Backward Type Inference

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Background

The Ptolemy II Type System is similar to HM(X): Hindley-Milner over a constraint system.

Characteristics

Static typing, dynamic checking, type inference, subtyping, automatic type conversion, polymorphism, structured types

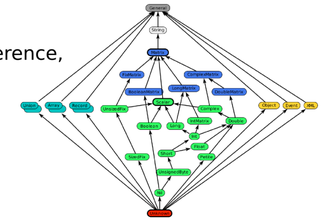


Figure 1: The PTII type lattice

(Forward) Type Inference

- Actors have typed ports
- Types are inferred for ports that are left typed unknown
- Type inference is driven by type constraints that are imposed to guarantee that tokens are (forward-)compatible with i.e., lossless convertible to the types of their respective downstream destinations
- Roughly, this means that between actors $\tau_{output} \leq \tau_{input}$, and within actors: $\tau_{input} \leq \tau_{output}$, where all types are ordered in a lattice.
- Prior to execution, all type constraints are harvested from the model, and a linear time [Rehof and Mogensen1999] constraint solving algorithm is run to find a least fixed point that satisfies all constraints
- The solution is accepted if all constraints are satisfied and no types are left unknown

Modifications

We leverage type inference to statically type dynamic data and leverage dynamic type checking to invoke error handling strategies that enhance robustness.

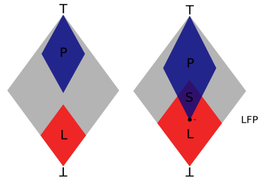


*Figure 2: we find a solution in area **S**, slightly higher than the original least fixed point.*

Additional type constraints

- Backward constraint between actors: $GLB(\tau_{outputSinks}) \leq \tau_{output}$
- Backward constraint within actors: $GLB(\tau_{outputs}) \leq \tau_{input}$ *(simplified)*
- Sinks actors: Input as general as possible

Implementation

- **Toggle backward type inference per composite actor**
- **No impact on run-time of type resolution**
- **Type errors trapped at the source**
- **Suitable as activation mechanism for custom error handling**

Problem

We want to build Ptolemy models that use online data, but such data is typically unreliable, subject to change, and most importantly, untyped.

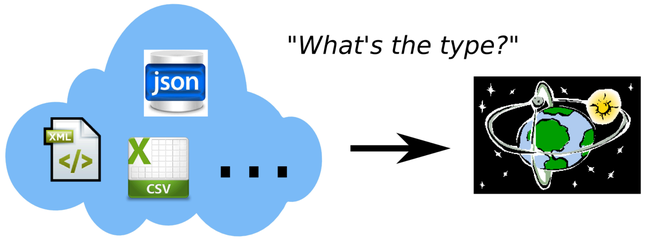
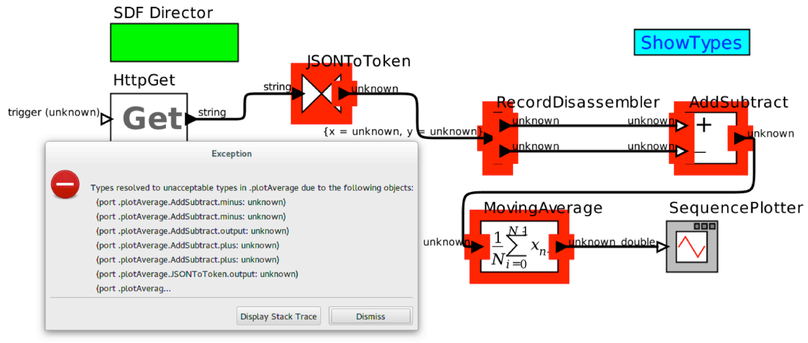


Figure 3: A Ptolemy model requires each port of every actor to be typed prior to execution, or otherwise, a type error is thrown. When an actor parses untyped data, the type of its output cannot be inferred.



Example 1: The JSONToToken actor, by nature of what it does, cannot provide any specific information about its output.

Solution

Enable backward type inference.

The types for otherwise under-determined outputs are backward inferred based on type constraints imposed by downstream actors.

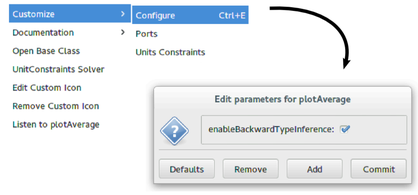
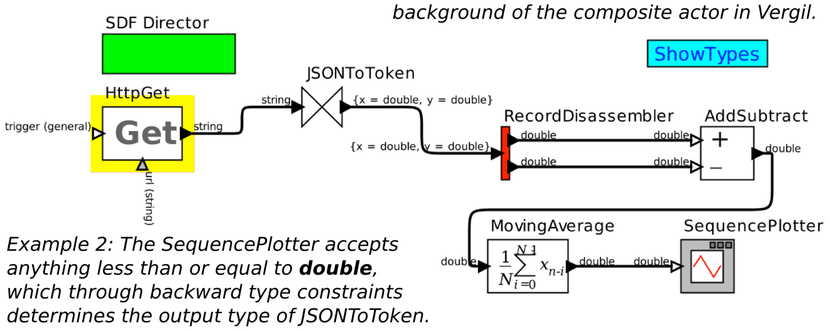


Figure 4: Dialog after right-clicking on the background of the composite actor in Vergil.

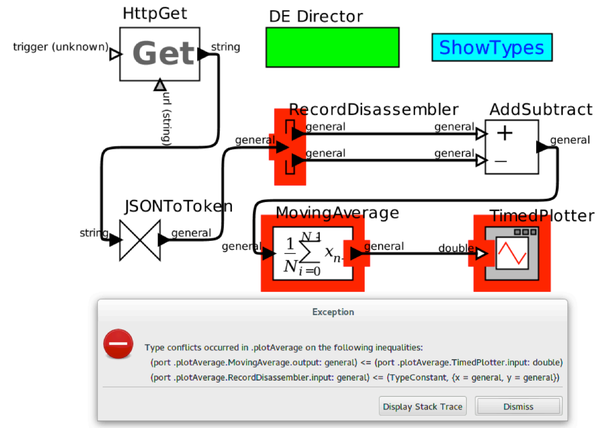


*Example 2: The SequencePlotter accepts anything less than or equal to **double**, which through backward type constraints determines the output type of JSONToToken.*

Goals

Maximally Permissive Composition

- Infer types that are specific enough **not to limit composability** yet general enough **not to impose unnecessary constraints**.



*Example 3: Declaring JSONToToken.output = **general** imposes no constraints on the parsed input, but limits the composability with downstream actors.*

Robustness

- Let type safe operation of actors be guaranteed by the run-time type checker.
- Do error handling at the sender's side to allow fall-back modes to kick in before the model comes to a grinding halt.

Convenience

- Automatically infer types to unburden the user. / programmer

Future

Ptolemy models that use web resources are still rather brittle; absence of an appropriate response to a request for remote data will raise a run-time type error, which brings execution to a halt.

By defining alternative error handling strategies, we can make models more robust, possibilities are:

- Retry
- Try another resource
- Resend a previous value
- Output a nil token
- Output no token at all

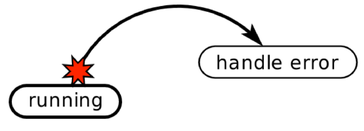


Figure 5: An error transition.