Translation from Workflow Nets to MSVL*

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Abstract. [illegible]

Keywords: [illegible]

1 Introduction

A [illegible] 16 [illegible] 1 [illegible] 8, 16 [illegible] 4 [illegible]

[illegible] 2, 10, 13 15, 17 [illegible] 2, 15 [illegible] 2 [illegible] 9, 12, 18, 19 [illegible]

* [illegible] 61133001, 61003078, 61272117, 61272118, [illegible] 61202038 [illegible] (973 [illegible]) [illegible] 2010 [illegible] 328102 [illegible] 1102001.

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[illegible] 2013 [illegible] 8144 [illegible] 281 296, 2013.

[illegible] 12 [illegible]) 6 [illegible]) 20 [illegible], *assignment*, *sequence*, *condition* [illegible] *loop*, [illegible] ++, [illegible] *await*, *parallel*, [illegible] *projection* [illegible] A 11 [illegible] 6 [illegible]) 6 [illegible] (A [illegible]) [illegible] : (1) [illegible] ; (2) [illegible] 2, [illegible] 3, [illegible] 4. [illegible] 5, [illegible] 6.

2 Preliminaries

[illegible]

2.1 Workflow Nets

Definition 1 (Workflow Nets). *A Petri net $N = (P, T, F)$ is a Workflow net if and only if: (1) there is one source place $i \in P$ such that ${}^\bullet i = \emptyset$; (2) there is one sink place $o \in P$ such that $o^\bullet = \emptyset$; (3) the net $\overline{N} = (P, T \cup \{t_N\}, F \cup \{(o, t_N), (t_N, i)\})$, $t_N \notin T$, is strongly connected.*

A [illegible] $\Sigma = (P, T, F, M_0)$ [illegible] $M_0 = \{i\}$. A [illegible] $N = (P, T, F)$ [illegible] *sound* 3 [illegible] (1) $\forall M$, $(\{i\} \xrightarrow{*} M) \Rightarrow (M \xrightarrow{*} \{o\})$; (2) $\forall M$, $(\{i\} \xrightarrow{*} M \wedge M \geq \{o\}) \Rightarrow (M = \{o\})$; (3) $\forall t \in T$, $\exists M, M'$, $\{i\} \xrightarrow{*} M \xrightarrow{t} M'$. A [illegible] $N = (P, T, F)$ [illegible] - [illegible] 5 [illegible] $\forall t_1, t_2 \in T$, [illegible]

$^\bullet t_1 \cap {}^\bullet t_2 \neq \emptyset$, n $^\bullet t_1 = {}^\bullet t_2$. n - n N, *complete choice* m m n n m n , n m n CC_N.

n n n m n n , n n n n n n m - n n m n n . A m m n n n , - n n n ffi n n m 5 . n n , n n n -

2.2 MSVL

n n n :

$$e ::= n|s|x$$
$$b ::= \mathtt{true}|\mathtt{false}|e_0 = e_1|\neg b|b_0 \text{ and } b_1$$

n n n , s n , n x . n m n n :

Assignment :	$x_1 <= e$	Sequential :	$p_1; p_2$
Conditional :	if b_1 then $\{p_1\}$ $else\{p_2\}$	While :	while b_1 do$\{p_1\}$
Guarded Conditional :	$(b_1 \to p_1)$ ... $(b_m \to p_m)$	Selection :	(p_1)or(p_2)
Interval Frame :	frame$(x_1, \ldots, x_n)$	Parallel :	$(p_1)\|\|(p_2)$
Await :	await(b_1)	Skip :	skip

e n n n, b_i n n, p_i m n , $i \in \{1, 2, \ldots, m\}$, n x_j m n , $j \in \{1, 2, \ldots, n\}$. $x_1 <= e$ m n x_1 n n e_1 n n p_{x_1} m n x_1, n m n m , . n , n - n , n m n m n n n m n . $(b_1 \to p_1)$ ... $(b_m \to p_m)$ m n n n n n , m ; n m p_i b_i n. $(p_1)or(p_2)$ m n p_1 p_2 . $frame(x_1, \ldots, x_n)$ n - x_j n n n n n nm n n n . $(p_1)||(p_2)$ m n p_1 n p_2 m n , , n n n n n . $await(b_1)$ n n n - , n n n b_1 m , n m n . *skip* n n n n .

n , n m n . n n m : m n, m n , n n. n m n m , n m n n ; n m n m , m n n m m m) 7 ; n n n m , n n m ( ) m m , n n m n

6 m n m .

3 Annotated Workflow Nets and Regular Structures

n n n m , n Ann (A) n n A .

3.1 Annotated Workflow Nets

Definition 2. *An* Ann (A) *is a tuple* (P, T, F, G, L)*, where* $N = (P, T, F)$ *is a WFN, G and L are condition and statement annotations on a transition* $t \in T$*, respectively. For each transition* $t \in T$*, the condition annotation* $G(t)$ *of t is a boolean expression, and the statement annotation* $L(t)$ *of t is a statement in MSVL.*

n n A , n n t *enabled* ff $p \in {}^{\bullet}t$, $M(p) > 0$ n $G(t)$. m n nn n $L(t)$ t . A n n m n n n m .

n n - $N = (P, T, F)$, n A $AN = (P, T, F, G, L)$ n n :

- $G(t) =$ `true` $t \in T$,
- $L(t) = (p_1 <= 0)$ `and` $\ldots$ `and` $(p_m <= 0)$ `and` `skip`; $(q_1 <= 1)$ `and` $\ldots$ `and` $(q_n <= 1)$ `and` `skip`, ${}^{\bullet}t = \{p_1, \ldots, p_m\}$ n $t^{\bullet} = \{q_1, \ldots, q_n\}$.

n , p N, p n m n n , n n n t, m n $L(t)$ m ff n n t n .

