Errata for Theories of Programming Languages

The following are corrections of the errors and obscurities in "Theories of Programming Languages" that I am currently aware of. Thanks go to

Alexander Garthwaite, Sun Labs
Kaustuv Chaudhuri, Carnegie Mellon University
David Swasey, Carnegie Mellon University
Krimo Nimour, Schlumberger
Fred Hosch, University of New Orleans
Noah Torp-Smith, IT University, Copenhagen
Mauro J. Jaskelioff, Universidad Nacional de Rosario, Argentina
Scott Stoller, Stony Brook University

and especially

Sunning Go, University of Waterloo

for their careful reading and conscientious reporting. (They are not to blame, however, if my corrections are unclear or still erroneous.)

- Page ix, line 3. "collection my favorites" should be "'collection of my favorites".
- Page 11, line 16 to 17. " '+' in terms of '+', and so forth" should be " '+' in terms of '+', '∀' in terms of '∀', and so forth".
- Page 22, line 3 of Exercise 1.3. "0, 1, negate, 0" should be "0, 1, negate, 2".
- Page 23, line 4 of Exercise 1.6. "with the same meaning as" should be "which is defined to have the same meaning as".
- Page 31, lines 3 to 5. The sentence here should be "One can think of such a chain as a (possibly jerky) succession of snapshots of the output at increasing times, and the limit as the ultimate total result."
- Page 31, last line. "two domain elements" should be "two predomain elements".

- Page 33, line 6 from bottom. "By the property of least upper bounds of least upper bounds ..." should be "By the property of least upper bounds of sets of least upper bounds ...".
- Page 34, first line of Proposition 2.3. "Suppose P, P', P'', Q, and Q' are predomains" should be "Suppose P, P', and P'' are predomains."
- Page 36, last line. $w_i + 1$ should be w_{i+1} and w_n should be w_i.
- Page 37, line 6. "at least" should be "more than".
- Page 49, line 9 - "semantics function" should be "semantic function".
- Page 50, lines 6 to 21 - Should be:

  remains fully abstract. For suppose $[\![c]\!]_{\mathrm{comm}} \neq [\![c']\!]_{\mathrm{comm}}$. Then there is a state σ such that $[\![c]\!]_{\mathrm{comm}}\sigma \neq [\![c']\!]_{\mathrm{comm}}\sigma$. If one of the commands c and c' does not terminate when starting in σ, then the same is true of the closed commands $C[c]$ and $C[c']$, where

  $$C \stackrel{\mathrm{def}}{=} \mathbf{newvar}\ v_0 := \kappa_0\ \mathbf{in}\ \cdots \mathbf{newvar}\ v_{n-1} := \kappa_{n-1}\ \mathbf{in}\ -.$$

  is a context initializing each variable v_i, that occurs free in either c or c', to a constant $\kappa_i = \sigma v_i$ whose value is the same as the value of v_i in σ.

  On the other hand, if both c and c' terminate when starting in σ, then there is a free variable v_k and a value κ such that $[\![c]\!]_{\mathrm{comm}}\sigma v_k = \kappa \neq [\![c']\!]_{\mathrm{comm}}\sigma v_k$. In this case, let D be the context

  $$\begin{aligned} D \stackrel{\mathrm{def}}{=} {} & \mathbf{newvar}\ v_0 := \kappa_0\ \mathbf{in}\ \cdots \mathbf{newvar}\ v_{n-1} := \kappa_{n-1}\ \mathbf{in} \\ & (- \,;\, \mathbf{if}\ v_k = \kappa\ \mathbf{then\ skip\ else\ while\ true\ do\ skip}). \end{aligned}$$

  Then $D[c]$ is a closed command that terminates, while $D[c']$ is a closed command that does not terminate. n

