Appendix B

NSP Language Definition

B.1 Context Free Grammar

string	::=	$s \in$ **String**
id	::=	$l \in$ **Label**
parameter-type	::=	$t \in \mathbb{T} \cup \mathbb{P}$
supported-type	::=	$t \in \mathbb{B}_{supported}$
system	::=	page | system system
page	::=	<nsp name="id"> websig-core </nsp>
websig-core	::=	param websig-core | webcall | include
param	::=	<param name="id" type="parameter-type"/>
webcall	::=	<html> head body </html>
head	::=	<head><title> strings </title></head>
strings	::=	ε | string strings
body	::=	<body> dynamic </body>
include	::=	<include> dynamic </include>

```
dynamic  ::=  dynamic dynamic
           |  ε | string
           |  ul | li
           |  table | tr | td
           |  call
           |  form | object | hidden | submit
           |  input | checkbox
           |  select | option
           |  expression
           |  code

      ul  ::=  <ul> dynamic </ul>
      li  ::=  <li> dynamic </li>

   table  ::=  <table> dynamic </table>
      tr  ::=  <tr> dynamic </tr>
      td  ::=  <td> dynamic </td>

    call  ::=  <call callee="id"> actualparams </call>

actualparams  ::=  ε_act | actualparam actualparams

actualparam  ::=  <actualparam param="id"> expr </actualparam>

    form  ::=  <form callee="id"> dynamic </form>

  object  ::=  <object param="id"> dynamic </object>

  hidden  ::=  <hidden param="id"> expr </hidden>

  submit  ::=  <submit/>

   input  ::=  <input type="supported-type" param="id"/>

checkbox  ::=  <checkbox param="id"/>
```

```
    select  ::=     <select param="id"> dynamic </select>

    option  ::=     <option>
                        <value> expr </value>
                        <label> expr </label>
                    </option>

expression  ::=     <expression> expr </expression>

      code  ::=     <code> com </code>

       com  ::=     </code> dynamic <code>
                |   com ; com
                |   if expr then com else com
                |   while expr do com
                |   stat

      stat  ::=     id := expr

      expr  ::=     id  | expr.id | expr[expr]
```

B.2 Types

B.2.1 Programming Language Types

$$\mathbb{T} \;=\; \mathbb{B} \cup \mathbb{V} \cup \mathbb{A} \cup \mathbb{R} \cup \mathbb{Y}$$

$$\begin{array}{rlll}
(\textit{basic types}) & \mathbb{B} & = & \mathbb{B}_{primitive} \cup \mathbb{B}_{supported} \\
(\textit{primitive basic types}) & \mathbb{B}_{primitive} & = & \{\texttt{int}, \texttt{float}, \texttt{boolean}\} \\
(\textit{supported basic types}) & \mathbb{B}_{supported} & = & \{\texttt{int}, \texttt{Integer}, \texttt{String}\}
\end{array}$$

$$\begin{array}{rlll}
(\textit{type variables}) & \mathbb{V} & = & \{X, Y, Z, \ldots\} \\
 & & \cup & \{\texttt{Person}, \texttt{Customer}, \texttt{Article}, \ldots\} \\
(\textit{array types}) & \mathbb{A} & = & \{\ \texttt{array of}\ T \mid T \in \mathbb{T} \setminus \mathbb{A}\} \\
(\textit{record types}) & \mathbb{R} & = & \textbf{Label} \twoheadrightarrow \mathbb{T} \\
(\textit{recursive types}) & \mathbb{Y} & = & \{\ \mu\ X\ .\ R \mid X \in \mathbf{V}\ ,\ R \in \mathbb{R}\ \}
\end{array}$$

B.2.2 Server Page Types

$$\begin{array}{rlll}
(\textit{page types}) & \mathbb{P} & = & \{\ w \rightarrow r \mid w \in \mathbb{W}\ ,\ r \in \mathbb{C} \cup \mathbb{D}\ \} \\
(\textit{web signatures}) & \mathbb{W} & = & \textbf{Label} \twoheadrightarrow (\mathbb{T} \cup \mathbb{P}) \\
(\textit{complete web page}) & \mathbb{C} & = & \{\Box\} \\
(\textit{document fragment types}) & \mathbb{D} & = & \mathbb{L} \times \mathbb{W} \\
(\textit{layout types}) & \mathbb{L} & = & \mathbb{E} \times \mathbb{F} \\
(\textit{element types}) & \mathbb{E} & = & \{\ \circ, \bullet, \textbf{TR}, \textbf{TD}, \textbf{LI}, \textbf{OP}\} \\
(\textit{form occurences}) & \mathbb{F} & = & \{\ \Downarrow, \Uparrow, \Updownarrow\ \} \\
(\textit{system types}) & \mathbb{S} & = & \{\ \diamond, \surd\ \}
\end{array}$$

