Language Design for Everyone

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Programming Languages (PLs)

As the theory and practice of PL advances:

New PLs:

TypeScript (Microsoft), Hack (Facebook), Go (Google), Dart (Google), Swift (Apple), Rust (Mozilla), Julia, Elixir, and so on.

New Domain-specific Languages (DSLs):

Halide. MIT (with help from Stanford, Google, Adobe.) for GPU
Turi. (formerly GraphLab) CMU/UoW acquired by Apple, for ML
GraphIt for Graph analytics.
and so on

This Talk: Some of My Work on

Empowering people to quickly deploy their own programming languages and domain-specific languages

Flexibility:

- **Lang-n-play**
- **Lang-n-change**
- **Lang-n-send**

Safety:

- **Lang-n-check**
- **Lang-SQL (or Lang-n-query)**
- **Lang-n-prove**

Lang-n-play
(Languages as first-class)

C-like array access a[10] **access anything, unsafe**
Java-like array access a[10] **checks length, safe**

```
addCArrays(Language lan):
   return lan + { evaluator of C-like _[_] }
addJavaArrays(Language lan):
   return lan + { evaluator of Java-like _[_] }

mylan := {syntax + evaluator }
if trustworthy(code):
    then addCArrays(mylan) exec code
    else addJavaArrays(mylan) exec code
```


Matteo Cimini. *A Calculus for Multi-language Operational Semantics.* **VSTTE 2021.**
Matteo Cimini. *On the Effectiveness of Higher-Order Logic Programming in Language-Oriented Programming.* **FLOPS 2020.**
Matteo Cimini. *Languages as First-Class Citizens (Vision Paper).* **SLE 2018.**

Lang-n-send
(Processes that send languages)

Server of language definitions

request
array operations

send syntax + semantics
of array operations

client

defines *mylan*
defines *code*

Server: replicate[send(arraysLan)]
  parallelWith
Client: receive(Server,*arrays*) ->
  (*mylan + arrays)* exec *code*

M. Cimini. *Lang-n-Send: Processes That Send Languages*. ICE 2022.
M. Cimini. *Lang-n-Send Extended: Sending Regular Expressions to Monitors*. PLACES 2022.

Lang-n-change
(Compiling languages to languages)

```
f(float x) { truncate(x) }
int x := 3;
f(x);
```

without subtyping: reject
with subtyping: accept

```
type_check(part_of_prg):
  if part_of_prg is function type var body arg
  if type == type_check(arg) then accept
  else reject
```

must become

```
type_check_with_subtype(part_of_prg):
  if part_of_prg is function type var body arg
  type2 := type_check_with_subtype(arg)
  if subtype(type2, type) then accept
  else reject
```

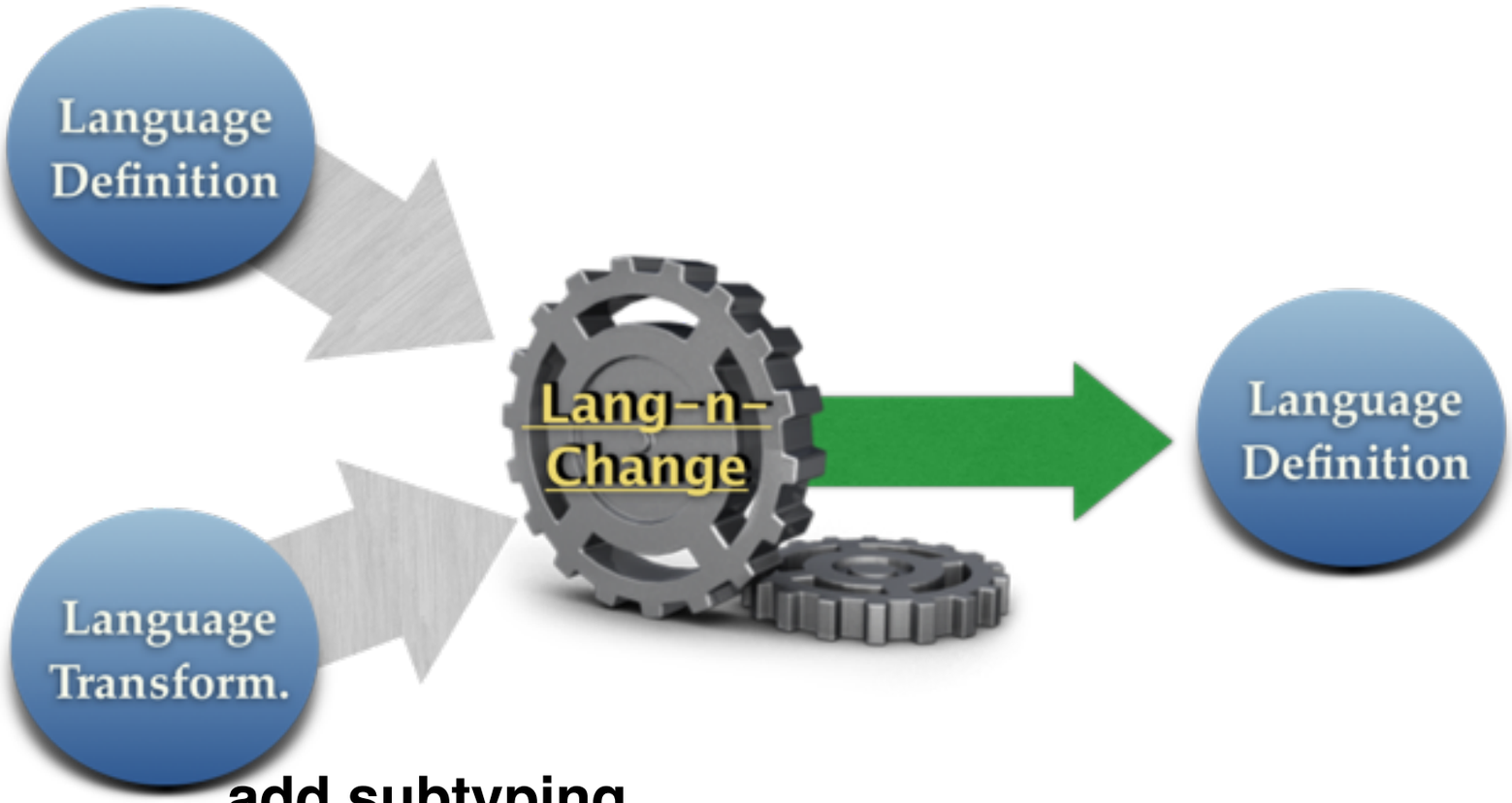
Lang-n-change
(Compiling languages to languages)