3.2 Regular Structures

$N = (P, T, F)$ n . n $x, y \in P \cup T$, m x y ff $(x, y) \in F^+$. N *standard* ff n n , n st_N n end_N (m n n n n n), n n m st_N end_N $X \subseteq P \cup T$ n . *projection* N X n $N|_X = (P|_X, T|_X, F|_X)$ N, $P|_X = P \cap X$, $T|_X = T \cap X$, $F|_X = F \cap ((P|_X \times T|_X) \cup (T|_X \times P|_X))$, n n $x \in X$, ${}^{\bullet}x|_X = {}^{\bullet}x \cap X$ n $x^{\bullet}|_X = x^{\bullet} \cap X$. $N|_X$ *autonomous* ff $N|_X$ n , $({}^{\bullet}st_{N|_X} \cup end_{N|_X}{}^{\bullet}) \cap X = \emptyset$, n ${}^{\bullet}X' \cup X'^{\bullet} = X$, $X' = X \backslash \{st_{N|_X}, end_{N|_X}\}$.

n n - A $N = (P, T, F, G, T)$ n $X \subseteq P \cup T$. m n A n :

1. n n : $N|_X$ *redundant place structure (RPS)* ff $X = \{p_1, p_2\} \subset P$, ${}^{\bullet}p_1 = {}^{\bullet}p_2$, n $p_1^{\bullet} = p_2^{\bullet}$. . 1 ( ) , $M(q_1) = M(q_2)$ n m n M.
2. n : $N|_X$ *sequence structure (SS)* ff $T|_X = \{t_1, t_2\}$, $P|_X = \{p\} = t_1^{\bullet} = {}^{\bullet}t_2$, ${}^{\bullet}p = \{t_1\}$, n $p^{\bullet} = \{t_2\}$. , n n n . . 2 ( ) n , t_1 n t_2 n .
3. : $N|_X$ n *explicit choice structure (ECS)* ff $P|_X = P_1 \cup P_2$, $P_1 \cap P_2 = \emptyset$, $|P_1| > 0$, $|P_2| > 0$, $|T|_X| > 1$, n $\forall t \in T|_X$, ${}^{\bullet}t = P_1$, $t^{\bullet} = P_2$. . 3 ( ) n , n t_1 n t_2 m .

4. m : $N|_X$ *simple loop structure (SLS)* ff $T|_X = \{t\}$ n $P|_X = {}^\bullet t = t^\bullet$. . 4 ( ) , t_0 n .
5. m : $N|_X$ *complex loop structure (CLS)* ff $N|_X$ n- n , $|T|_X| > 1, \forall t \in T|_X, |{}^\bullet t| = |t^\bullet| = 1,$ n $\forall p \in P|_X, |{}^\bullet p|_X| = |p^\bullet|_X| = 1.$ n N - , $\forall p \in P|_X, \forall t \in p^\bullet, {}^\bullet t = \{p\}.$ n n . 5 ( ) , n n n n n , n n n .
6. m : $N|_X$ *complex choice structure (CCS)* ff $N|_X$ n n , $st_{N|_X}, end_{N|_X} \in P|_X, \forall t \in T|_X, |t^\bullet| = |{}^\bullet t| = 1, \forall p \in P|_X \backslash \{st_{N|_X}, end_{N|_X}\},$ $|p^\bullet|_X| = |{}^\bullet p|_X| = 1, |st_{N|_X}{}^\bullet|_X| = |{}^\bullet end_{N|_X}|_X| = 2, {}^\bullet st_{N|_X} \neq \emptyset, end_{N|_X}{}^\bullet \neq \emptyset,$ n $\forall t \in end_{N|_X}{}^\bullet, |{}^\bullet t| = 1.$ m , n N - n , $p \in P|_X$ n $t \in p^\bullet,$ ${}^\bullet t = \{p\}.$ n n . 6 ( ). n : t_1 n t_2, t_3 n t_4 , n t_1 t_4 .
7. n n : $N|_X$ *concurrent structure (CoS)* ff $N|_X$ n m , $st_{N|_X}, end_{N|_X} \in T|_X, \forall p \in P|_X, |{}^\bullet p| = |p^\bullet| = 1,$ n $T|_X = {}^\bullet(P|_X) \cup (P|_X)^\bullet$. A *minimal CoS* n m n n n . . 7 ( ). n , n t_0, n n n .
8. : $N|_X$ n *irregular structure (IS)* ff X n m n n- n n n . A *minimal IS* n n m n n n . n N n n , n n n n n $N|_X$, n $N|_X$ n n n n . . 8 ( ) n n t_0 t_1 , t_3 n .

4 Translation from AWFNs to MSVL

, n n n n m n m A n m .

4.1 Rule RRP: Removal of Redundant Places

m n n - A , n m n n- n n n n m . , n - n n n n n m . A n , n n $N|_X$, m n n X.

m , n n $N|_X$ n - A $N = (P, T, F, G, L)$, ULE , n n - A $N' = (P', T, F', G, L)$ n , $P' = P \setminus \{p\}, p \in X,$ n $F' = (F \cap ((P' \times T) \cup (T \times P')))$.

A n m , n n n . 1 ( ), ULE , q_2 m n . 1 ( ).

