A Modern Compiler for the French Tax Code

Raphaël Monat, with Denis Merigoux and Jonathan Protzenko

IRILL Seminar
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rmonat.fr


Introduction

Income Tax in France

Each year

- Tax computation by DGFiP

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Trusting the computation?

- Correct computation with respect to the law
- Reproducibility of the computation
- Accurate simulation of tax reforms

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Sample code

```
IRNETTER = max(0, IRNET2
  + (TAXASSUR + PTAXA - min(TAXASSUR+PTAXA+0,max(0,INE-IRB+AVFISCOPTER))
  - max(0,TAXASSUR + PTAXA  - min(TAXASSUR + PTAXA + 0,max(0,INE-IRB+AVFISCOPTER))+ min(0,IRNET2)))
  + (IPCAPTAXT + PPCAP - min(IPCAPTAXT + PPCAP,max(0,INE-IRB+AVFISCOPTER-TAXASSUR-PTAXA))
  - max(0,IPCAPTAXT+PPCAP -min(IPCAPTAXT+PPCAP,max(0,INE-IRB+AVFISCOPTER-TAXASSUR-PTAXA))
    + min(0,TAXANEG)))
  + (TAXLOY+PTAXLOY-min(TAXLOY+PTAXLOY,max(0,INE-IRB+AVFISCOPTER-TAXASSUR-PTAXA-IPCAPTAXT-PPCAP))
  -max(0,TAXLOY+PTAXLOY-min(TAXLOY+PTAXLOY,max(0,INE-IRB+AVFISCOPTER-TAXASSUR-PTAXA-IPCAPTAXT
    -PPCAP))+min(0,PCAPNEG)))
  + (IHAUTREVT + PHAUTREV +CHRPVIMP- max(0,IHAUTREVT+PHAUTREV +CHRPVIMP+ min(0,LOYELEVNEG))));
```

Income Tax Code

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We started our open-source compiler in March 2019.

Outline

M, the tip of the iceberg

M, briefly

The core of M: **arithmetic expressions** assigned to variables.

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- Loops indexed by characters that are substituted in variable names; unrollable
- `undef` value

Example

Variable declaration

```
IRNETBIS : calculee primrest = 0 : "IRNET avant bidouille du 8ZI" ;
8ZI : "Impot net apres depart a l'etranger (non residents)" ;
```

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```

Computation rule

```
rule 221220:
application : iliad  ;
IRNETBIS = max(0, IRNETTER -
                  PIR * positif(SEUIL_12 - IRNETTER + PIR)
                      * positif(SEUIL_12 - PIR)
                      * positif_ou_nul(IRNETTER - SEUIL_12));
```

A formal semantics for M

We reverse-engineered the semantics:

- At first, using the online simulator[1]
- Later, using the private tests DGFiP sent us (August 7, 2019)

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The `undefined` value

- Used for: default inputs, runtime errors & missing cases in inline conditionals
- Fun facts: $f + \texttt{undef} = f$, $f \div 0 = 0$, $x[|x| + 1] = \texttt{undef}$, $x[-1] = 0$...

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Test failures

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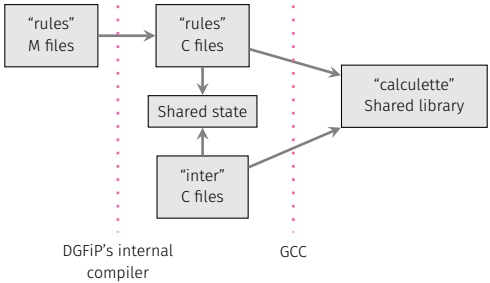
Patience is the key

Aug. 2019	Sent official technical questions to DGFiP
Jan. 2020	Meeting with DGFiP (5 levels of hierarchy involved!)
Apr. 2020	Agreement signed
Jun. 2020	First access to the unpublished sources!

Below the surface: extracting M++

DGFiP's legacy architecture

Discovered in June 2020:



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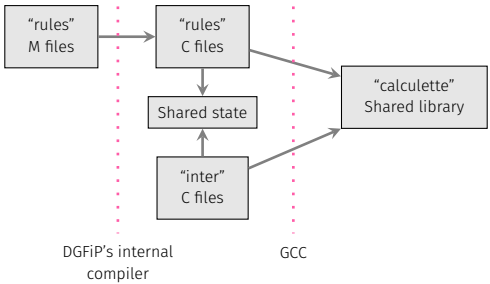

"inter" files : 35k lines of C code written to compensate M's lack of functions.

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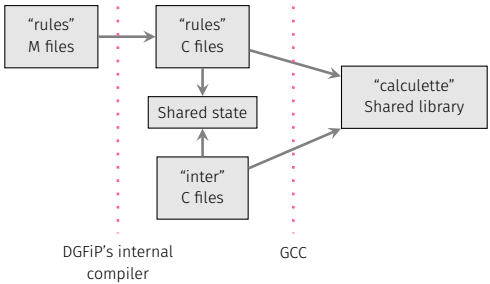

"inter" files : 35k lines of C code written to compensate M's lack of functions.