B.3 Subtyping Relation

B.3.1 Establishing Subtyping Rules

$$(reflexivity) \qquad \frac{}{\vdash T < T}$$

$$(array\ types) \qquad \frac{}{\vdash T < \texttt{array of}\ T}$$

$$\binom{record\ types}{web\ signatures} \qquad \frac{T_j \notin \mathbb{B}_{primitive} \cup \mathbb{P} \quad j \in 1 \ldots n}{\vdash \{l_i \mapsto T_i\}^{i \in 1 \ldots j-1, j+1 \ldots n} < \{l_i \mapsto T_i\}^{i \in 1 \ldots n}}$$

$$(html\ types) \qquad \frac{T \in \mathbb{E}}{\vdash \circ\ <\ T}$$

$$(form\ occurences) \qquad \frac{T \in \mathbb{F}}{\vdash \Updownarrow <\ T}$$

B.3.2 Preserving Subtyping Rules

$$(array\ types) \qquad \frac{\vdash S < T}{\vdash \texttt{array of}\ S < \texttt{array of}\ T}$$

$$\binom{record\ types}{web\ signatures} \qquad \frac{\vdash S_1 < T_1 \ldots \vdash S_n < T_n}{\vdash \{l_i \mapsto S_i\}^{i \in 1 \ldots n} < \{l_i \mapsto T_i\}^{i \in 1 \ldots n}}$$

$$(recursive\ types) \qquad \frac{\vdash S[{}^{\mu X.S}/_{X}] < T}{\vdash \mu X.S < T} \qquad \frac{\vdash S < T[{}^{\mu X.T}/_{X}]}{\vdash S < \mu X.T}$$

$$(page\ types) \qquad \frac{\vdash w' < w \qquad \vdash R < R'}{\vdash w \to R < w' \to R'}$$

$$\binom{dynamic}{layout\ types} \qquad \frac{\vdash S_1 < T_1 \quad \vdash S_2 < T_2}{\vdash (S_1, S_2) < (T_1, T_2)}$$

B.4 Type Operators

$\_* \ : \ \mathbb{T} \rightarrow \mathbb{T}$

$$T* \equiv_{\texttt{DEF}} \begin{cases} \texttt{array of } T & , T \notin \mathbb{A} \\ T & , else \end{cases}$$

$\_ \odot \_ \ : \ \mathbb{W} \multimap \mathbb{W}$

$w_1 \odot \ w_2 \equiv_{\texttt{DEF}}$

$$\begin{cases} \bot & , \textbf{\textit{if}} \ \exists (l_1 \mapsto T_1) \in w_1 \bullet \ \exists (l_2 \mapsto T_2) \in w_2 \bullet \ l_1 = l_2 \ \wedge \ P_1 \in \mathbb{P} \ \wedge \ P_2 \in \mathbb{P} \\ \bot & , \textbf{\textit{if}} \ \exists (l_1 \mapsto T_1) \in w_1 \bullet \ \exists (l_2 \mapsto T_2) \in w_2 \bullet \ l_1 = l_2 \ \wedge \ T_1 \sqcup T_2 \ undefined \\ & \\ & (\texttt{dom } w_2) \lhd w_1 \ \cup \ (\texttt{dom } w_1) \lhd w_2 \\ \cup & \ \{ \ (l \mapsto (T_1 \sqcup T_2)*) \ | (l \mapsto T_1) \in w_1 \ \wedge \ (l \mapsto T_2) \in w_2 \ \} \end{cases} , \textbf{\textit{else}}$$

B.5 Environments and Judgements

$$\Gamma : \textbf{Label} \pfun (\mathbb{T} \cup \mathbb{P}) \quad = \mathbb{W} \quad (identifiers)$$

$$\Delta : \textbf{Label} \pfun \mathbb{P} \quad \subset \mathbb{W} \quad (page \ definitions)$$

$$\Gamma \vdash e : \mathbb{T} \cup \mathbb{P} \qquad e \in \textbf{expr}$$

$$\Gamma \vdash n : \mathbb{D} \qquad n \in \textbf{com} \cup \textbf{dynamic}$$

$$\Gamma \vdash c : \mathbb{P} \qquad c \in \textbf{websig-core}$$

$$\Gamma \vdash a : \mathbb{W} \qquad a \in \textbf{actualparams}$$

$$\Gamma, \Delta \vdash s : \mathbb{S} \qquad s \in \textbf{system}$$

B.6 Typing Rules

$$\frac{\begin{array}{c}\Gamma \in \mathbb{R} \\ (dom\ \Delta) \cap bound(s) = \emptyset \\ \Gamma, \Delta \vdash s : \Diamond\end{array}}{\Gamma, \Delta \vdash s : \surd} \tag{B.1}$$

