

Q&A



http://xkcd.com/974