4.2 Rule FSS: Folding Sequence Structures

n n , n n n . m n n n n m n nn n n n m n m n nn n n n n .

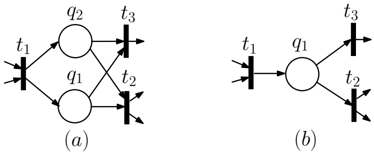

Fig. 1.

$N|_X$ ... $N = (P, T, F, G, L)$, ... ULE ... $N' = (P', T', F', G', L')$ ...

- $P' = P \backslash X$;
- $T' = (T \backslash X) \cup \{d_X\}$, $d_X \notin P \cup T$;
- $F' = (F \cap ((P' \times T') \cup (T' \times P'))) \cup ({}^{\bullet}st_{N|_X} \times \{d_X\}) \cup (\{d_X\} \times end_{N|_X}{}^{\bullet})$;
- $\forall t \in T' \backslash \{d_X\}$, $G'(t) = G(t)$, n $G'(d_X) = G(st_{N|_X})$;
- $\forall t \in T' \backslash \{d_X\}$, $L'(t) = L(t)$, n $L'(d_X) = L(st_{N|_X}); L(end_{N|_X})$.

ULE ... 2 ( ) ... d_X ... 2 ( ) $G'(d_X) = G(t_1)$, n $L'(d_X) = L(t_1); L(t_2)$.

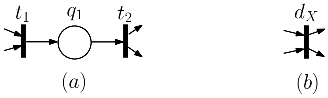

Fig. 2.

4.3 RULE FECS: Folding Explicit Choice Structures

$N|_X$ ... $N = (P, T, F, G, L)$, ULE ... $N' = (P, T', F', G', L')$

- $T' = (T \backslash X) \cup \{d_X\}$, $d_X \notin P \cup T$;
- $F' = (F \cap ((P \times T') \cup (T' \times P))) \cup ({}^{\bullet}(T|_X) \times \{d_X\}) \cup (\{d_X\} \times T|_X{}^{\bullet})$;
- $\forall t \in T' \backslash \{d_X\}$, $G'(t) = G(t)$, n $G'(d_X) = \mathtt{OR}_{d \in T|_X} G(d)$;
- $\forall t \in T' \backslash \{d_X\}$, $L'(t) = L(t)$, n $L'(d_X) = (G(t_0) \rightarrow L(t_0)) \ \ldots \ G(t_n) \rightarrow L(t_n))$, $T|_X = \{t_0, \ldots, t_n\}$.

ULE ... 3 ( ) ... d_X ... 3 ( ) $G'(d_X) = G(t_1)$ or $G(t_2)$ n $L'(d_X) = (G(t_1) \rightarrow L(t_1))$ $(G(t_2) \rightarrow L(t_2))$.

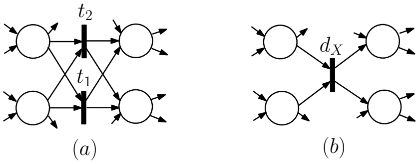

Fig. 3.

4.4 Rule FSLS: Folding Simple Loop Structures

n m , n n .
n n n n m n m n nn n.
m , m $N|_X$ n - A $N = (P, T, F, G, L)$, ULE , n n - A $N' = (P', T', F', G', L')$ - n ,

- $P' = (P \backslash X) \cup P_0 \cup P_1$, $P_0 \cap P_1 = \emptyset$, $(P_0 \cup P_1) \cap (P \cup T) = \emptyset$, n m n μ_0, $P|_X \rightarrow P_0$, n μ_1, $P|_X \rightarrow P_1$;
- $T' = (T \backslash X) \cup \{d_X\}$, $d_X \notin P \cup T \cup P_0 \cup P_1$;
- $F' = (F \cap ((P' \times T') \cup (T' \times P'))) \cup (P_0 \times \{d_X\}) \cup (\{d_X\} \times P_1) \cup F_0 \cup F_1$, $F_0 = \{(x, \mu_0(p)) | \forall p \in P|_X, \forall (x, p) \in F|_X\}$ n $F_1 = \{(\mu_1(p), x) | \forall p \in P|_X, \forall (p, x) \in F|_X\}$;
- $\forall t \in T' \backslash \{d_X\}$, $G'(t) = G(t)$, n $G'(d_X) =$ `true`;
- $\forall t \in T' \backslash \{d_X\}$, $L'(t) = L(t)$ n $L'(d_X) = over_X <= 0$ and skip; while($over_X = 0$ and $G(t)$){($over_X <= 1$ and skip) or ($L(t)$)}, $T|_X = \{t\}$.

n n , ULE , m n . 4 ( ) n - n d_X n . 4 ( ), $G'(d_X) =$ `true` n $L'(d_X) = over_X <= 0$ and skip; while ($over_X = 0$ and $G(t_0)$){($over_X <= 1$ and skip) or ($L(t_0)$)}.

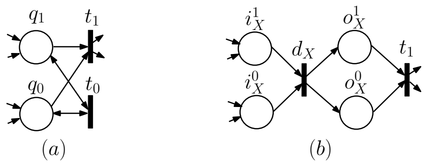

Fig. 4.