$$\frac{\begin{array}{c}s_1, s_2 \in \textbf{system} \quad (dom\ \Delta_1) \cap (dom\ \Delta_2) = \emptyset \\ ((dom\ \Gamma_2) \lhd\ \Delta_1) < ((dom\ \Delta_1) \lhd\ \Gamma_2) \\ ((dom\ \Gamma_1) \lhd\ \Delta_2) < ((dom\ \Delta_2) \lhd\ \Gamma_1) \\ \Gamma_1, \Delta_1 \vdash s_1 : \Diamond \qquad \Gamma_2, \Delta_2 \vdash s_2 : \Diamond\end{array}}{((dom\ \Delta_2) \lhd\!\!\!\cdot \Gamma_1) \cup ((dom\ \Delta_1) \lhd\!\!\!\cdot \Gamma_2)\ ,\ \Delta_1 \cup \Delta_2\ \vdash s_1\ s_2\ :\ \Diamond} \tag{B.2}$$

$$\frac{\Gamma \vdash l : P \qquad \Gamma \vdash c : P \qquad c \in \textbf{websig-core}}{\Gamma \backslash (l \mapsto P), \{(l \mapsto P)\}\ \vdash <\texttt{nsp}\ \ \texttt{name} = "l" > c < /\texttt{nsp} >\ :\ \Diamond} \tag{B.3}$$

$$\frac{\Gamma \vdash l : T \qquad \Gamma \vdash c : w \to D \qquad l \notin (dom\ w)}{\Gamma \backslash (l \mapsto T) \vdash \begin{array}{l} <\texttt{param}\ \ \texttt{name} = "l"\ \ \texttt{type} = "T" / > \\ c : (w \cup \{(l \mapsto T)\}) \to D\end{array}} \tag{B.4}$$

$$\frac{\Gamma \vdash d : ((\bullet \vee \circ, \Updownarrow \vee \Uparrow), \emptyset) \qquad t \in \textbf{strings} \qquad d \in \textbf{dynamic}}{\Gamma \vdash \begin{array}{l} <\texttt{html}> \\ \quad <\texttt{head}><\texttt{title}> t <\ /\texttt{head}><\ /\texttt{title}> \\ \quad <\texttt{body}> d <\ /\texttt{body}> \\ <\ /\texttt{html}> : \emptyset \to \Box\end{array}} \tag{B.5}$$

$$\frac{\Gamma \vdash d : D \qquad d \in \textbf{dynamic}}{\Gamma \vdash <\texttt{include}> d <\ /\texttt{include}> : \emptyset \to D} \tag{B.6}$$

$$\frac{d \in \textbf{string}}{\Gamma \vdash d : ((\bullet, \Updownarrow), \emptyset)} \tag{B.7}$$

$$\frac{}{\Gamma \vdash \varepsilon : ((\circ, \Updownarrow), \emptyset)} \tag{B.8}$$

$$\frac{\begin{array}{c}d_1, d_2 \in \textbf{dynamic} \\ \Gamma \vdash d_1 : (L_1, w_1) \quad \Gamma \vdash d_2 : (L_2, w_2) \quad L_1 \sqcup L_2 \downarrow \quad w_1 \odot w_2 \downarrow\end{array}}{\Gamma \vdash d_1\ d_2 : (L_1 \sqcup L_2, w_1 \odot w_2)} \tag{B.9}$$

$$\frac{\Gamma \vdash d : ((\mathbf{LI} \vee \circ, F), w)}{< \texttt{ul} > d < /\texttt{ul} > \ : \ ((\bullet, F), w)} \tag{B.10}$$

$$\frac{\Gamma \vdash d : ((\bullet \vee \circ, F), w)}{< \texttt{li} > d < /\texttt{li} > \ : \ ((\mathbf{LI}, F), w)} \tag{B.11}$$

$$\frac{\Gamma \vdash d : ((\mathbf{TR} \vee \circ, F), w)}{< \texttt{table} > d < /\texttt{table} > \ : \ ((\bullet, F), w)} \tag{B.12}$$

