Syntactic Editing of Tabular Forms by Attribute edNCE Graph Grammars

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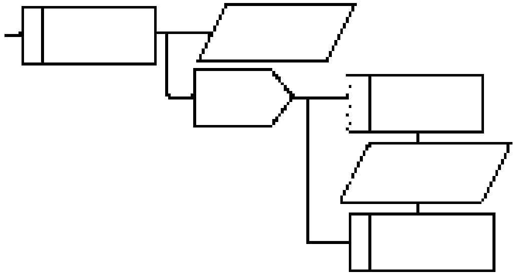
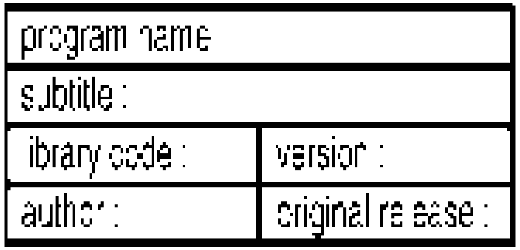
1. Introduction

Target

	Flow Chart	Program Specification
Diagram	Hierarchical Diagram	Nested Diagram
		 program name subtitle : library code : version : author : original release :
Graph	Attribute Tree	Attribute Marked Tree (ICSE98)
Graph Grammar	Attribute NCE CFGG (COMPSAC96)	Attribute NCE CFGG (IFIP2000)
Editor Command	○ (COMPSAC96)	This paper

Motivation

- Graph grammar was used to the formalism of the tabular forms.
- Uses an attribute for the layout.
  - It’s necessary to make syntactic editing method by an attribute graph grammar.

Back Ground

The Cornel Program Synthesizer (CPS)

(text-based editor) T.Teitelbaum (1981)

The graph editing by the graph grammar

Göttler (1986)

Attribute Graph Grammar Nishino(1989)

edNCE Graph Grammar Rozenberg(1996)

Our History

1996 Hichart Diagram Syntactic Editing
Command [COMPSAC9 6] (Anzai et al.)

1997 Program Specification Hiform
[APEC97] (Sugita et al,)

2000 Syntactic Processing of Diagrams by
Graph Grammars [IFIP WCC 2000]

This paper Tabular Diagram Editing Methods

Related Works

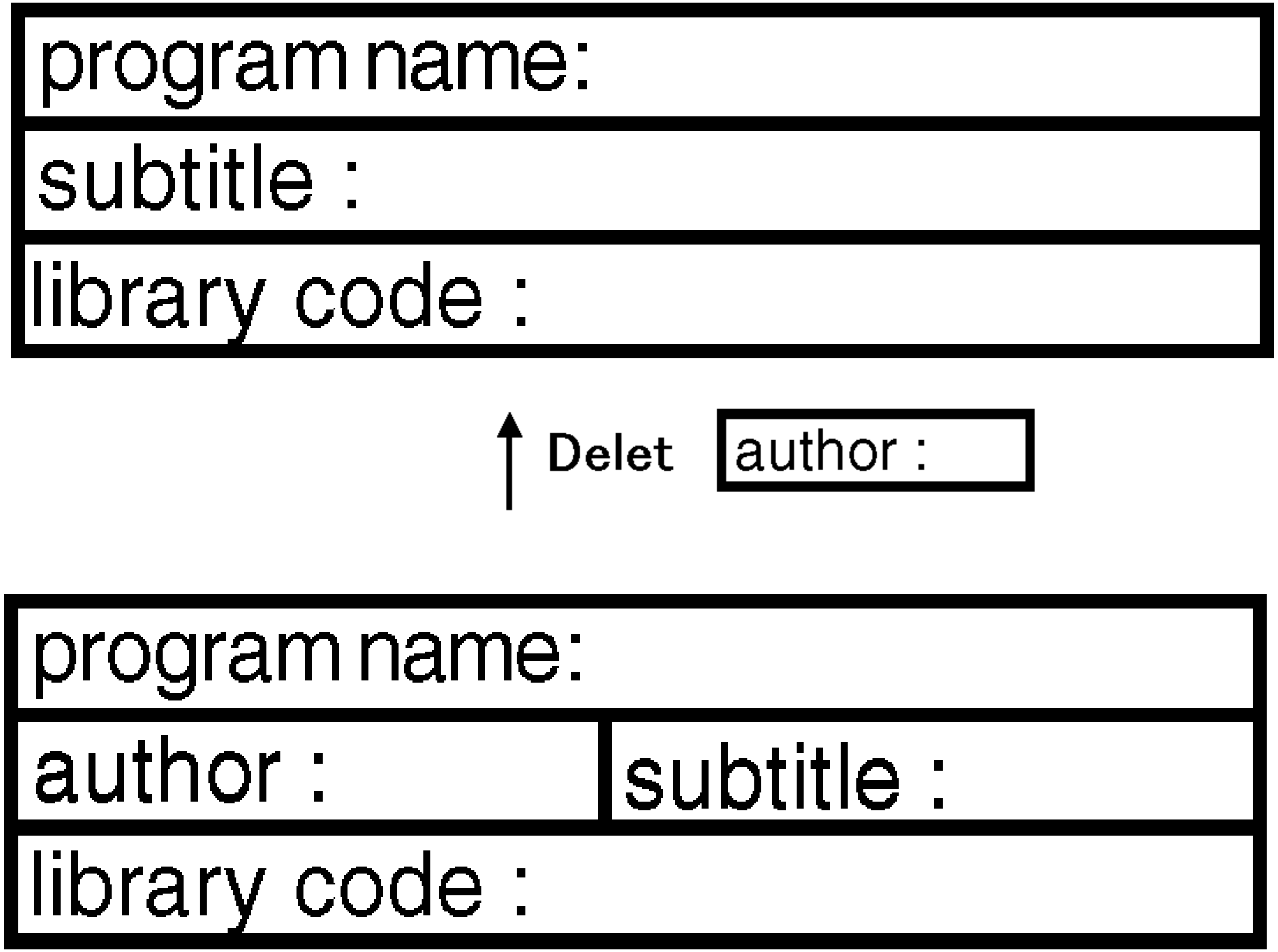
- Application of Graph Grammar were developed such as DIAGEN, IPSEN and APPLIGRAPH.
- Our project for graph processing was named KEYAKI-CASE2000.