Lang-n-change can express:

```
retrieve type_checker,
compile ‘type1 == type2’ into:
     ‘newVar1 := type1;
      newVar2 := type2;
      if subtype(newVar1, newVar2) then accept
         else reject’
```


Matteo Cimini, Benjamin Mourad.
Language Transformations in the Classroom. **EXPRESS/SOS 2021.**
Benjamin Mourad, Matteo Cimini.
A Declarative Gradualizer with Language Transformations. **IFL 2020.**
Benjamin Mourad, Matteo Cimini. *System Description: Lang-n-Change - A Tool for Transforming Languages.* **FLOPS 2020.**
Benjamin Mourad, M. Cimini. *A Calculus for Language Transformations.* **SOFSEM 2020.**

Lang-n-change
(Compiling languages to languages)



add subtyping
add object-oriented programming
add pattern-matching
…

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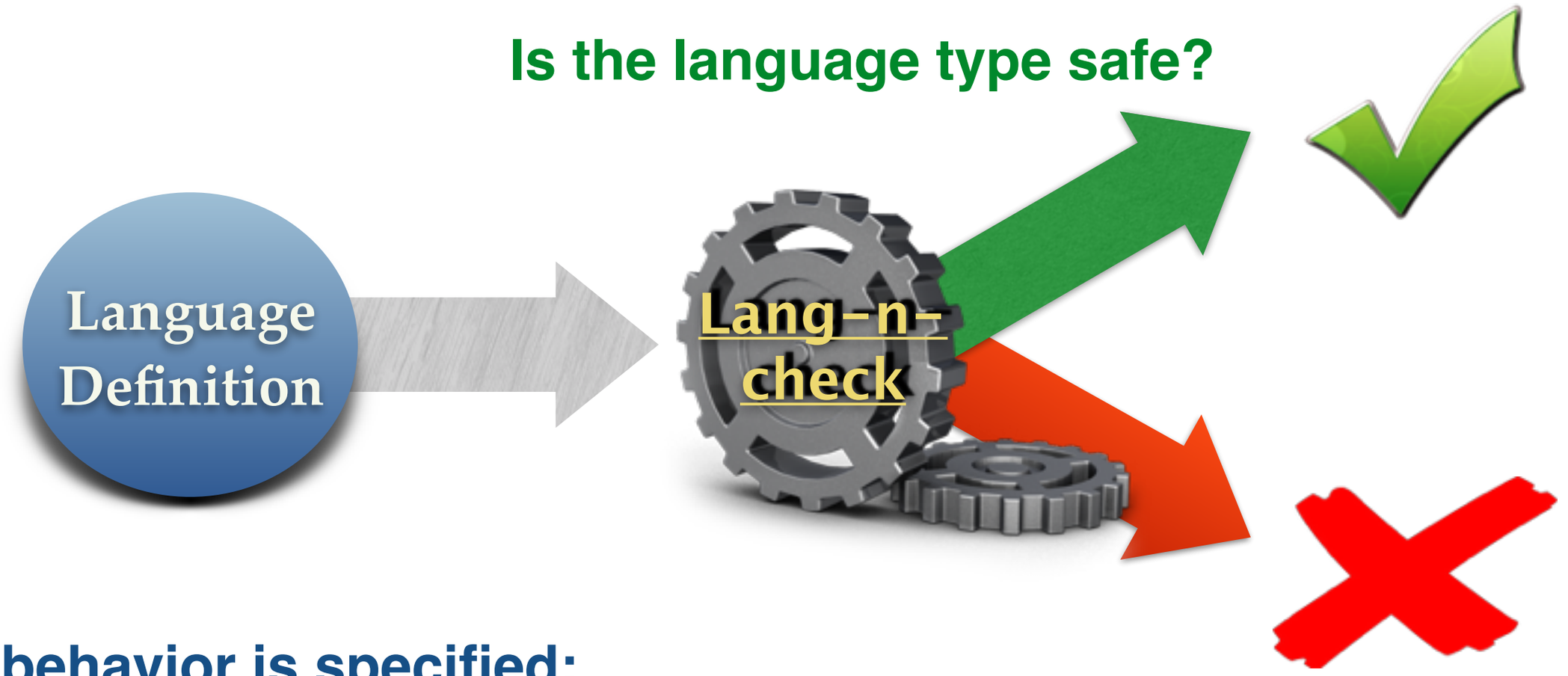
Safety: Lang-n-check
(A type checker for language definitions)