$$\frac{\Gamma \vdash d : ((\mathbf{TD} \vee \circ, F), w)}{< \texttt{tr} > d < /\texttt{tr} > \ : \ ((\mathbf{TR}, F), w)} \tag{B.13}$$

$$\frac{\Gamma \vdash d : ((\bullet \vee \circ, F), w)}{< \texttt{td} > d < /\texttt{td} > \ : \ ((\mathbf{TD}, F), w)} \tag{B.14}$$

$$\frac{\Gamma \vdash l : w \rightarrow D \qquad \Gamma \vdash as : v \qquad \vdash v < w}{\Gamma \vdash < \texttt{call} \quad \texttt{callee} = "l" > as < /\texttt{call} > \ : \ D} \tag{B.15}$$

$$\frac{}{\Gamma \vdash \varepsilon_{\texttt{act}} : \emptyset} \tag{B.16}$$

$$\frac{\Gamma \vdash as : w \qquad \Gamma \vdash e : T \qquad l \notin (dom\ w)}{\begin{array}{l} < \texttt{actualparam} \quad \texttt{param} = "l" > \\ \Gamma \vdash \qquad e \\ < /\texttt{actualparam} > as \ : \ w \cup \{(l \mapsto T)\} \end{array}} \tag{B.17}$$

$$\frac{\Gamma \vdash l : w \rightarrow \Box \qquad \Gamma \vdash d : ((e, \Downarrow), v) \qquad \vdash v < w}{\Gamma \vdash < \texttt{form} \quad \texttt{callee} = "l" > d < /\texttt{form} > : ((e, \Uparrow), \emptyset)} \tag{B.18}$$

$$\frac{\Gamma \vdash d : (L, w)}{\Gamma \vdash < \texttt{object}\ \texttt{param} = "l" > d < /\texttt{object} > \ : \ (L, \{(l \mapsto w)\})} \tag{B.19}$$

$$\frac{\Gamma \vdash e : T}{\Gamma \vdash < \texttt{hidden}\ \texttt{param} = "l" > e < /\texttt{hidden} > \ : \ ((\circ, \Downarrow), \{(l \mapsto T)\})} \tag{B.20}$$

$$\frac{}{\Gamma \vdash < \texttt{submit}/ > \ : \ ((\bullet, \Downarrow), \emptyset)} \tag{B.21}$$

$$\frac{T \in \mathbb{B}_{supported}}{\Gamma \vdash \ < \texttt{input type} = \text{"}T\text{"} \ \texttt{param} = \text{"}l\text{"} / > : ((\bullet, \Downarrow), \{(l \mapsto T)\})} \tag{B.22}$$

$$\frac{}{\Gamma \vdash < \texttt{checkbox} \quad \texttt{param} = \text{"}l\text{"} / > \ : \ ((\bullet, \Updownarrow), \{(l \mapsto \mathit{boolean})\})} \tag{B.23}$$

$$\frac{\Gamma \vdash d : \big((\mathbf{OP}, \Updownarrow), \{(l \mapsto \texttt{array of } T)\}\big)}{\begin{array}{l}\Gamma \vdash \quad < \texttt{select} \quad \texttt{param} = \text{"}l\text{"} > \\ \qquad\quad d \\ \qquad < /\texttt{select} > \ : \ ((\bullet, \Downarrow), \{(l \mapsto \texttt{array of } T)\})\end{array}} \tag{B.24}$$

$$\frac{\Gamma \vdash v \ : \ T \qquad \Gamma \vdash e : S \quad S \in \mathbb{B} \qquad l \in \mathbf{Label}}{\begin{array}{l}\Gamma \vdash \quad < \texttt{option} > \\ \qquad\quad < \texttt{value} > v < /\texttt{value} > \\ \qquad\quad < \texttt{label} > e < /\texttt{label} > \\ \qquad < /\texttt{option} > : ((\mathbf{OP}, \Updownarrow), \{(l \mapsto \texttt{array of } T)\})\end{array}} \tag{B.25}$$

$$\frac{\Gamma \vdash e : T \quad T \in \mathbb{B}}{\Gamma \vdash < \texttt{expression} > e < /\texttt{expression} > \ : \ ((\bullet, \Updownarrow), \emptyset)} \tag{B.26}$$

$$\frac{\Gamma \vdash c : D}{\Gamma \vdash < \texttt{code} > c < /\texttt{code} > \ : \ D} \tag{B.27}$$

$$\frac{\Gamma \vdash d : D}{\Gamma \vdash < /\texttt{code} > d < \texttt{code} > \ : \ D} \tag{B.28}$$