Purpose

- Constructing the tabular form editing mechanisms based on graph grammar

Results

- The definitions of the editing methods based on the attribute edNCE graph grammars for the tabular forms
- The example of the insertion and the deletion of the Item



program name:

subtitle :

library code :

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author :

program name:

author :

subtitle :

library code :

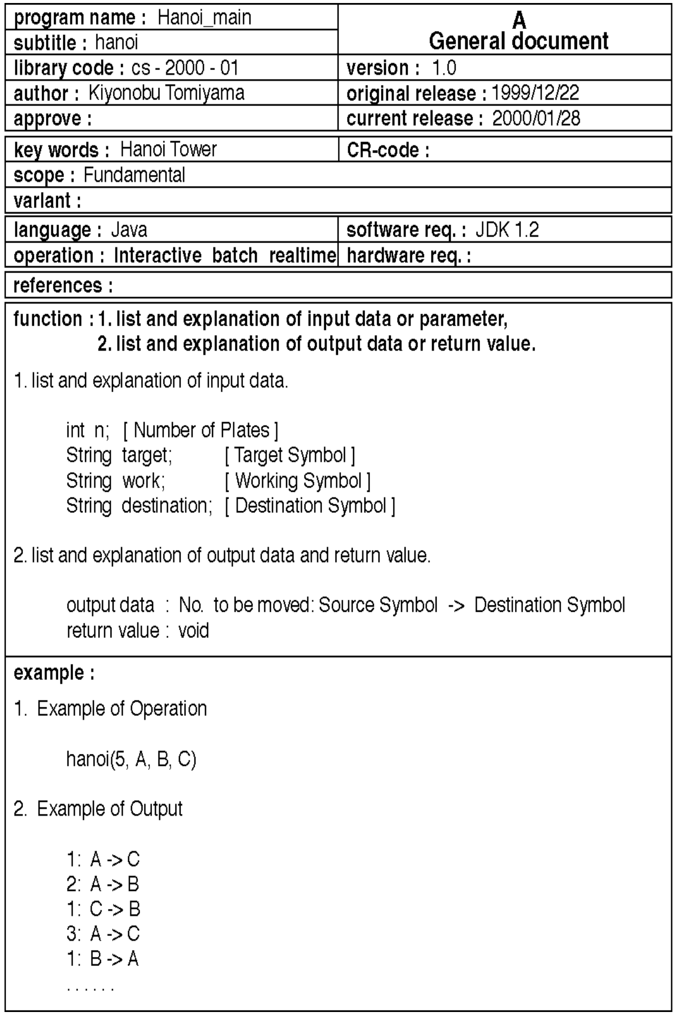
2. Preliminaries

2. Preliminaries

Program Specification Hiform [10]

(a program specification language)

- ●17 type of Forms based on ISO6592
- ●A collection of tabular forms



program name : Hanoi_main	A **General document**
subtitle : hanoi	
library code : cs - 2000 - 01	**version :** 1.0
author : Kiyonobu Tomiyama	**original release :** 1999/12/22
approve :	**current release :** 2000/01/28
key words : Hanoi Tower	**CR-code :**
scope : Fundamental	
varIant :	
language : Java	**software req. :** JDK 1.2
operation : Interactive batch realtime	**hardware req. :**
references :	

function : 1. list and explanation of input data or parameter,
2. list and explanation of output data or return value.

1. list and explanation of input data.

```
int  n;   [ Number of Plates ]
String  target;        [ Target Symbol ]
String  work;          [ Working Symbol ]
String  destination;   [ Destination Symbol ]
```

2. list and explanation of output data and return value.

```
output data  :  No.  to be moved: Source Symbol  ->  Destination Symbol
return value :  void
```

example :

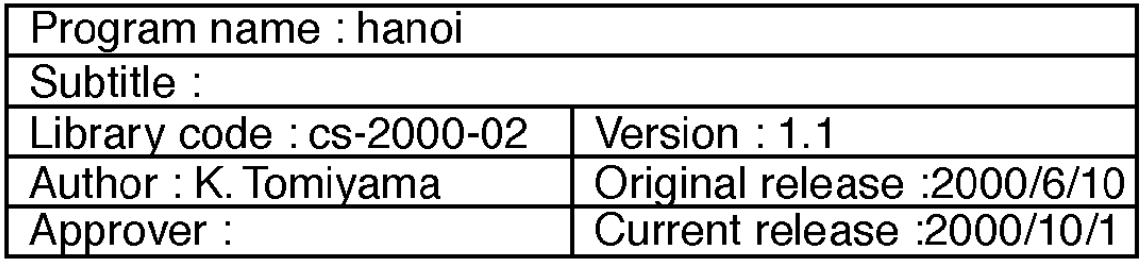
1. Example of Operation

```
hanoi(5, A, B, C)
```

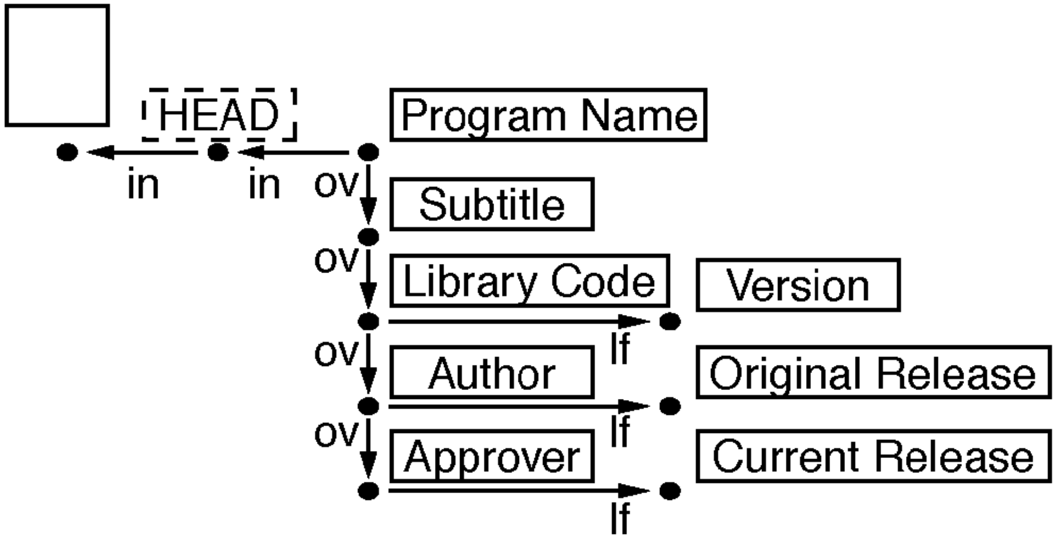
2. Example of Output

```
1:  A -> C
2:  A -> B
1:  C -> B
3:  A -> C
1:  B -> A
. . . . . .
```

Tabular form and its corresponding graph



Program name : hanoi	
Subtitle :	
Library code : cs-2000-02	Version : 1.1
Author : K. Tomiyama	Original release :2000/6/10
Approver :	Current release :2000/10/1



2.1 An Attribute edNCE Graph Grammar

An attribute edNCE Graph Grammar：AGG=＜G,Att,F＞

G= （Σ,Δ,Γ,Ω,P,S）：Underlying graph grammar of AGG

Att= $\underset{Y\in V}{\dagger}$ Att（Y） （Att(Y)=Inh(Y)∪Syn(Y)）

F= $\underset{p\in P}{\dagger}$ F_p ：Semantic rules of AGG

edNCE Graph Grammar[6]