- Page 59, rules (SP) and (WC). The metavariable s should be c.
- Page 61, line 7 (labelled "$2n$"). p_1 should be p_0.
- Page 66, line 14. "to expand w_{n-2}" should be "to expand w_{n+2}".
- Page 66, line 15. "$[\![c]\!]_{\mathrm{comm}}$ is a state" should be "$[\![c]\!]_{\mathrm{comm}}\sigma$ is a state".
- Page 72, line 6 from bottom. *idy* should be y.
- Page 76, line 16. "unwieldly" should be "unwieldy".
- Page 86, line 3. Both occurrences of $\forall i$ should be $\forall \mathsf{i}$.
- Page 102, line 11-10 from bottom. "ith components" should be "an ith component".
- Page 109, first display.

  $$P_0 \times \cdots \times P_{n-1} = \{\, \langle x_0, \ldots, x_{n-1} \rangle \mid x_0 \in P_0 \text{ and } \cdots \text{ and } \mathrm{x_{n-1} \in P_{n-1}} \,\}$$

should be

$$P_0 \times \cdots \times P_{n-1} = \{\, \langle x_0, \ldots, x_{n-1} \rangle \mid x_0 \in P_0 \text{ and } \cdots \text{ and } x_{n-1} \in P_{n-1} \,\}$$

- Page 112, line 8 from bottom. "Although we will repeated rely on this fact" should be "Although we will repeatedly rely on this fact".
- Page 136, line 5 from bottom. "the the union" should be "the union".
- Page 137, line 6 (not counting the section heading). "will given" should be "will be given".
- Page 156, line 11 from bottom. "When c_0 and c_1 do not interfere" should be "When c_0 and c_1 are determinate commands that do not interfere".
- Page 167, first line of second display.

$$\text{“}\sum_{i=0}^{n-1} \#\,\mathrm{dom}\,\alpha_i\text{” should be “}\left(\sum_{i=0}^{n-1} \#\,\mathrm{dom}\,\alpha_i\right) - 1\text{”.}$$

- Page 167, second line of second display.

$$\text{“}\sum_{i=0}^{\infty} \#\,\mathrm{dom}\,\alpha_i\text{” should be “}\left(\sum_{i=0}^{\infty} \#\,\mathrm{dom}\,\alpha_i\right) - 1\text{”.}$$

- Page 200, line 19. "of of" should be "of".
- Page 202, second rule from bottom. "Canonical Forms" should be "Canonical Forms (termination)".
- Page 204, line 8 from bottom. Insert paragraph after end of proof:

  (In the above proof, we have neglected the possible use of the TR RULE for renaming that is given in the definition of $\to$ in Section 10.2. If renaming is permitted, or the choice of v_{new} in the definition of substitution is not defined unambiguously, then Proposition 10.6 will hold only if renamed expressions are regarded as identical.)

- Page 230, line 14.

$$\text{“and } v_0, \ldots\ v_{n-1} \notin \{u_0, \ldots, u_{n-1}\}\text{”}$$

  should be

$$\text{“and } v_0, \ldots, v_{n-1} \notin \{u_0, \ldots, u_{n-1}\}, \text{ and no } u_i \text{ occurs free in any } \lambda u_j.\ e_j\text{”.}$$

- Page 230, line 14. "The restriction on the v_i" should be "These restrictions".
- Page 246–247, Exercise 11.4. There is a nasty problem here that was brought to my attention by Scott Stoller: It is impossible to give a workable definition of the free variable occurrences of an **open** expression.

Consider, for example,

$$\begin{aligned}&\mathbf{let}\ \mathsf{x} \equiv 100\ \mathbf{in}\\ &\qquad \mathbf{let}\ \mathsf{y} \equiv \cdots\ \mathbf{in\ open}\ \mathsf{y}\ \mathbf{in}\ \mathsf{x},\end{aligned}$$

where $\cdots$ is some closed expression. From the semantics of **let** expressions, we know that this display has the same meaning as the result of substituting 100 for the free occurrences of x in the second line, which are just the free occurrences of x in **open** y **in** x — for which the only possibility is the final occurrence of x. If this occurrence is free, the above display has the same meaning as