$$\frac{\Gamma \vdash c_1 : (L_1, w_1) \qquad \Gamma \vdash c_2 : (L_2, w_2) \qquad L_1 \sqcup L_2 \downarrow \qquad w_1 \odot w_2 \downarrow}{\Gamma \vdash c_1 ; c_2 \ : \ (L_1 \sqcup L_2, w_1 \odot w_2)} \tag{B.29}$$

$$\frac{\Gamma \vdash e : \texttt{boolean} \quad \Gamma \vdash c_1 : D_1 \quad \Gamma \vdash c_2 : D_2 \qquad D_1 \sqcup D_2 \downarrow}{\Gamma \vdash \texttt{if } e \texttt{ then } c_1 \texttt{else } c_2 \ : \ D_1 \sqcup D_2} \tag{B.30}$$

$$\frac{\Gamma \vdash e : \texttt{boolean} \qquad \Gamma \vdash c : (L, w)}{\Gamma \vdash \texttt{while } e \texttt{ do } c \ : \ (L, w \odot w)} \tag{B.31}$$

$$\frac{\Gamma \vdash x : T \qquad \Gamma \vdash e : T \qquad T \in \mathbb{T}}{\Gamma \vdash x := e \ : \ ((\circ, \Updownarrow), \emptyset)} \tag{B.32}$$

$$\frac{(v \mapsto T) \in \Gamma}{\Gamma \vdash v : T} \tag{B.33}$$

$$\frac{\Gamma \vdash e : \{l_i \mapsto T_i\}^{i \in 1 \ldots n} \qquad j \in 1 \ldots n}{\Gamma \vdash e.l_j : T_j} \tag{B.34}$$

$$\frac{\Gamma \vdash e : \texttt{ array of } T \qquad \Gamma \vdash i : \texttt{int}}{\Gamma \vdash e[i] : T} \tag{B.35}$$

B.7 Example Type Derivation I

Listing B.1

```
01 <nsp name="A">
02    <param name="x" type="array of int"/>
03    <include> ε </include>
04 </nsp>
05
06 <nsp name="B">
07    <param name="x" type="int"/>
08    <include>
09       <li>
10          <expression> x </expression>
11       </li>
12    </include>
13 </nsp>
14
15 <nsp name="C">
16    <param name="p" type="{(x ↦ int)} → ((LI, ⇳), ∅)"/>
17    <include>
18       <call callee="p">
19          <actualparam param="x"> 815 </actualparam>
20       </call>
21    </include>
22 </nsp>
23
24 <nsp name="D">
25    <html>
26       <head><title> Main Page </title></head>
27       <body>
28          <ul>
29             <call callee="C">
30                <actualparam param="p"> A </actualparam>
31             </call>
32             <call callee="C">
33                <actualparam param="p"> B </actualparam>
34             </call>
35          </ul>
36       </body>
37    </html>
38 </nsp>
```

$\Gamma_{CONST} \equiv_{\texttt{DEF}} \{\texttt{815} \mapsto \texttt{int}\}$

$w_A \equiv_{\texttt{DEF}} \{(x \mapsto \texttt{array of int})\}$
$\Gamma_A \equiv_{\texttt{DEF}} \Gamma_{CONST} \cup \Delta_A \cup w_A$
$T_A \equiv_{\texttt{DEF}} w_A \to ((\circ, \Updownarrow), \emptyset)$
$\Delta_A \equiv_{\texttt{DEF}} \{(A \mapsto T_A)\}$

$w_B \equiv_{\texttt{DEF}} \{(x \mapsto \texttt{int})\}$
$\Gamma_B \equiv_{\texttt{DEF}} \Gamma_{CONST} \cup \Delta_B \cup w_B$
$T_B \equiv_{\texttt{DEF}} w_B \to ((LI, \Updownarrow), \emptyset)$
$\Delta_B \equiv_{\texttt{DEF}} \{(B \mapsto T_B)\}$

$w_C \equiv_{\texttt{DEF}} \{(p \mapsto T_B)\}$
$\Gamma_C \equiv_{\texttt{DEF}} \Gamma_{CONST} \cup \Delta_C \cup w_C$
$\Delta_C \equiv_{\texttt{DEF}} \{(C \mapsto (w_C \to ((LI, \Updownarrow), \emptyset)))\}$

$\Gamma_D^{FINAL} \equiv_{\texttt{DEF}} \Gamma_{CONST} \cup \Delta_A \cup \Delta_B \cup \Delta_C$
$\Gamma_D \equiv_{\texttt{DEF}} \Gamma_D^{FINAL} \cup \Delta_D$
$\Delta_D \equiv_{\texttt{DEF}} \{(\ D \mapsto (\emptyset \to \Box)\ )\}$