Definition

edNCE graph grammar：G= (Σ, Δ, Γ, Ω,P,S)

Σ：The alphabet of node labels

Δ ⊆ Σ：The alphabet of terminal node labels

Γ：The alphabet of edge labels

Ω ⊆ Δ： The alphabet of final edge labels

P： The finite set of productions

S∈ Σ - Δ： The initial nonterminal

edNCE (continue)

production $p : X \rightarrow (D,C)$

$X \in \Sigma - \Delta$

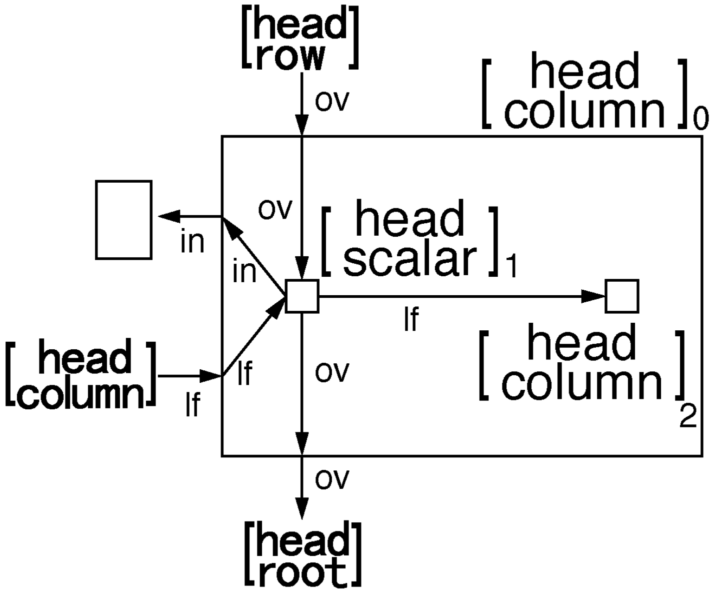
$(D,C) \in GRE_{\Sigma,\Gamma}$

$D \in GR_{\Sigma,\Gamma}$

$C \subseteq \Sigma \times \Gamma \times \Gamma \times V_D \times \{in,out\}$: connection relation

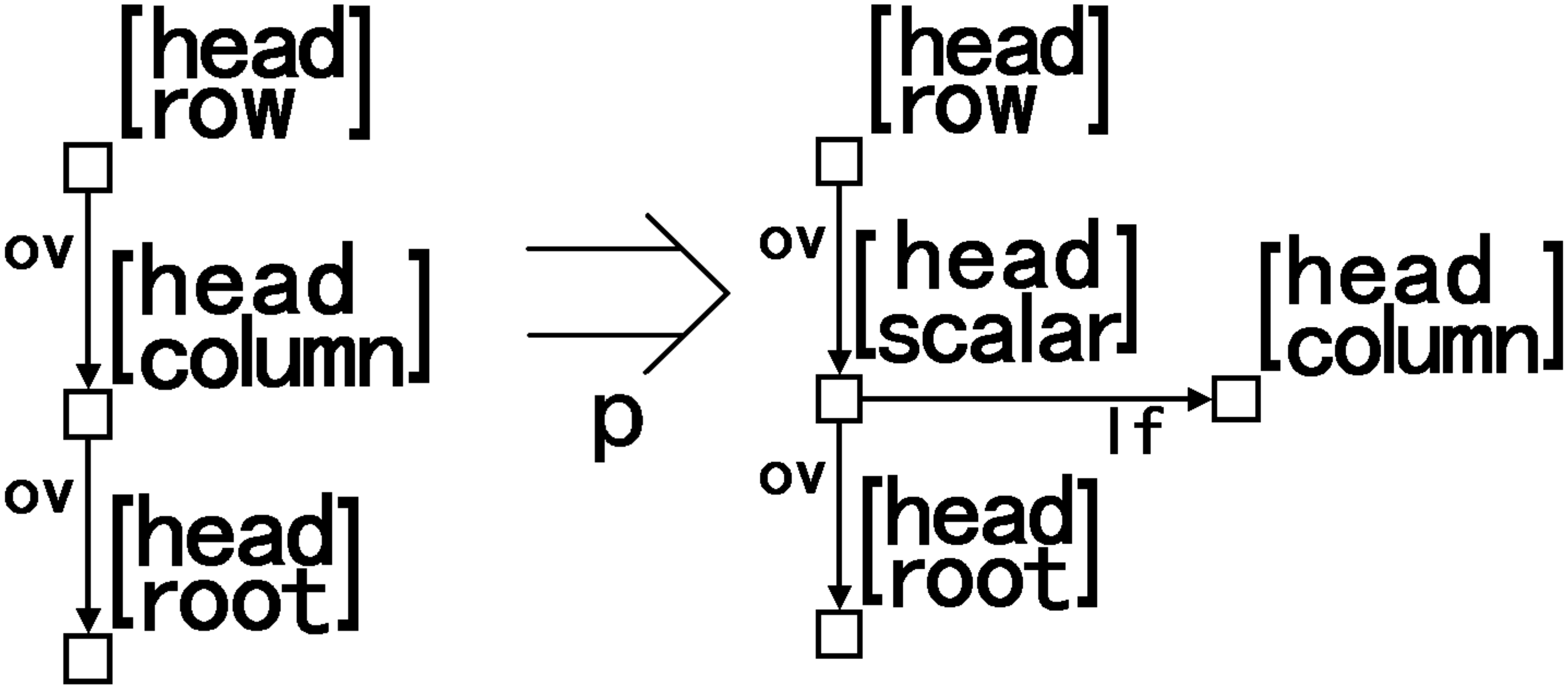
Production

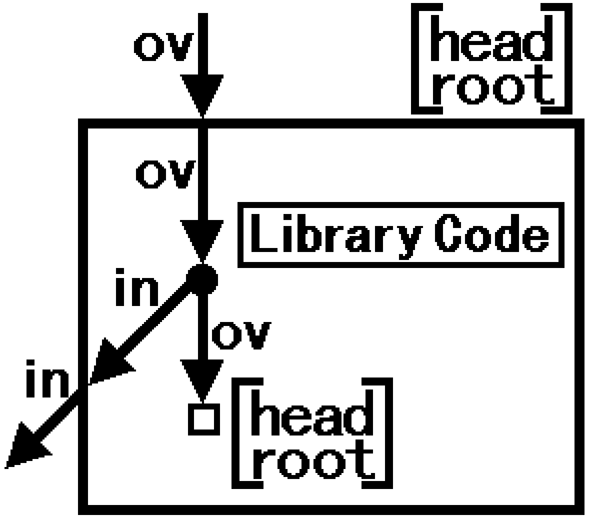
p :