4.5 Rule FCLS: Folding Complex Loop Structures

n m , n n n , n n n .
. A n , m n n
m n m n nn n. , n m m n n n
, $LPNext_X$ n $LPOut_X$ m
n n n n n .
$N|_X$ m n - A $N = (P, T, F, G, L)$. $entry_X$ n $exit_X$ n n n $N|_X$, . m , $entry_X = \{p | \forall p \in P|_X, {}^\bullet p \backslash X \neq \emptyset\}$ n $exit_X = \{p | \forall p \in P|_X, p^\bullet \backslash X \neq \emptyset\}$. n n n

n $N|_X$ n n $N|_X$ n , n $N|_X$. n n n $N|_X$ n $N|_X$ n , n $N|_X$ n . , n n q $N|_X$ n, n $N|_X$ n n n n n d, $N|_X$, q n n , . . $\mathrm{OR}_{t\in p^\bullet\backslash X}G(t)$. n n n , $EG_X(p)$ n $\mathrm{OR}_{t\in p^\bullet\backslash X}G(t)$ p n $exit_X$. m n n m n, n n n .

$LN_X \subseteq entry_X \times entry_X$ n n n $(p_0, p_1) \in LN_X$, n $N|_X$ m p_0 p_1 n n n n n $N|_X$. $N|_Y$ m n N_X ff $Y \subseteq X$, $N|_Y$ n n , n $(st_{N|_Y}, end_{N|_Y}) \in LN_X$ n n LN_X m n , n m m n LN_X (SLN_X) $N|_{Y_1}$ n $N|_{Y_2}$ n m n . $(N|_{Y_1}, N|_{Y_2}) \in SLN_X$ ff $(st_{N|_{Y_1}}, st_{N|_{Y_2}}) \in LN_X$. n n , n m $N|_X$ n n . 5 ( ), $entry_X = \{q_1, q_2\}$, $exit_X = \{q_1, q_3\}$, $EG_X(q_1) = G(t_5)$, $EG_X(q_3) = G(t_7)$, n $LN_X = \{(q_1, q_2), (q_2, q_1)\}$. m n $N|_{X_1}$ n $N|_{X_2}$ $N|_X$, $X_1 = \{q_1, q_2, t_0\}$, $X_2 = \{q_2, q_3, q_1, t_1, t_2\}$, n $(N|_{X_1}, N|_{X_2}), (N|_{X_2}, N|_{X_1}) \in SLN_X$.

n m n nn n n n m ULE , m n m m n n n m n , n n m n n n n m n m n m n , n n n m n . . n m n n SLN_X.

, n m $N|_X$ n - A $N =$ (P, T, F, G, L), n n - A $N' = (P', T', F', G', L')$ n ULE ,

- $P' = (P\backslash X) \cup \{i_X, o_X\}$ $\{i_X, o_X\} \cap (P \cup T) = \emptyset$;
- $T' = (T\backslash X) \cup \{d_X\}$, $d_X \notin P \cup T \cup \{i_X, o_X\}$;
- $F' = (F \cap ((P' \times T') \cup (T' \times P'))) \cup ((^\bullet entry_X\backslash X) \times \{i_X\}) \cup \{(i_X, d_X), (d_X, o_X)\} \cup (\{o_X\} \times (exit_X{}^\bullet\backslash X))$;
- $G'(t) = G(t)$, $t \in T'\backslash(exit_X{}^\bullet \cup \{d_X\})$; $G'(t) = G(t)$ and $LPOut_X =$ p, , $t \in exit_X{}^\bullet\backslash X$, $^\bullet t = \{p\}$; n $G'(d_X) =$ true;
- $L'(t) = L(t)$, $t \in T'\backslash(^\bullet entry_X \cup exit_X{}^\bullet \cup \{d_X\})$, $L'(t) = L(t)$; $LPNext_X$ <= p and skip, $t \in {}^\bullet entry_X\backslash X$, $t^\bullet \cap X = \{p\}$, $L'(t) = LPOut_X$ <= $NULL$ and skip; $L(t)$, $t \in exit_X{}^\bullet\backslash X$, n $L'(d_X)$ n n m n Ann n 1.

n m n Ann n 1, m n $N|_Y$ $N|_X$ n n m n m n 3 16. n n n n 3 n $st_{N|_Y}$ $N|_Y$ n. n n n , n n m n . , $LPNext_X$ n $end_{N|_Y}$, , m n n m n n m n . , m n nn n n- n t^1_Y n $st_{N|_Y}$ n r^1_Y n r^1_Y n $N|_Y$. n r^1_Y n, n n . n nm n m n n n 5 , n $N|_X$ n n n m $LPOut_X$. , n $N|_X$ n. t^2_Y n n n r^1_Y n r^2_Y. t^3_Y n n n r^2_Y n - n . r^k_Y n $N|_Y$ n t^v_Y n n n r^k_Y n $end_{N|_Y}$. A n n m n . . n m n n SLN_X.

Statement Annotation 1.

```
while(¬(LPNext_X = NULL)) do{
  ...
  if(LPNext_X = st_{N|Y}) then {
    LPNext_X <= end_{N|Y} and skip; L(t^1_Y);
    (EG_X(r^1_Y) → LPNext_X <= NULL and LPOut_X <= r^1_Y and skip)
    (G(t^2_Y) → L(t^2_Y);
      (EG_X(r^2_Y) → LPNext_X <= NULL and LPOut_X <= r^2_Y and skip)
      (G(t^3_Y) → L(t^3_Y);
          ...
            (EG_X(r^k_Y) →
              LPNext_X <= NULL and LPOut_X <= r^k_Y and skip
            ) (G(t^v_Y) → L(t^v_Y))
          ...
      )
    )
  }
  ...
}
```