I	$\Gamma_A \vdash \varepsilon : ((\circ, \Updownarrow), \emptyset)$	B.8
II	$\Gamma_A \vdash$ 03:$\emptyset \to ((\circ, \Updownarrow), \emptyset)$	I B.6
III	$\Gamma_A \vdash$ x:array of int	B.33
IV	$\Gamma_A \setminus w_A \vdash$ 02-03:T_A	III II B.4
V	$\Gamma_A \setminus w_A \vdash A : T_A$	B.33
VI	$\Gamma_{CONST}, \Delta_A \vdash$ 01-04:$\Diamond$	V IV B.3
VII	$\Gamma_B \vdash$ x:int	B.33
VIII	$\Gamma_B \vdash$ 10:$((\bullet, \Updownarrow), \emptyset)$	VII B.26
IX	$\Gamma_B \vdash$ 09-11:$(LI, \Updownarrow), \emptyset)$	VIII B.11
X	$\Gamma_B \vdash$ 08-12:$\emptyset \to ((LI, \Updownarrow), \emptyset)$	IX B.6
XI	$\Gamma_B \setminus w_B \vdash$ 07-12:T_B	VII X B.4
XII	$\Gamma_B \setminus w_B \vdash B : T_B$	B.33
XIII	$\Gamma_{CONST}, \Delta_B \vdash$ 06-13:$\Diamond$	XII XI B.3
XIV	$\Gamma_C \vdash$ "815":int	B.33
XV	$\Gamma_C \vdash$ 19:w_B	$\varepsilon_{\texttt{act}}$:$\emptyset$ XIV B.17
XVI	$\Gamma_C \vdash$ p:T_B	B.33
XVII	$\Gamma_C \vdash$ 18-20:$((LI, \Updownarrow), \emptyset)$	XVI XV $w_B < w_B$ B.15
XVIII	$\Gamma_C \vdash$ 17-21:$\emptyset \to ((LI, \Updownarrow), \emptyset)$	XVII B.6
XIX	$\Gamma_C \setminus w_C \vdash$ 16-21:$w_C \to ((LI, \Updownarrow), \emptyset)$	XVI XVIII B.4
XX	$\Gamma_C \setminus w_C \vdash$ C:$w_C \to ((LI, \Updownarrow), \emptyset)$	B.33
XXI	$\Gamma_{CONST}, \Delta_C \vdash$ 15-22:$\Diamond$	XX XIX B.3