$$\mathbf{let}\ \mathsf{y} \equiv \cdots\ \mathbf{in\ open}\ \mathsf{y}\ \mathbf{in}\ 100,$$

which is clearly wrong when $\cdots$ is, say, $\langle \mathsf{x} \equiv 10\rangle$. On the other hand, if the final occurrence is not free, the display has the same meaning as

$$\mathbf{let}\ \mathsf{y} \equiv \cdots\ \mathbf{in\ open}\ \mathsf{y}\ \mathbf{in}\ \mathsf{x},$$

which is not a sensible closed expression when $\cdots$ is a named tuple not containing the tag x.

The same problem arises with Exercise 12.2 on page 271. It does not arise for Exercise 16.5 on page 378, since there one can define the free variable occurrences of **open** e **in** e' to be the free variable occurrences in e, plus the free occurrences in e' of variables that are not tags in the *type* of e.

- Page 261, line 6. "$i + i'$" should be "$i \div i'$".
- Page 267, line 12. "$i + i'$" should be "$i \div i'$".
- Page 268, line 4 from bottom. "fo η" should be "fo $e'\ \eta$".
- Page 271, Exercise 12.2. See remarks on Exercise 11.4 on pages 246–247.
- Page 277, rule named "Reference Evaluation". This rule should be qualified by the condition "when $r \in \operatorname{dom} \sigma_1$".
- Page 278, line 13 from bottom. "are are similar" should be "are similar".
- Page 287, last line. The display should end with a comma rather than a period. After the display, there should be be a line of text: "where k is distinct from v and does not occur in e or e'."
- Page 289, line 17. $x =_{\mathrm{ref}} y$ should be $x =_{\mathrm{ref}} v$.
- Page 302, line 14 (not counting the section heading).

$$\mathsf{reduce}\,(\lambda \mathsf{i}.\ \lambda \mathsf{z}.\ \mathbf{if}\ \mathsf{p\ i}\ \mathbf{then}\ \mathsf{f\ i}\ \mathbf{else}\ \mathsf{z})\ \mathsf{e}$$

should be

$$\mathsf{reduce}\,\mathsf{x}\,(\lambda \mathsf{i}.\ \lambda \mathsf{z}.\ \mathbf{if}\ \mathsf{p\ i}\ \mathbf{then}\ \mathsf{f\ i}\ \mathbf{else}\ \mathsf{z})\ \mathsf{e}.$$

- Page 302, line 2 from bottom. "$\mathsf{find}\,(\mathsf{k}-1)\,\mathsf{e}$" should be "$\mathsf{find}\,(\mathsf{k}-1)\,\mathsf{r}\,\mathsf{e}$".
- Page 303, line 2. "$\mathsf{find}\,\mathsf{k}\,\mathsf{e}$" should be "$\mathsf{find}\,\mathsf{k}\,\mathsf{x}\,\mathsf{e}$".
- Page 316, line 14. "Our exposition will be limited" should be "Most of our exposition will be limited".
- Page 326, line 9 from bottom. "**if** $\mathsf{n} = 0$ **then** 0" should be "**if** $\mathsf{n} = 0$ **then** 1".
- Page 337, line 4. "giving" should be "given".
- Page 338, line 11 from bottom. "phases" should be "phrases".
- Page 351, after second display. Add the text: "(In a similar way, the type constructor **cont** θ would be antimonotone in its argument θ. However, we will not consider continuations further in our discussion of type systems.)"
- Page 355, line 3 from bottom. After the displayed proof, add the text "(Here (16.27) and (16.28) are rules for addition and division that will be given in Section 16.5.)".
- Page 359, line 2 from bottom. Before "Only the definition" add "In addition, we drop the condition $x \neq \text{tyerr}$ and $x' \neq \text{tyerr}$ in the definition for products."
- Page 360, line labeled (d′) and next line. Delete "$x \neq \text{tyerr}$ and $x' \neq \text{tyerr}$ and".
- Page 360, lines 11 and 10 from bottom. "all values belong to the set denoted by **ns**, and all values are equivalent for this type" should be "all values belong to the set denoted by **ns** — or its supertypes $\theta \to \mathbf{ns}$ and $\mathbf{prod}(\iota{:}\,\mathbf{ns})$ — and all values are equivalent for these types."
- Page 365, line 7 from bottom.