ULE ... , ... Fig. 5 ( ) ... d_X ... Fig. 5 ( ),

$G'(t_5) = G(t_5)$ and $LPOut_X = q_1$, $L'(t_5) = LPOut_X <= NULL$ and skip; $L(t_5)$,
$G'(t_7) = G(t_7)$ and $LPOut_X = q_3$, $L'(t_7) = LPOut_X <= NULL$ and skip; $L(t_7)$,
$L'(t_3) = L(t_3); LPNext_X <= q_1$ and skip,
$L'(t_4) = L(t_4); LPNext_X <= q_1$ and skip,
$L'(t_6) = L(t_6); LPNext_X <= q_2$ and skip,
$G'(d_X) =$ true,
$L'(d_X) =$ while$(\neg(LPNext_X = NULL))$ do{
if$(LPNext_X = q_1)$ then{$LPNext_X <= q_2$ and skip;
$(G(t_5) \rightarrow LPNext_X <= NULL$ and $LPOut_X <= q_1$ and skip) $(G(t_0) \rightarrow L(t_0))$}
if$(LPNext_X = q_2)$ then{$LPNext_X <= q_1$ and skip; $L(t_1)$;
$(G(t_7) \rightarrow LPNext_X <= NULL$ and $LPOut_X <= q_3$ and skip) $(G(t_2) \rightarrow L(t_2))$}}

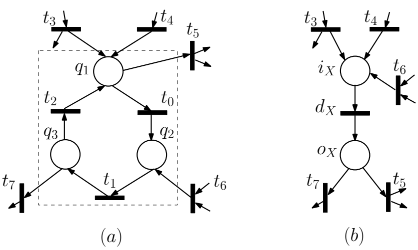

Fig. 5. ... n ... m ...

4.6 Rule FCCS: Folding Complex Choice Structure

... m ... $N|_X$ ... n ... n ... n ... n ... m n ... m n ... nn ... n. ... m ... m ... , ... m ... m ... n n n ... n ... n ... m ... . , ...

$CCNext_X$ n $CCOut_X$ m n n n $N|_X$ n .

$N|_X$ m n - A $N = (P, T, F, G, L)$.

n n $entry_X, exit_X, EG_X$, n LN_X m m - . $N|_Y$ *segment* $N|_X$ ff $Y \subset X$, $N|_Y$ n n , n (1) $(st_{N|_Y}, end_{N|_Y}) \in LN_X$, (2) $Y \cap entry_X = st_{N|_X}$ n $end_{N|_Y} = end_{N|_X}$ m n m n $N|_X$, n $st_{N|_X}$ n n $end_{N|_X}$. n n SLN_X m m n n , m $N|_X$ n n n . 6 ( ), $entry_X = \{q_0, q_2\}$, $exit_X = \{q_1, q_3\}$, $EG_X(q_1) = G(t_7)$, $EG_X(q_3) = G(t_5)$, $LN_X = \{(q_0, q_2), (q_2, q_3), (q_0, q_3)\}$. m n $N|_{X_1}, N|_{X_2}$, n $N|_{X_3}$ $N|_X$, $X_1 = \{q_0, q_2, t_3\}$, $X_2 = \{q_2, q_3, t_4\}$, $X_3 = \{q_0, q_1, q_3, t_1, t_2\}$, n $SLN_X = \{(N|_{X_1}, N|_{X_2})\}$.

A n n n m $N|_X$, ff - n m $st_{N|_X}$ $end_{N|_X}$. n m n nn n n n m ULE , (1) m $st_{N|_X}$ $end_{N|_X}$, n m n n n n m n n m m n n ; (2) n - n m n , n n m n . . n m n n SLN_X; n (3) n n n m n n- m n n n .

, n m $N|_X$ n - A $N = (P, T, F, G, L)$, n n - A $N' = (P', T', F', G', L')$ n ULE ,

- $P' = (P \backslash X) \cup \{i_X, o_X\}$, n $\{i_X, o_X\} \cap (P \cup T) = \emptyset$;
- $T' = (T \backslash X) \cup \{d_X\}$, $d_X \notin P \cup T \cup \{i_X, o_X\}$;
- $F' = (F \cap ((P' \times T') \cup (T' \times P'))) \cup ((^\bullet entry_X \backslash X) \times \{i_X\}) \cup \{(i_X, d_X), (d_X, o_X)\} \cup (\{o_X\} \times (exit_X{}^\bullet \backslash X))$;
- $G'(t) = G(t)$, $t \in T' \backslash (exit_X{}^\bullet \cup \{d_X\})$; $G'(t) = G(t)$ and $CCOut_X =$ p, , $t \in exit_X{}^\bullet \backslash X$, $^\bullet t = \{p\}$; n $G'(d_X) =$ true;
- $L'(t) = L(t)$, $t \in T' \backslash (^\bullet entry_X \cup exit_X{}^\bullet \cup \{d_X\})$; $L'(t) = L(t)$; $CCNext_X <=$ p and skip, $\forall t \in {}^\bullet entry_X \backslash X$, $t^\bullet \cap X = \{p\}$; $L'(t) = CCOut_X <= NULL$ and skip; $L(t)$, $t \in exit_X{}^\bullet \backslash X$; n $L'(d_X) =$

1 : ($CCNext_X =$ a_0 and ($G(t_0)$ or $EG_X(a_0)$) or $CCNext_X =$ a_1 or ... or $CCNext_X =$ a_m $\rightarrow$
2 : ...)
3 : ($CCNext_X =$ b_0 and ($G(t_1)$ or $EG_X(b_0)$) or $CCNext_X =$ b_1 or ... or $CCNext_X =$ b_n $\rightarrow$
4 : ...)

n $L'(d_X)$, a_i n b_j, $i \in \{0, 1, \ldots, m\}$, $j \in \{0, 1, \ldots, n\}$, n n m n n m $st_{N|_X}$ $end_{N|_X}$ $a_0 = b_0 = st_{N|_X}$. t_0 n t_1 n n n m $st_{N|_X}$ $end_{N|_X}$. n n m $st_{N|_X}$ $end_{N|_X}$ n . m n , n n 2 (4) n n m n m n m n 3 16 n m n Ann n 1 $LPNext_X$ n $LPOut_X$ n $CCNext_X$ n $CCOut_X$. A n n m n n n 2 n 4 . . n m n n SLN_X. m n $N|_Y$ n n $end_{N|_X}$, m n $CCNext_X <= end_{N|_Y}$ n n 4 m n Ann n 1 $CCNext_X <= NULL$, n n n 10 n 12 m n Ann n 1 m .