Security concerns meant no publication possible. How to extract the logic of the code, without publishing the "inter" code itself?

Introducing a new DSL: M++

Tax benefits computation in M++

```
compute_benefits():
 if exists_deposit_defined_variables() or exists_taxbenefit_ceiled_variables():
    partition with var_is_taxbenefit:
      V_INDTEO = 1
      V_CALCUL_NAPS = 1
      NAPSANSPENA, IAD11, INE, IRE, PREM8_11 <- call_m()
      V_CALCUL_NAPS = 0
      iad11 = cast(IAD11)
      ire = cast(IRE)
      ine = cast(INE)
      prem = cast(PREM8_11)
      PREM8_11 = prem
    V_IAD11TEO = iad11
    V_IRETEO = ire
    V_INETEO = ine
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      iad11 = cast(IAD11)
      ire = cast(IRE)
      ine = cast(INE)
      prem = cast(PREM8_11)
      PREM8_11 = prem
    V_IAD11TEO = iad11
    V_IRETEO = ire
    V_INETEO = ine
```

- High-level, no mutable state under the hood
- Tailored for the needs of the “inter” files and DGFiP devs
- 6,000 lines of “inter” C code $\Rightarrow$ 100 lines of M++

MLANG, a compiler for the French Tax Code

MLANG's architecture

MLANG: written in OCaml, 10k lines of code

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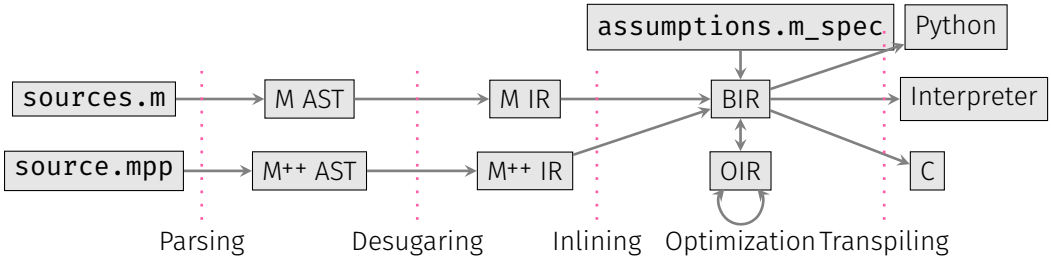


MLANG's correctness

How to check that MLANG is correct?

476 tests from DGFiP

- private
- quality?

Let's generate our own tests

- Randomized tests
- Fuzzer-based tests

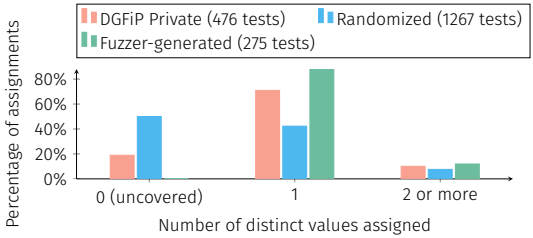
Measuring tests quality

Instrument the interpreter to measure coverage

Mlang's correctness

It works (precise down to the euro)!

- All backends validated
- On DGFiP's tests for 2018 and 2019 and our tests



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Compiler optimizations

- Global value numbering
- Dead code elimination
- Partial evaluation
- Dataflow defined-ness analysis

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Spec. name	# inputs	# outputs	# instructions	% reduction
All	2,459	10,411	129,683	80.2%
Selected outs	2,459	11	99,922	84.8%
Tests	1,635	646	111,839	83.0%
Simplified	228	11	4,172	99.4%
Basic	3	1	553	99.9%

# of instructions with optimizations disabled (2018 code): 656,020.

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M compiler	no	MLANG
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⇒ Income tax computation now reproducible outside DGFiP!

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From research to production

DGFiP is moving to MLANG. Transition started in June 2021.

Looking ahead

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- Semantic analyses of the income tax code
- A success story, encouraging further opening of critical “state software”
- Deriving correct-by-construction implementations from the law

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Technical paper at Compiler Construction 2021.
Thanks to DGFiP and in particular bureau SI-1E for the collaboration!

Looking ahead: Catala

How to maintain the implementation of the law?

- The structure of the law is lost during the translation.
- Law texts are complicated, and have a specific structure.
- High number of changes in some cases (tax code).

Catala[2] to the rescue

- Literate programming
- Relies on default logic
- Fosters cooperation between lawyers and developpers
- Formal semantics

[2] Merigoux, Chataing, and Protzenko. "Catala: a programming language for the law". ICFP 2021.

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Questions

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