C={([head-row],ov/ov,1,in),(□,in/in,1,out),
([head-column],lf/lf,1,in),([head-root],ov/ov,1,out)}

Derivation


[head row]
ov
[head column]
ov
[head root]
p
[head row]
ov
[head scalar]
lf
[head column]
ov
[head root]



C={ (α ,ov/ov,1,in) ,(β ,in/in,1,out)} such that ∀ α , β ∈ Σ

2.2 COMPOSITION OF PRODUCTION COPIES [4]

Definition

$G=(\Sigma,\Delta,\Gamma,\Omega,P,S)$ ：edNCE-CFGG

$p_1{:}X_1\rightarrow(D_1,C_1)$, $p_2{:}X_2\rightarrow(D_2,C_2)$ ：production copy of G

X_2exists in node labels of D_1

The composite production copy p：$X_1\rightarrow(D,C)$

is defined as follows：

$D=D_1-\{X_2\}\cup D_2$

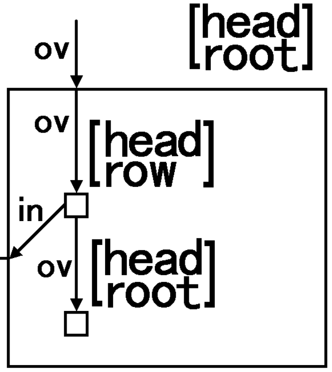
$C=\{(\sigma,\beta/\gamma,\omega,d)\in C1|\omega\in V_{D1}-V_{X2}\}$

$\cup\{(\sigma,\beta/\delta,y,d)|\exists\,\omega\in V_{X2}\exists\,\gamma\in\Gamma,(\sigma,\beta/\gamma,\omega,d)\in C_1,$
$(\sigma,\gamma/\delta,y,d)\in C_2\}$

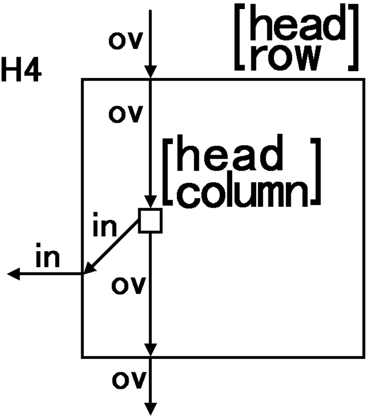
Denoted by p1○p2

COMPOSITION OF PRODUCTION COPIES

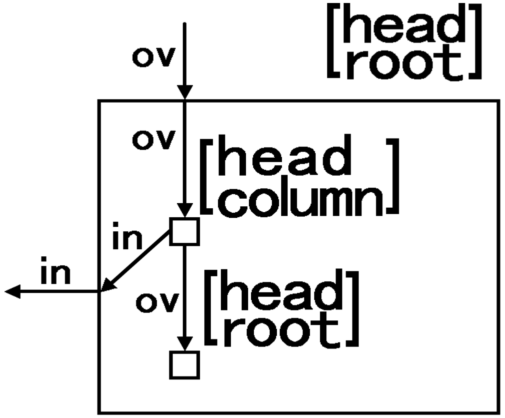
p_{H2}



p_{H4}



p_{H2} □ p_{H4}



2.3 Confluence Property [6]

Definition

An edNCE graph grammar G= (Σ,Δ,Γ,Ω,P,S) is confluent if the following holds for every sentential form H of G:

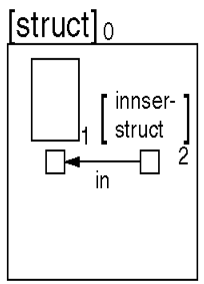
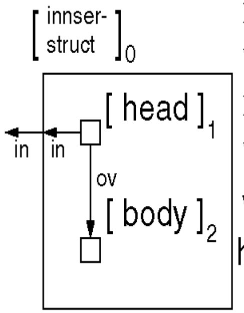
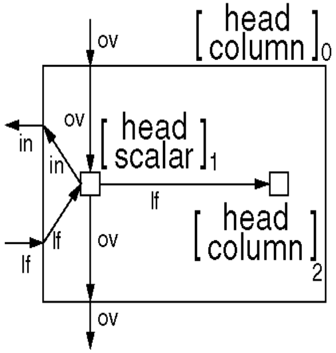
If $\boxed{H \Rightarrow_{u1,p1} H_1 \Rightarrow_{u2,p2} H_{12}}$ and $\boxed{H \Rightarrow_{u2,p2} H_1 \Rightarrow_{u1,p1} H_{21}}$ (p1,p2∈P)
are derivation of G with
u1,u2∈VH and u1≠u2,
then $\boxed{H12=H21}$

2.4 HNGG [10]

Hiform Nested Graph Grammar

HNGG=$<G_N, A_N, F_N,>$

Underlying graph grammar G_N= $(\Sigma_N, \Delta_N, \Gamma_N, \Omega_N, P_N, S_N)$ (context-free edNCE graph grammar)

p_1		$x(1) = x(0)$ $y(1) = y(0)$ $x(2) = x(0)$ $y(2) = y(0)$ $width(0) = width(2)$ $height(0) = height(2)$
p_2		$x(1) = x(0)+Mleft$ $y(1) = y(0)+Mtop$ $x(2) = x(0)+Mleft$ $y(2) = y(0)+height(1)+Mcen$ $width(0) = max(width(1),width(2))$ $height(0) = height(1)+height(2) +Mtop+Mcen+Mbottom$
p_{H5}	 ov [head column]0 ov in in [head scalar]1 lf lf lf ov [head column]2 ov	$x(1) = x(0)$ $x(2) = x(0)+width(1)+HSh$ $y(1) = y(0)$ $y(2) = y(0)$ $width(0) = width(1)+width(2)+HSh$ $height(0) = max(height(1), height(2))$

3 Editing of Nested Tabular Form

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3. 1 Production Instance

Production Instance : (ω, p_i, H'_{p_i})

$\omega \in VD_{i-1}$:a node removed during the derivation $D_{i-1} \Rightarrow_{pi} D_i$

$p_i \in P$:a production

H'_{p_i} :an embedded graph isomorphic H_{p_i} during $D_{i-1} \Rightarrow_{pi} D_i$

$D_{i-1} \overset{\omega H'pi}{\underset{pi}{\Rightarrow}} D_i$:

D_{i-1} is directly derived D_i by applying the (ω, p_i, H'_{p_i})

3.2 Syntactic Insertion

3.2 Syntactic Insertion

Definition (insertable)