XXII	$\Gamma_D \vdash$ A:T_A	B.33
XXIII	$\Gamma_D \vdash$ 30:$\{(p \mapsto T_A)\}$	ε_{act}:$\emptyset$ XXII B.17
XXIV	$\Gamma_D \vdash$ C:$w_C \rightarrow ((LI, \Updownarrow), \emptyset)$	B.33
XXV	$\vdash w_B < w_A$	array/record subtyping
XXVI	$\vdash ((\circ, \Updownarrow), \emptyset) < ((LI, \Updownarrow), \emptyset)$	layout subtyping
XXVII	$\vdash T_A < T_B$	XXV XXVI page subtyping
XXVIII	$\vdash \{\, p \mapsto T_A\} < w_C$	XXVII record subtyping
XXIX	$\Gamma_D \vdash$ 29-31:$((LI, \Updownarrow), \emptyset)$	XXIV XXIII XXVIII B.15
XXX	$\Gamma_D \vdash$ B:T_B	B.33
XXXI	$\Gamma_D \vdash$ 33:w_C	ε_{act}:$\emptyset$ XXX B.17
XXXII	$\Gamma_D \vdash$ 31-32:$((LI, \Updownarrow), \emptyset)$	XXIV XXXI $w_c < w_c$ B.15
XXXIII	$\Gamma_D \vdash (LI, \Updownarrow) \sqcup (LI, \Updownarrow) = (LI, \Updownarrow) \ \wedge \ \emptyset \odot \emptyset = \emptyset$	
XXXIV	$\Gamma_D \vdash$ 29-34:$((LI, \Updownarrow), \emptyset)$	XXIX XXXII XXXIII B.9
XXXV	$\Gamma_D \vdash$ 28-35:$((\bullet, \Updownarrow), \emptyset)$	XXXIV B.10
XXXVI	$\Gamma_D \vdash$ 25-37:$\emptyset \rightarrow \square$	XXXV B.5
XXXVII	$\Gamma_D \vdash$ D:$\emptyset \rightarrow \square$	
XXXVIII	$\Gamma_D^{FINAL}, \Delta_D \vdash$ 24-38:$\diamond$	XXXVII XXXVI B.3
XXXIX	$(dom\ \Delta_A) \cap (dom\ \Delta_B) = \emptyset$ $\wedge \ ((dom\ \Gamma_{Const}) \lhd\ \Delta_B) = \emptyset = ((dom\ \Delta_A) \lhd\ \Gamma_{Const})$ $\wedge \ ((dom\ \Gamma_{Const}) \lhd\ \Delta_A) = \emptyset = ((dom\ \Delta_B) \lhd\ \Gamma_{Const})$	
XXXX	$\Gamma_{CONST}, \Delta_A \cup \Delta_B \vdash$ 01-13:$\diamond$	XXXIX VI XIII B.2
XXXXI	*analog of* XXXIX *concerning* $(\emptyset, \Delta_A \cup \Delta_B)$ *and* $(\emptyset, \Delta_D)$	
XXXXII	$\Gamma_{CONST}, \Delta_A \cup \Delta_B \cup \Delta_C \vdash$ 01-22:$\diamond$	XXXXI XXXX XXI B.2
XXXXIII	$(dom\ (\Delta_A \cup \Delta_B \cup \Delta_C)) \cap (dom\ \Delta_D) = \emptyset$ $\wedge \ (dom\ \Gamma_D^{FINAL}) \lhd (\Delta_A \cup \Delta_B \cup \Delta_C) = (dom(\Delta_A \cup \Delta_B \cup \Delta_C)) \lhd \Gamma_D^{FINAL}$ $\wedge \ (dom\ \Gamma_{CONST}) \lhd \Delta_D = (dom\ \Delta_D) \lhd \Gamma_{CONST}$	
XXXXIV	$\Gamma_{CONST}, \Delta_A \cup \Delta_B \cup \Delta_C \cup \Delta_D \ \vdash$ 01-38:$\diamond$	XXXXIII XXXXII XXXVIII B.2
XXXXV	$\Gamma_{CONST}, \Delta_A \cup \Delta_B \cup \Delta_C \cup \Delta_D \ \vdash$ 01-38:$\surd$	XXXXIV ($\Gamma_{CONST} \in \mathbb{R}$) B.1

B.8 Example Type Derivation II

Listing B.2

```
01 <form callee="target">
02   <code>
03     if cond then
04       while cond do
05         </code>
06           <object param="x">
07             <input param="name" type="String">
08             <object param="next">
09               <input param="name" type="String">
10             </object>
11           </object>
12         <code>
13       ;
14       </code>
15         <object param="x">
16           <input param="name" type="String">
17           <object param="address">
18             <input param="street" type="String">
19             <input param="zip" type="int">
20           </object>
21         </object>
22       <code>
23     else
24      </code>
25        <select param="x">
26           <option>
27             <value> v </value>
28             <label> l </label>
29           </option>
30         </select>
31       <code>
32   </code>
33   <submit/>
34 </form>
```

Listing B.3

```
01 <nsp name="target">
02   <param name="x" type="array of
03                              μX.{name↦String,
04                                  address↦{street↦String,
05                                           zip↦int},
06                                  next↦X
07                                 }"
08   />
09   <html>
10     ...
11   </html>
12 </nsp>
```

$w_{target} \equiv_{\texttt{DEF}} \{\ x \mapsto \texttt{array of}\ \mu X.\{name \mapsto \texttt{String}, address \mapsto \{street \mapsto \texttt{String}, zip \mapsto \texttt{int}\}, next \mapsto X\}\ \}$

$\Gamma \equiv_{\texttt{DEF}} \{\ cond \mapsto \texttt{boolean}\ ,\ v \mapsto \mu X.\{name \mapsto \texttt{String}, address \mapsto \{street \mapsto \texttt{String}, zip \mapsto \texttt{int}\}, next \mapsto X\}\ ,\ l \mapsto \texttt{String}\ ,\ target \mapsto (w_{target} \to \Box)\ \}$