RULE ... , ... 6( ) ... d_X ... 6( ),

$G'(t_5) = G(t_5)$ and $CCOut_X$ = q_3 , $L'(t_5) = CCOut_X$ <= $NULL$ and skip; $L(t_5)$,
$G'(t_7) = G(t_7)$ and $CCOut_X$ = q_1 , $L'(t_7) = CCOut_X$ <= $NULL$ and skip; $L(t_7)$,
$L'(t_0) = L(t_0)$; $CCNext_X$ <= q_0 and skip,
$L'(t_6) = L(t_6)$; $CCNext_X$ <= q_2 and skip,
$G'(d_X)$ = true,
$L'(d_X)$ = ($CCNext_X$ = q_0 and $G(t_1) \rightarrow$
if($CCNext_X$ = q_0) then {$CCNext_X$ <= $NULL$ and skip; $L(t_1)$;
($G(t_7) \rightarrow CCNext_X$ <= $NULL$ and $CCOut_X$ <= q_1 and skip)
($G(t_2) \rightarrow L(t_2)$; $CCNext_X$ <= $NULL$ and $CCOut_X$ <= q_3 and skip)})
($CCNext_X$ = q_0 and $G(t_3)$ or $CCNext_X$ = q_2 $\rightarrow$
if($CCNext_X$ = q_0) then {$CCNext_X$ <= q_2 and skip; $L(t_3)$};
if($CCNext_X$ = q_2) then {$L(t_4)$; $CCNext_X$ <= $NULL$ and $CCOut_X$ <= q_3 and skip})

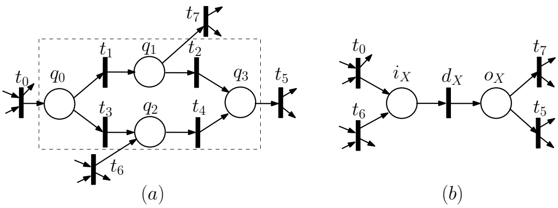

Fig. 6. ...

4.7 RULE FCoS: Folding Concurrent Structure

... $N|_X$, ... $st_{N|_X}$ ...

... A ... $N = (P, T, F, G, L)$ ... $N|_X$, ... $t \in T|_X, B_X(t)$ ... $L(t); (B_X(t_1)|| \ldots ||B_X(t_m))$, $\{t_1, \ldots, t_m\} = t^{\bullet\bullet} \cap (T|_X \backslash \{end_{N|_X}\})$. ... $L(t)$ ... await($vp_1 = 1$ and ... and $vp_m = 1$); vp_1 <= 0 and ... and vp_m <= 0 and skip; $L(t)$, ... $t \in T|_X \backslash \{st_{N|_X}, end_{N|_X}\}$ ... $|{}^{\bullet}t| > 1$, ... $\{p_1, \ldots, p_m\} = {}^{\bullet}t \backslash \{p\}, p \in {}^{\bullet}t$, ... t ... (p, t). ... $t \in T|_X$ ... $\exists q \in t^{\bullet}$, $q^{\bullet} = \emptyset$, ... $L(t)$ ... $L(t); vq_1$ <= 1 and ... and vq_n <= 1 and skip, $\{q_1, \ldots, q_n\} = \{q | \forall q \in t^{\bullet}, q^{\bullet} = \emptyset\}$. ... $\forall t \in T|_X \backslash \{st_{N|_X}, end_{N|_X}\}, |{}^{\bullet}t| = 1$. ... $N|_X$ ... A ... $N' = (P', T', F', G', L')$,

- $P' = (P \backslash X) \cup \{i_X, o_X\}, \{i_X, o_X\} \cap (P \cup T) = \emptyset$;
- $T' = (T \backslash (X \backslash \{st_{N|_X}, end_{N|_X}\})) \cup \{d_X\}, d_X \notin P \cup T \cup \{i_X, o_X\}$;
- $F' = (F \cap ((P' \times T') \cup (T' \times P'))) \cup \{(st_{N|_X}, i_X), (i_X, d_X), (d_X, o_X), (o_X, end_{N|_X})\}$;
- $\forall t \in T' \backslash \{d_X\}, G'(t) = G(t)$, ... $G'(d_X)$ = true;
- $\forall t \in T \backslash \{d_X\}, L'(t) = L(t)$, ... $L'(d_X)$ = frame($vr_1, \ldots, vr_i$) and vr_1 <= 0 and ... and vr_i <= 0 and(($B_X(t_1)$)|| ... ||($B_X(t_n)$)) ... $\{t_1, \ldots, t_n\} \subseteq T|_X$ ... $st_{N|_X}$ ... $vr_1, \ldots, vr_i$ ...