For the derivation sequence

$D_0 \overset{\omega 1\, H'p1}{\underset{\mathbf{p}1}{\Rightarrow}} \cdots \overset{\omega i-1\, H'pi-1}{\underset{\mathbf{p}i-1}{\Rightarrow}} \boxed{D_{i-1}} \boxed{\overset{\omega\, H'pi}{\underset{\mathbf{p}i}{\Rightarrow}} D_i \overset{\omega i+1\, H'pi+1}{\underset{\mathbf{p}i+1}{\Rightarrow}} \cdots \overset{\omega n\, H'pn}{\underset{\mathbf{p}n}{\Rightarrow}} D_n}$ $(p_j : X_{p_j} \to (H_{p_j}, C_{p_j}), 1 \leqq j \leqq n)$,

Production q is <u>insertable</u> (for pi) :

Instance $(\omega_{,q}, H'_q)$ $(q = X_q \to (H_q, C_q) \in P)$ such that $\boxed{D_{\,i-1} \overset{\omega\, H'q}{\underset{q}{\Rightarrow}} Q,}$

$D_{i-1} \overset{\omega\, H'q}{\underset{q}{\Rightarrow}} Q \boxed{\overset{\omega'\, H'pi}{\underset{\mathbf{p}i}{\Rightarrow}} D'_i \overset{\omega i+1\, H'pi+1}{\underset{\mathbf{p}i+1}{\Rightarrow}} \cdots \overset{\omega n\, H'pn}{\underset{\mathbf{p}n}{\Rightarrow}} D'_n}$ exists.

□

Since a production $q \in P_N$ is insertable for p_i , then insertion of an production q into an production sequence $(p_1 , \cdots, p_i , \cdots , p_n)$ makes an production sequence

$(p_1 , \cdots, p_{i-1} , q , p_i , \cdots, p_n)$ which derives a graph D'_n as follows.

1. Trace the derivation sequence D_n back to D_{i-1}.

$$D0 \overset{\omega 1\ H'p1}{\underset{\mathbf{p}1}{\Rightarrow}} \cdots \overset{\omega i{-}1\ H'pi\text{-}1}{\underset{\mathbf{p}\,i-1}{\Rightarrow}} Di\text{-}1$$

2. Apply the production q to D_{i-1}, and get the resultant graph Q .

$$D0 \overset{\omega 1\ H'p1}{\underset{\mathbf{p}1}{\Rightarrow}} \cdots \overset{\omega i{-}1\ H'pi\text{-}1}{\underset{\mathbf{p}\,i-1}{\Rightarrow}} Di\text{-}1 \overset{\omega\ H'q}{\underset{q}{\Rightarrow}} Q$$

3. Apply the production sequence $(p_i , p_{i+1} , \bullet \bullet \bullet, p_n)$ to Q, and get the resultant graph D'_n.

$$D0 \overset{\omega 1\ H'p1}{\underset{\mathbf{p}1}{\Rightarrow}} \cdots \overset{\omega i{-}1\ H'pi\text{-}1}{\underset{\mathbf{p}\,i-1}{\Rightarrow}} Di\text{-}1 \overset{\omega\ H'q}{\underset{q}{\Rightarrow}} Q \overset{\omega'\ H'pi}{\underset{\mathbf{p}\,i}{\Rightarrow}} D'i \overset{\omega\, i{+}1\ H'pi{+}1}{\underset{\mathbf{p}\,i+1}{\Rightarrow}} \cdots \overset{\omega\, n\ H'pn}{\underset{\mathbf{p}\,n}{\Rightarrow}} D'n$$

Definition

To insert a source graph *A* at edge *x* in a target graph *H*.

$$\overset{def}{\Leftrightarrow}$$

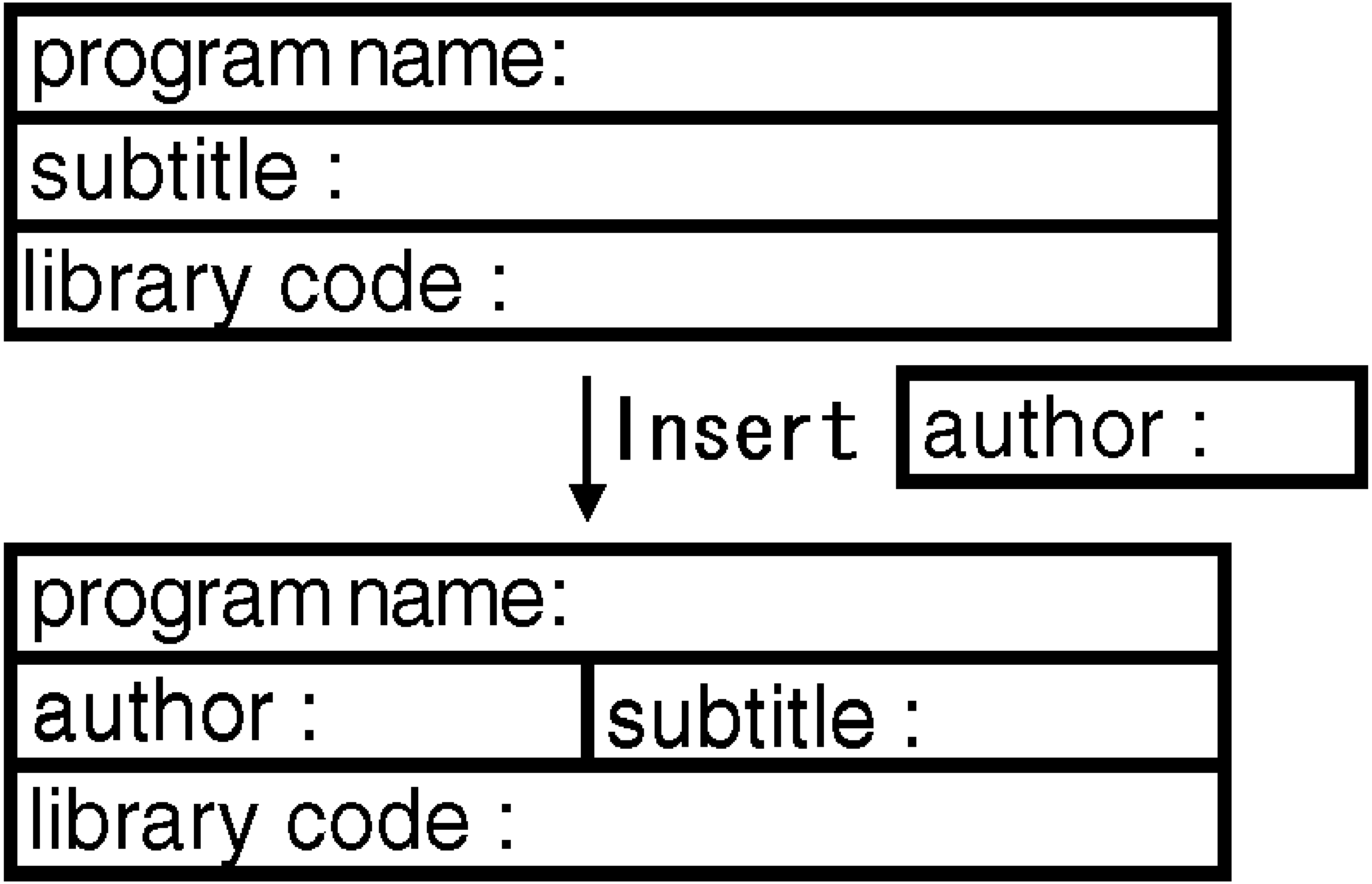
1. A composite production copy *q* for the graph *A* exists.

