Let all variables be integer. Add recursive time. Any way you can, find a fixed-point of

(a) \[ \text{walk} \; = \; \text{if } i \geq 0 \; \text{then } i := i - 2. \; \text{walk.} \; i := i + 1. \text{ walk.} \; i := i + 1 \text{ else } \text{ok fi} \]

Putting \( t := t + 1 \) before just the first call of \text{walk} is enough, though we could put it before both calls. If the \( \equiv \) had been \( \iff \), we could prove \( i' = i \land t' \leq t + 2^i \). Proof by cases:

\[
i \geq 0 \land (i := i - 2. \; i' = i \land t' \leq t + 2^i. \; i := i + 1. \; i' = i \land t' \leq t + 2^i. \; i := i + 1)
\]

(b) \[ \text{crawl} \; = \; \text{if } i \geq 0 \; \text{then } i := i - 1. \; \text{crawl.} \; i := i + 2. \text{ crawl.} \; i := i - 1 \text{ else } \text{ok fi} \]

Putting \( t := t + 1 \) before just the first call of \text{crawl} is enough, though we could put it before both calls. Here are two answers.

\[
\text{if } i \geq 0 \; \text{then } t' = \infty \text{ else ok fi}
\]

\[
\text{if } i \geq 0 \; \text{then } t := \infty \text{ else ok fi}
\]

I'll check the second one.

\[
\text{if } i \geq 0 \; \text{then } i := i - 1. \; t := t + 1. \; \text{if } i \geq 0 \; \text{then } t := \infty \text{ else ok fi.}
\]

\[
i := i + 2. \; \text{if } i \geq 0 \; \text{then } t := \infty \text{ else ok fi.}
\]

\[
i := i - 1
\]

\[
\text{else ok fi}
\]

\[
\text{if } i \geq 0 \; \text{then } t := \infty \text{ else ok fi}
\]

So it's a fixed-point.

(c) \[ \text{run} \; = \; \text{if even } i \; \text{then } i := i / 2 \text{ else } i := i + 1 \text{ fi.} \]

\[
\text{if } i = 1 \; \text{then } \text{ok else run fi}
\]

Without adding time, \( i' = 1 \) and \( i \geq 1 \Rightarrow i' = 1 \) are fixed-points. With time, it's difficult to say a fixed-point since it requires saying the exact execution time. If we had an implication instead of an equation, we could get away with a time bound. Recursive construction just leads to a mess, and isn't helpful. To state the exact execution time, define

\[
f = \langle i: \text{int} \rightarrow \text{if } i = 2 \; \text{then } 0 \text{ else if even } i \; \text{then } 1 + f(i / 2) \text{ else } 1 + f(i + 1) \text{ fi fi} \rangle
\]

Now we can find the following two fixed-points:

\[
i' = 1 \land t' = t + f
\]

\[
(i \geq 1 \Rightarrow i' = 1) \land t' = t + f
\]

although \( f \) seems like an unfair trick.