ULE o , n n n . 7 ( ) n m n n d_X n . 7 ( ), $G'(d_X)$ = true n $L'(d_X) = frame(vq_4)$ and vq_4 <= 0 and $((L(t_1);(L(t_3)||(\texttt{await}(vq_4 = 1);vq_4$ <= 0 and skip; $L(t_4))))||(L(t_2);vq_4$ <= 1 and skip)).

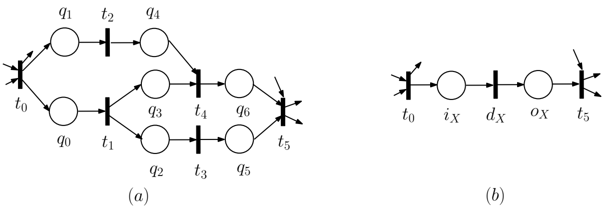

Fig. 7. n n n

4.8 Rule FIS: Folding Irregular Structures

n n $N|_X$, n n n , n $N|_X$ n- n n n . A n - n m , n n m n - m n nn n, n n n n m n .

$N|_X$ n n - A $N = (P, T, F, G, L)$. n $stp_X = \{st_{N|_X}\} \cap P$, $endp_X = \{end_{N|_X}\} \cap P$, $stt_X = \{st_{N|_X}\} \cap T$, n $endt_X = \{end_{N|_X}\} \cap T$. $N|_X$ m n m N. n - n n t_{over} N $t_{over}{}^\bullet = \emptyset$, $L(t_{over}) = over_X$ <= 1 and skip, ${}^\bullet t_{over} = {}^\bullet end_{N|_X} \cap X$ n $G(t_{over}) = G(end_{N|_X})$ $endt_X \neq \emptyset$, ${}^\bullet t_{over} = \{end_{N|_X}\}$ n $G(t_{over}) = \mathrm{OR}_{t \in end_{N|_X}{}^\bullet \setminus X} G(t)$. A n , n n - A $N' = (P', T', F', G', L')$ n ,

- $P' = (P \setminus X) \cup \{i_X, o_X\}$, $\{i_X, o_X\} \cap (P \cup T \cup \{t_{over}\}) = \emptyset$,
- $T' = (T \setminus ((X \cup \{t_{over}\}) \setminus (stt_X \cup endt_X))) \cup \{d_X\}$, $d_X \notin P \cup T \cup \{t_{over}, i_X, o_X\}$,
- $F' = (F \cap ((P' \times T') \cup (T' \times P'))) \cup \{(i_X, d_X), (d_X, o_X)\} \cup F_i \cup F_o$, $F_i = ({}^\bullet stp_X \times \{i_X\}) \cup (\{i_X\} \times (stp_X{}^\bullet \setminus X))$, $stp_X \neq \emptyset$, $F_i = stt_X \times \{i_X\}$; $F_o = (({}^\bullet endp_X \setminus X) \times \{o_X\}) \cup (\{o_X\} \times endp_X{}^\bullet)$, $endp_X \neq \emptyset$, $F_o = \{o_X\} \times endt_X$;
- $G'(t) = G(t)$, $t \in T' \setminus \{d_X\}$; $G'(d_X) = \texttt{true}$, $stp_X = \emptyset$, , $G'(d_X) = \mathrm{OR}_{d \in stp_X{}^\bullet|X} G(d)$;
- $\forall t \in T' \setminus \{d_X\}$, $L'(t) = L(t)$, n $L'(d_X) =$

```
...
pro D() = {
  while(overX = 0){await(vr1 = 1 and ... and vri = 1 or overX = 1);
    if(overX = 0) then{vr1 <= 0 and ... and vri <= 0 and skip;
      (G(t1) → L(t1); vs1 <= 1 and ... and vsj1 <= 1 and skip)
      ...
       (G(tk) → L(tk); vsk <= 1 and ... and vsjk <= 1 and skip)}}};
...
define startX() = {vpj1 <= 1 and ... and vpjk <= 1 and skip};
define endX() = {overX <= 0 and skip};
frame(vp1, ..., vpn, overX) and vp1 <= 0 and ... and vpn <= 0 and overX <= 0 and
(startX(); (D1X()|| ... ||DhX()); endX())
```

n $L'(d_X)$, $p \in P|_X$, n vp

n n . An $st^{\bullet}_{N|_X} = \{p_{j_1}, \ldots, p_{j_k}\}$, $stt_X \neq \emptyset$, $k = 1$ n $p_{j_1} = st_{N|_X}$.

$\{t_1, \ldots, t_k\} = D \in CC_{N|_X} = \{D^1_X, \ldots, D^h_X\}$,

$D()$ n n n m n n n n D . n

D, n n $\{r_1, \ldots, r_i\}$ n , n n

n $N|_X$ n mm n n n. n n

n n , n n n n m , n

n.

ULE , n . 8 ( ) n m n n n .

