# GL: Symbolic Simulation in the ACL2 Logic

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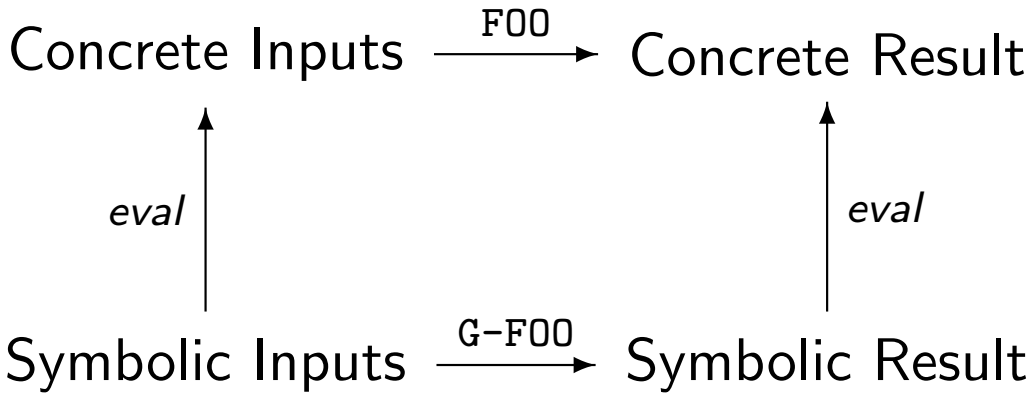
# What is GL?

- GL is "G in the Logic" – a verified rewrite of Bob and Warren's G system.
- GL is a utility for proving theorems by symbolic execution.
- Similar to proof by exhaustive testing, but one symbolic execution can replace $n$ concrete tests.
  - Often for very large $n$!

# Introduction to GL

GL allows symbolic execution of ACL2 functions.

- Code transform produces a new function `G-FOO` from a given function `FOO`
- Run `G-FOO` on *symbolic inputs* to produce *symbolic outputs*
- The symbolic outputs produced by `G-FOO` represent the value of `FOO` on all concrete inputs represented by the supplied symbolic inputs.



# Symbolic Values

- Symbolic values are objects that represent functions.
  - GL uses BDDs to represent Boolean-valued functions of Booleans, and wraps these in structured objects to produce arbitrary-valued functions of Booleans.
  - An evaluator gives the value of this function on a set of Boolean inputs.
- Example (with $v_0, v_1$ BDD variables):

  `(:G-ITE (:G-BOOLEAN . `$v_0$`) FOO . (:G-BOOLEAN . `$v_1$`))`

  represents this function:

$$f(v_0, v_1) = \begin{cases} \texttt{FOO} & \text{if } v_0 = \texttt{T} \\ \texttt{T} & \text{if } v_0 = \texttt{NIL} \text{ and } v_1 = \texttt{T}, \\ \texttt{NIL} & \text{if } v_0 = v_1 = \texttt{NIL}. \end{cases}$$

- Exercise: What is `G-BOOLEANP` of the above object?

# DEMO: Symbolic objects and evaluation

# Symbolic Functions

- Symbolic versions of ACL2 primitives are defined and proven correct manually.
- Symbolic versions of user functions can be created with the `MAKE-G-WORLD` event.
  - Produces symbolic analogues and correctness lemmas for a set of functions.
- Each symbolic function takes arguments corresponding to the original function's formals, plus two extra:
  - *hyp* - a BDD describing a working assumption for the simulation. Typically use `T` at the top level.
  - *clk* - a natural number which is decreased on recursive calls. When it reaches 0, symbolic functions will produce `G-APPLY` objects instead of simulating further. Use something sufficiently large.

# DEMO: Symbolic functions

# Proofs using GL

General strategy:

- Design symbolic objects that cover all inputs that satisfy the hyps
- Produce the symbolic analogue of the conclusion
- Show that running it on the symbolic inputs always yields T.
- Use the correctness lemma of the symbolic analogue to complete the proof.
- Automated in `DEF-G-THM`, `DEF-G-PARAM-THM`.

# DEMO: Proofs

# Implementation

- Hand-defined primitives
- `MAKE-G-WORLD`:
  - Define new evaluator
  - "Factor" functions
  - Generate symbolic analogues
  - Prove return types and guards
  - Prove correctness theorems
- Automation necessities
  - Restricted theories
  - Specialized clause processors orchestrated by computed hints