$$\mathcal{D}(\mathbf{bool}) = \mathbf{B} \qquad \mathcal{D}(\mathbf{nat}) = \mathbf{N} \qquad \mathcal{D}(\mathbf{int}) = \mathbf{Z} \qquad \mathcal{D}(\mathbf{real}) = \mathbf{R}.$$

  should be

$$\mathcal{D}(\mathbf{bool}) = \mathbf{B}_\perp \qquad \mathcal{D}(\mathbf{nat}) = \mathbf{N}_\perp \qquad \mathcal{D}(\mathbf{int}) = \mathbf{Z}_\perp \qquad \mathcal{D}(\mathbf{real}) = \mathbf{R}_\perp.$$

- Page 366, line 10. "$\lambda\langle k, z\rangle$" should be "$\lambda\langle \iota, z\rangle$".
- Page 367, line 7. This equation should be

$$[\![\mathbf{bool} \le \mathbf{nat}]\!] = (\lambda b \in \mathbf{B}.\ \mathbf{if}\ b\ \mathbf{then}\ 1\ \mathbf{else}\ 0)_\perp$$

- Page 367, above upper arrow in diagram. "$\theta'_1 \to \theta'_2$" should be "$\theta'_0 \to \theta'_1$".
- Page 367, line 12 from bottom. "$\theta'_1 \to \theta'_2$" should be "$\theta'_0 \to \theta'_1$".
- Page 367, line 6 from bottom. "$\iota_{k_{n-1}}{:}\,[\![\theta_{k_{n-1}} \le \theta'_{k_{n-1}}]\!](t(\iota_{k_{n-1}}))$" should be "$\iota_{k_{m-1}}{:}\,[\![\theta_{k_{m-1}} \le \theta'_{k_{m-1}}]\!](t(\iota_{k_{m-1}}))$".
- Page 378, Exercise 16.5. See remarks on Exercise 11.4 on pages 246–247.
- Page 391, in Proposition 17.2. "$[\![\delta\tau]\!]\xi' = \xi\,\tau$" should be "$\mathcal{P}(\delta\tau)\xi' = \xi\,\tau$".

- Page 395, line 2 of Exercise 17.1. "three" should be "four".
- Page 412, line 6. "$\mathsf{make}\ n\ r$" should be "$\mathsf{make}\ \langle m, n\rangle\ r$".
- Page 430, line 13 from bottom. The period after r_0 should be a comma.
- Page 441, line 16 from bottom. "$\mathsf{fib}(\mathsf{X}(\mathsf{X}(0)))$" should be "$\mathsf{fib}\ \mathsf{n}\ (\mathsf{X}(\mathsf{X}(0)))$".
- Page 441, line 15 from bottom. "$\mathsf{X}(0) = 0$ and $\mathsf{X}(1) = 7$" should be "$\mathsf{X}(0) = 0$, $\mathsf{X}(1) = 7$, and $\mathsf{n} > 0$".
- Page 441, line 10 from bottom. "$\mathsf{fib}(\textbf{if}\ \mathsf{x} = 0\ \textbf{then}\ \mathsf{x}\ \textbf{else}\ \mathsf{y})$ will malfunction" should be "$\mathsf{fib}\ \mathsf{n}\ (\textbf{if}\ \mathsf{x} = 0\ \textbf{then}\ \mathsf{x}\ \textbf{else}\ \mathsf{y})$ will malfunction when $\mathsf{n} > 0$".
- Page 456, line 3. $S_1, \ldots S_n$ should be $S_0, \ldots S_{n-1}$.

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last updated January 4, 2006