8 ( ), $G'(d_X) = \texttt{true}$ n $L'(d_X)$ =

```
pro D^1_X() = {
   while(over_X = 0){await(vq_1 = 1 and vq_2 = 1 or over_X = 1);
      if(over_X = 0) then{vq_1 <= 0 and vq_2 <= 0 and skip;(G(t_3) → over_X <= 1 and skip)}}};
pro D^2_X() = {
   while(over_X = 0){await(vq_3 = 1 or over_X = 1);
      if(over_X = 0) then{vq_3 <= 0 and skip; (G(t_2) → L(t_2); vq_1 <= 1 and skip)}}};
pro D^3_X() = {
   while(over_X = 0){await(vq_0 = 1 or over_X = 1);
      if(over_X = 0) then{vq_0 <= 0 and skip;
         (G(t_0) → L(t_0); vq_1 <= 1 and vq_2 <= 1 and skip)
         (G(t_1) → L(t_1); vq_2 <= 1 and vq_3 <= 1 and skip)}}};
define start_X() = {vq_0 <= 1 and skip};
define end_X() = {over_X <= 0 and skip};
frame(vq_3, vq_2, vq_1, vq_0, over_X) and vq_3 <= 0 and vq_2 <= 0 and vq_1 <= 0 and vq_0 <= 0
and over_X <= 0 and (start_X(); (D^1_X()||D^2_X()||D^3_X()); end_X())
```

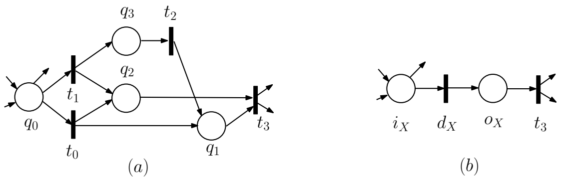

Fig. 8.

4.9 Translation Algorithm

n n n , A m n n n

m n - m .

n m n A m , $p_h \in P = \{p_1, \ldots, p_a\}$, p_h n n m. , p_1

N. $v_1, \ldots, v_b$ n n -

n $v^1_i, \ldots, v^j_i$ ($v^1_s, \ldots, v^k_s$) n (n) m n m.

n n t T n n m n , $^{\bullet}t = \{p^1_t, \ldots p^m_t\}$ n $t^{\bullet} = \{q^1_t, \ldots, q^n_t\}$.

Algorithm PN2MSVL:
Translation from sound free-choice WFNs to MSVL programs

Input: A n - $N = (P, T, F)$;
Output: A m;

n N n n A $AN = (P, T, F, G, L)$;
while $|T| > 1$
  if AN n n **then** A ULE AN; n n ;
  if AN n **then** A ULE AN; n n ;
  if AN n **then** A ULE AN; n n ;
  if AN m **then** A ULE AN; n n ;
  if AN m **then** A ULE AN; n n ;
  if AN m **then** A ULE AN; n n ;
  if AN n n **then** A ULE o AN; n n ;
  if AN n **then** A ULE AN; n n ;
A n n, m n n n m n $L(t)$; /* $T = \{d\}$ */
return n m n .
  frame($p_1, \ldots, p_a, v_1, \ldots, v_b$) and p_1 <= 1 and p_2 <= 0 and … and p_a <= 0 and
  v_i^1 <= 0 and … and v_i^j <= 0 and v_s^1 <= $NULL$ and … and v_s^k <= $NULL$ and (
    define $t()$ = {p_t^1 <= 0 and … and p_t^m <= 0 and skip;
      q_t^1 <= 1 and … and q_t^n <= 1 and skip};
    …
    $L(d)$)

5 Experiments

A m n m
(http://ictt.xidian.edu.cn/toolkit/). n -
m n 21 n m.
n - n . 9, m n n
.

```
frame(p9, p8, p7, p6, p5, p4, p3, p2, p1, p0, LPNext0, LPOut0) and p0 <= 1 and p9 <= 0
and p8 <= 0 and p7 <= 0 and p6 <= 0 and p5 <= 0 and p4 <= 0 and p3 <= 0 and p2 <= 0
and p1 <= 0 and LPNext0 <= NULL and LPOut0 <= NULL and (
  define t8() = {p8 <= 0 and p6 <= 0 and skip; p9 <= 1 and skip};
  ...
  t0();
  frame(vp7) and vp7 <= 0 and (
    (await(vp7 = 1); vp7 <= 0 and skip; t6())||
    (
      (true → t5(); LPNext0 <= p4 and skip) (true → t1(); LPNext0 <= p3 and skip);
      while(¬(LPNext0 = NULL)){
        if(LPNext0 = p3)then{LPNext0 <= p4 and skip; t2()}
        if(LPNext0 = p4)then{LPNext0 <= p3 and skip; t3();
          (true → LPNext0 <= NULL and LPOut0 <= p5 and skip) (true → t7())}};
      LPOut0 <= NULL and skip; t4(); vp7 <= 1 and skip));
  t8())
```

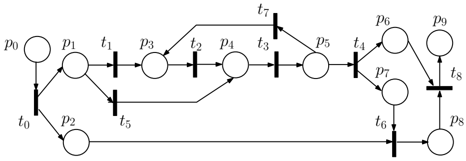

Fig. 9. A n

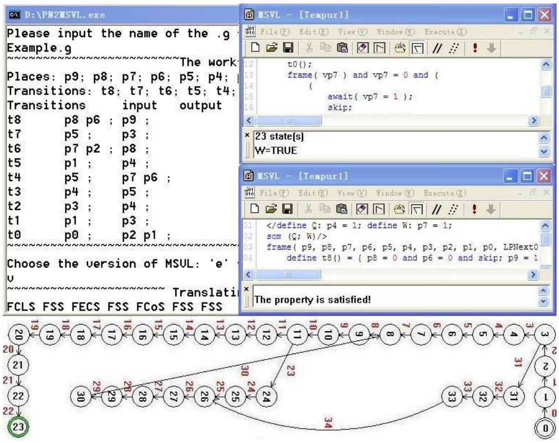

Fig. 10.

. 10, W = true

$$\Diamond(Q; W)$$

Q W $p4 = 1$ $p7 = 1$, $p4 = 1$, $p7 = 1$. 10. . 10.

6 Conclusion

An

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