all behavior is specified:
  reject if eval(n div 0) is not specified
all behavior is consistent:
  reject int_to_string(4/2) ==> int_to_string(4) / int_to_string(2)

Matteo Cimini, Dale Miller, Jeremy G. Siek.
Extrinsically Typed Operational Semantics for Functional Languages. **SLE 2022.**
Matteo Cimini. *Early Experience in Teaching the Basics of Functional Language Design with a Language Type Checker.* **TFP 2019.**

Language Testing

small questions { **what constructors bind names?**
what polymorphism?
what are the canonical forms?
…

canonical forms

`value`	`type`
true	*bool*
false	*bool*
function	*arrow*
$[a_1, \ldots, a_n]$	*list*

helpful for debugging

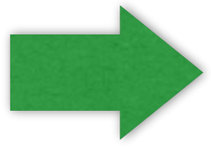
Lang-SQL
(A query language for querying languages)

"*Interrogating languages should be akin to interrogating databases*"

- **languages-as-databases.** *Stores languages as database tables.*
- **Lang-SQL**, *tailored for interrogating languages*

canonical forms

```
SELECT GET-OPNAME(term) AS value,
       GET-OPNAME(EXPRESSION(args)) AS type
FROM Value, rule
WHERE predname = type_check AND role = CONCL
AND GET-OPNAME(term) = GET-OPNAME(OUTPUT-TYPE(args)))
```



value	type
true	*bool*
false	*bool*
fun	*arrow*
[...]	*list*

Matteo Cimini. *Testing Languages with a Languages-as-Databases Approach.* **TAP 2023.**
Matteo Cimini. *A Declarative Validator for GSOS Languages.* **PLACES 2023.**
Matteo Cimini. *A Query Language for Language Analysis.* **SEFM 2022.**

Lang-n-prove: a proof language for language proofs

1. `Theorem` *progress* : $\forall e, T.\ Main : \vdash\ e : T \Rightarrow e\ is\ a\ result\ \vee \exists e'.e \longrightarrow e'$.
2. `Proof`
3. *induction on Main.*
4. *apply inductive hypothesis on the typing of the arg. (e of* (`head` e) *and* (`fst` e)*).*
5. *case analysis on the progress of that argument.*

(a) `head` e

6. *apply canonical-form-list.*
7. *appeal to existence of a rule for nil.*
8. *appeal to existence of a rule for cons*
9. *proof continues.*

(b) `fst` e

6. *apply canonical-form-×. (product)*
7. *appeal to existence of a rule for* $\langle v, v \rangle$.
8. *proof continues.*

Lang-n-prove can express:

```
if e handles type t then
   apply canonical-form_t.
   for each v in valuesOf(t): QED “rule exists”.
```


Matteo Cimini.
Towards the Complexity Analysis of Programming Language Proof Methods. **ICTAC 2023.**
Matteo Cimini. *Lang-n-Prove: A DSL for Language Proofs.* **SLE 2022.**

Thankful to NSF for grant *Language-agnostic proofs.* **PI: Matteo Cimini.**

Conclusion: Some of My Work on

Empowering people to quickly deploy their own programming languages and domain-specific languages

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Thank you!