2. The composite production copy *q* can be insertable at the edge *x* in the graph *H*.

3. $H \rightarrow \bullet\bullet\bullet \longrightarrow H'$ **:**

***H'* is the inserted graph which inserts the graph *A* at the edge *x*.**

□



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author :

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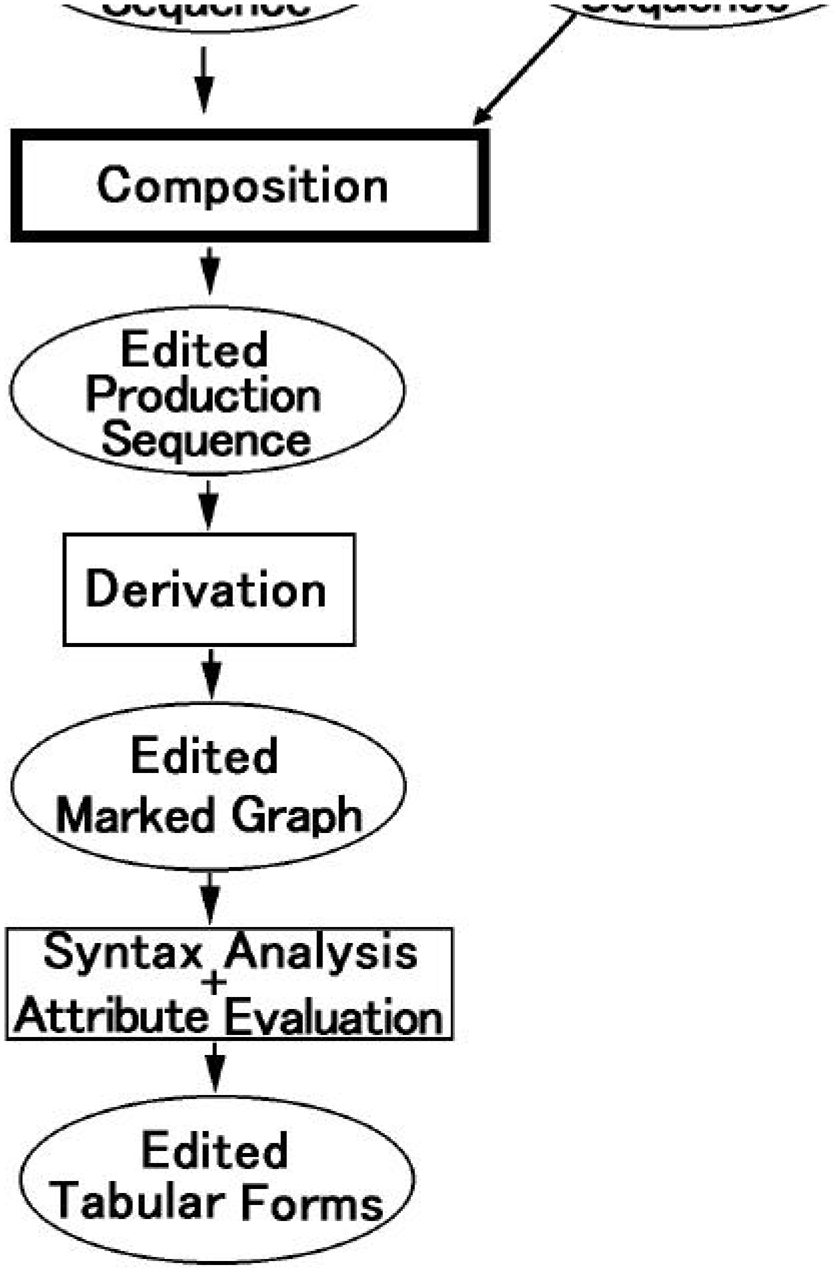


A process flow for an insertion of Hiform editing system

3.3 Syntactic Deletion of Item

3.3 Syntactic Deletion of Item

Definition (deletable)

For the derivation sequence $D_0 \underset{p1}{\overset{\omega 1\ H'p1}{\Rightarrow}} \cdots \underset{pk}{\overset{\omega k\ H'k}{\Rightarrow}} F \underset{p}{\overset{\omega\ H'p}{\Rightarrow}} D\ p \underset{pl}{\overset{\omega l\ H'l}{\Rightarrow}} \cdots \underset{pn}{\overset{\omega n\ H'pn}{\Rightarrow}} D_n$,

The graph that D_p has node $u \in V_D$ for the first time

Node u is not applied to any production after that.

Production $p=X_p \rightarrow (D_p,C_p) \in P_N$ is deletable if one of the following Assumptions 1-3 is met

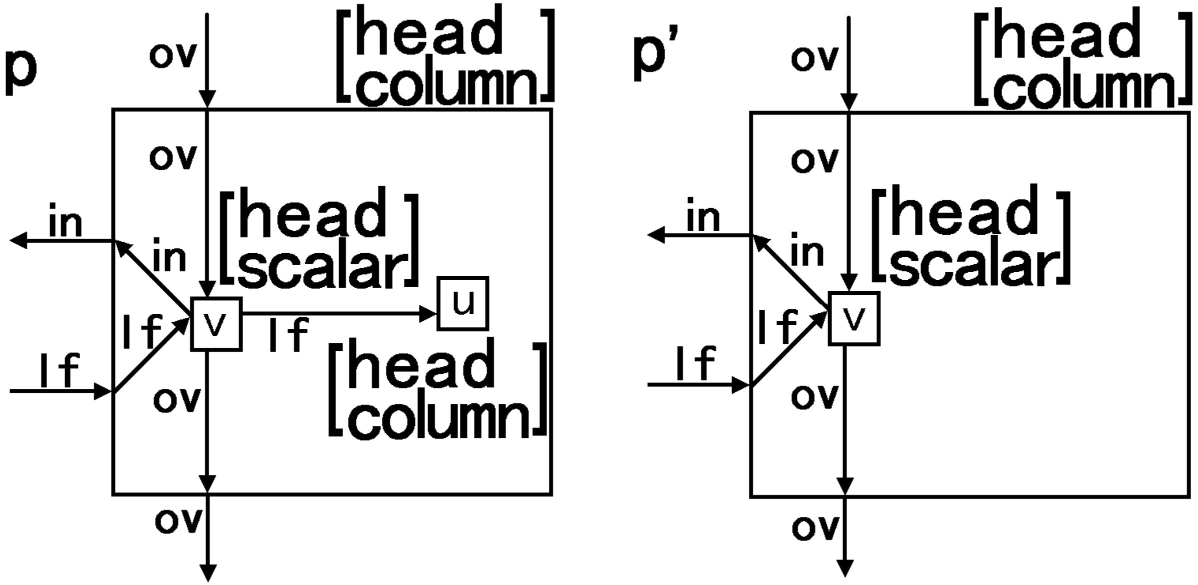
Assumption 1

For $p \in P_N$, $\exists$ p': $X_p \to D({}_p, C_p) \in P_N$ s.t.