I	$\Gamma \vdash$ 09:$((\bullet, \Downarrow), \{name \mapsto \texttt{String}\})$	B.22
II	$\Gamma \vdash$ 08-10:$((\bullet, \Downarrow), \{next \mapsto \{name \mapsto \texttt{String}\}\})$	I B.19
III	$\Gamma \vdash$ 07:$((\bullet, \Downarrow), \{name \mapsto \texttt{String}\})$	B.22
IV	$\Gamma \vdash$ 07-10:$((\bullet, \Downarrow), \{name \mapsto \texttt{String}, next \mapsto \{name \mapsto \texttt{String}\}\})$	I III B.9
V	$\Gamma \vdash$ 06-11:$((\bullet, \Downarrow), \{x \mapsto \{name \mapsto \texttt{String}, next \mapsto \{name \mapsto \texttt{String}\}\}\})$	IV B.19
VI	$\Gamma \vdash$ 05-12:$((\bullet, \Downarrow), \{x \mapsto \{name \mapsto \texttt{String}, next \mapsto \{name \mapsto \texttt{String}\}\}\})$	V B.28
VII	$\Gamma \vdash cond$:boolean	B.33
VIII	$\Gamma \vdash$ 04-12:$((\bullet, \Downarrow), \{x \mapsto \texttt{array of}\ \{name \mapsto \texttt{String}, next \mapsto \{name \mapsto \texttt{String}\}\}\})$	VII VI B.31
IX	$\Gamma \vdash$ 19:$((\bullet, \Downarrow), \{zip \mapsto \texttt{int}\})$	B.22
X	$\Gamma \vdash$ 18:$((\bullet, \Downarrow), \{street \mapsto \texttt{String}\})$	B.22
XI	$\Gamma \vdash$ 18-19:$((\bullet, \Downarrow), \{street \mapsto \texttt{String}, zip \mapsto \texttt{int}\})$	IX X B.9
XII	$\Gamma \vdash$ 17-20:$((\bullet, \Downarrow), \{adress \mapsto \{street \mapsto \texttt{String}, zip \mapsto \texttt{int}\}\})$	XI B.19
XIII	$\Gamma \vdash$ 16:$((\bullet, \Downarrow), \{name \mapsto \texttt{String}\})$	B.22
XIV	$\Gamma \vdash$ 16-20:$((\bullet, \Downarrow), \{name \mapsto \texttt{String}, adress \mapsto \{street \mapsto \texttt{String}, zip \mapsto \texttt{int}\}\})$	XIII XII B.9
XV	$\Gamma \vdash$ 15-21:$((\bullet, \Downarrow), \{x \mapsto \{name \mapsto \texttt{String}, adress \mapsto \{street \mapsto \texttt{String}, zip \mapsto \texttt{int}\}\}\})$	XIV B.19

XVI	$\Gamma \vdash$ 14-22:$((\bullet, \Downarrow), \{x \mapsto \{name \mapsto \texttt{String}, adress \mapsto \{street \mapsto \texttt{String}, zip \mapsto \texttt{int}\}\}\})$	XV B.28
XVII	$\Gamma \vdash$ 04-22:$((\bullet, \Downarrow), \{x \mapsto \texttt{array of } \{name \mapsto \texttt{String}, adress \mapsto \{street \mapsto \texttt{String}, zip \mapsto \texttt{int}\}, next \mapsto \{name \mapsto \texttt{String}\}\}\}$	VIII XVI B.29
XVIII	$\Gamma \vdash$ v:$\mu X.\{name \mapsto \texttt{String}, address \mapsto \{street \mapsto \texttt{String}, zip \mapsto \texttt{int}\}, next \mapsto X\}$	B.33
XIX	$\Gamma \vdash$ l:$String$	B.33
XX	$\Gamma \vdash$ 26-29:$((OP, \Updownarrow), \{x \mapsto \texttt{array of } \mu X.\{name \mapsto \texttt{String}, address \mapsto \{street \mapsto \texttt{String}, zip \mapsto \texttt{int}\}, next \mapsto X\}\})$	XVIII XIX B.25
XXI	$\Gamma \vdash$ 25-30:$((\bullet, \Downarrow), w_{target})$	XX B.24
XXII	$\Gamma \vdash$ 24-31:$((\bullet, \Downarrow), w_{target})$	XXI B.28
XXIII	$\Gamma \vdash$ 03-31:$((\bullet, \Downarrow), w_{target})$	XVII XXII B.30
XXIV	$\Gamma \vdash$ 02-32:$((\bullet, \Downarrow), w_{target})$	XVIII B.27
XXV	$\Gamma \vdash$ 33:$((\bullet, \Downarrow), \emptyset)$	B.21
XXVI	$\Gamma \vdash$ 02-33:$((\bullet, \Downarrow), w_{target})$	XXIV XXV B.9
XXVII	$\Gamma \vdash target : w_{target} \rightarrow \Box$	B.33
XXVIII	$\Gamma \vdash$ 01-34:$((\bullet, \Uparrow), \emptyset)$ XXVII XXVI $\vdash w_{target} < w_{target}$	B.18