1. $X_{p'} = X_p$
2. $H_{p'} \equiv H'_p - \{u\}$
3. f, g: isomorphic mappings, $f: V_{H'p} \to V_{Hp}$ 、 $g: V_{Hp - \{f(u)\}} \to V_{Hp'}$

   then $(\sigma, \beta / \gamma, y, d) = (\sigma, \beta / \gamma, g(y), d)$

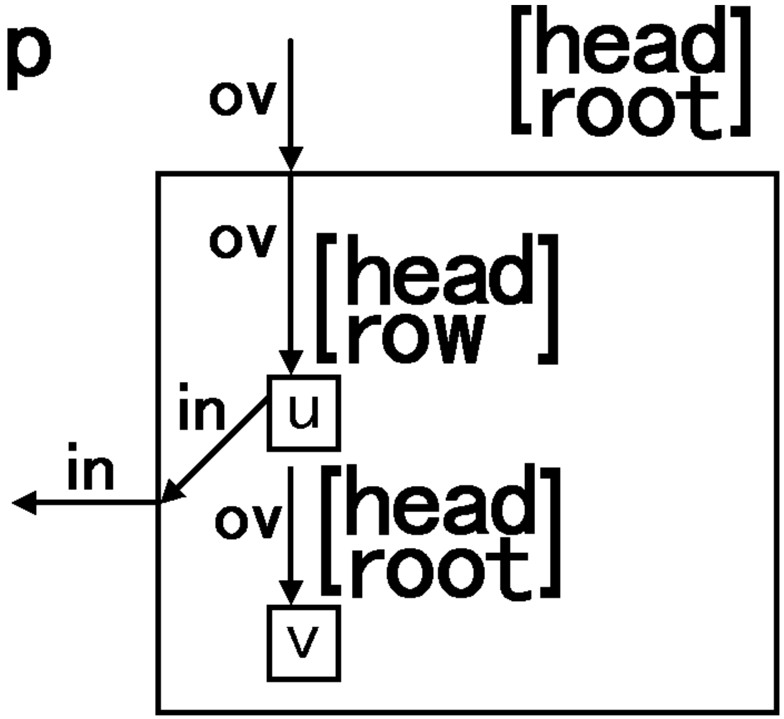
For example:



Assumption 2

$$V_{H'p} = \{u,v\}, \quad X_{H'p} = \rho_{H'p}(v)$$

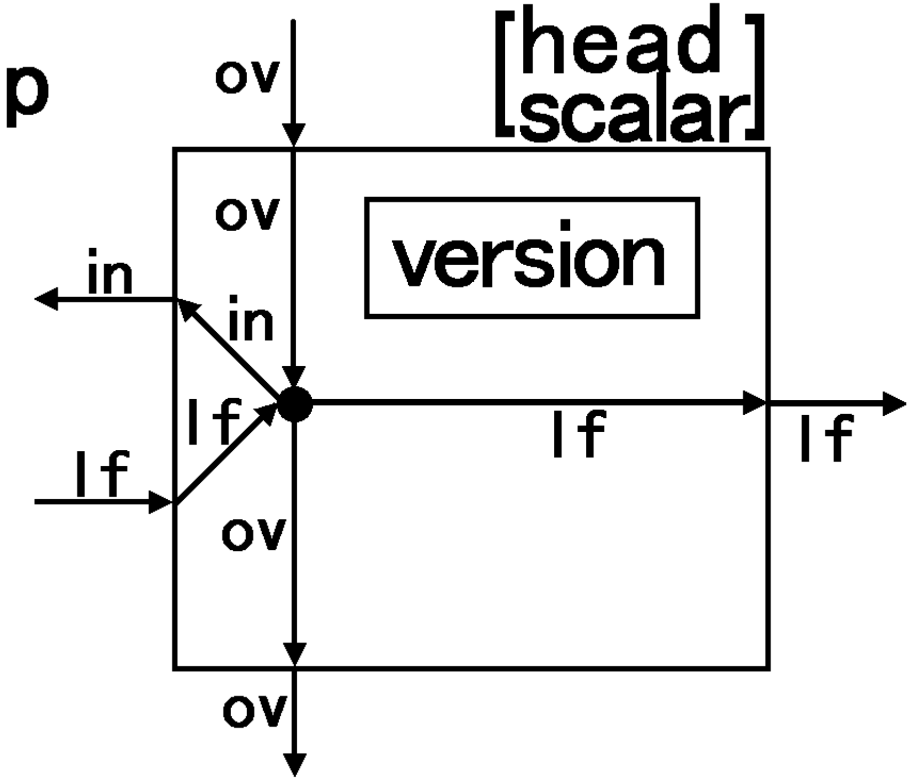
For example:



Assumption 3

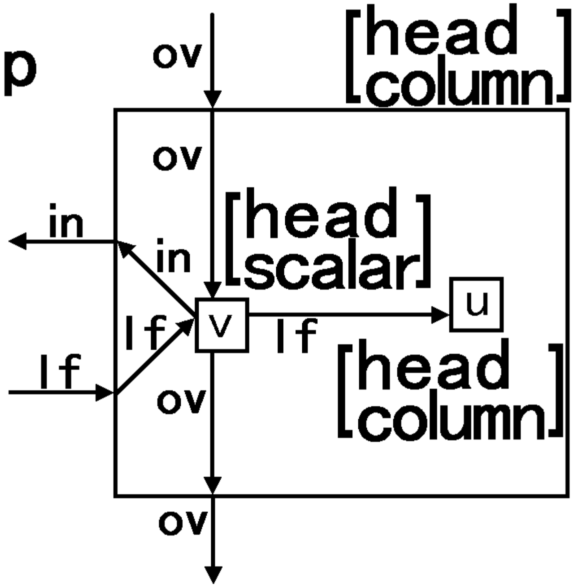
$$\omega_j \notin H'_p \; , \quad 1 \leqq j \leqq n$$

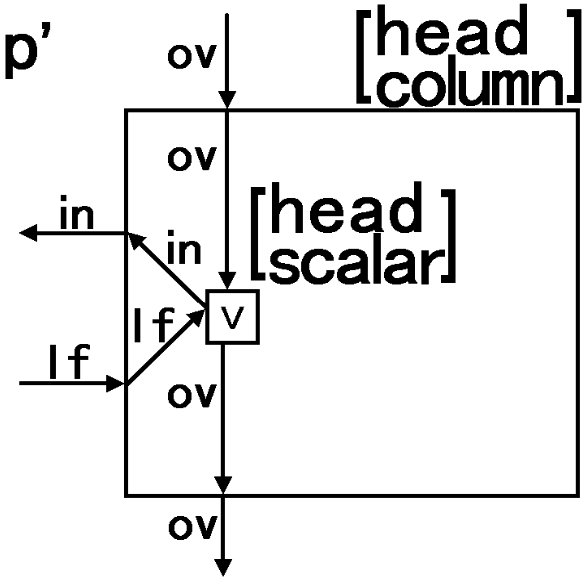
For example:



□

The case of Assumption1





Since a production $p \in P_N$ is deletable, deletion of a production p from a production sequence

$L=(p_1 ,\cdots,p_k ,$ p , $p_l ,\cdots, p_n)$ makes an production sequence $(p_1,\cdots, p_k ,$p'$, p_l , \cdots , p_n)$,which derives a graph D'n as follows.

1. Trace the derivation sequence Dn back to F.

$$D0 \underset{\mathbf{p}1}{\overset{\omega 1\, H'p1}{\Rightarrow}} \cdots \underset{\mathbf{p}k}{\overset{\omega k\, H'k}{\Rightarrow}} F$$

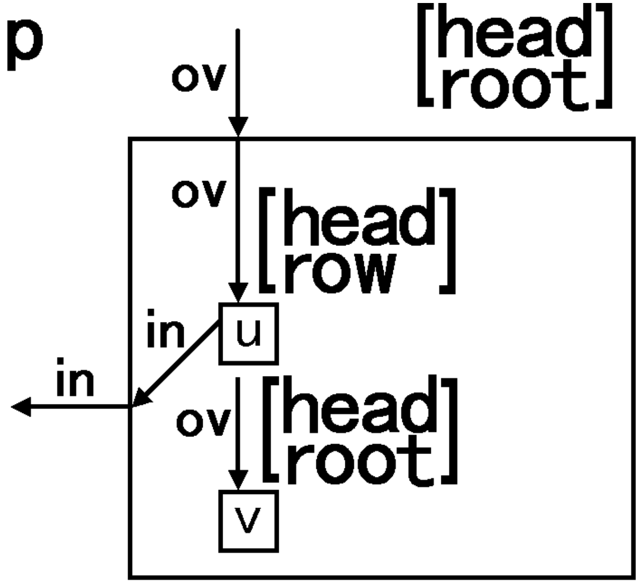
2. Apply the production p’ to F, and get the resultant graph D'p.

$$D0 \underset{\mathbf{p}1}{\overset{\omega 1\, H'p1}{\Rightarrow}} \cdots \underset{\mathbf{p}k}{\overset{\omega k\, H'k}{\Rightarrow}} F \underset{\mathbf{p}'}{\overset{\omega\, H'p'}{\Rightarrow}} D\,'p$$

3. Apply the production sequence (p_l , • • •, p_n) to D'p, and get the resultant graph D’n.

$$D0 \underset{\mathbf{p}1}{\overset{\omega 1\, H'p1}{\Rightarrow}} \cdots \underset{\mathbf{p}k}{\overset{\omega k\, H'k}{\Rightarrow}} F \underset{\mathbf{p}'}{\overset{\omega\, H'p'}{\Rightarrow}} D\,'p \underset{\mathbf{p}\,l}{\overset{\omega\, l\ H'l}{\Rightarrow}} \cdots \underset{\mathbf{p}\,n}{\overset{\omega\, n\ H'pn}{\Rightarrow}} D\,'n$$

The case of Assumption 2



Since a production $p \in P_N$ is deletable, deletion of a production p from a production sequence

$L=(p_1, \cdots, p_k, p, p_l, \cdots, p_n)$ makes an instance sequence $(p_1, \cdots, p_k, p_l, \cdots, p_n)$, which derives a graph D‘n as follows.

1. Trace the derivation sequence Dn back to F.

$$D0 \underset{p1}{\overset{\omega 1\, H'p1}{\Rightarrow}} \cdots \underset{pk}{\overset{\omega k\; H'k}{\Rightarrow}} F$$

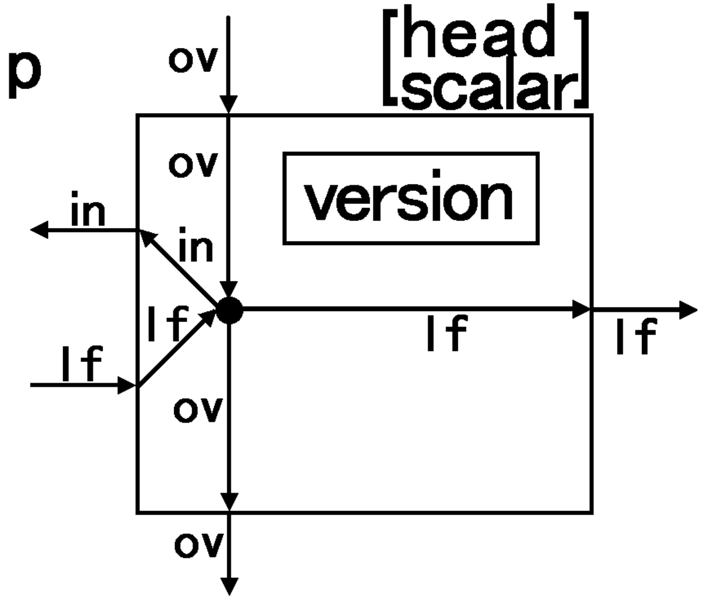
2. Rename the node $\omega \in V_F$ as v, and get the resultant graph F'.

$$D0 \underset{p1}{\overset{\omega 1\, H'p1}{\Rightarrow}} \cdots \underset{pk}{\overset{\omega k\; H'k}{\Rightarrow}} F'$$

3. Apply the production sequence $(p_l$, ..., $p_n)$ to F', and get the resultant graph D'n.

$$D0 \underset{p1}{\overset{\omega 1\, H'p1}{\Rightarrow}} \cdots \underset{pk}{\overset{\omega k\; H'k}{\Rightarrow}} F' \underset{pl}{\overset{\omega l\; H'l}{\Rightarrow}} \cdots \underset{pn}{\overset{\omega n\; H'pn}{\Rightarrow}} D\ 'n$$

The case of Assumption 3



Since a production $p \in P_N$ is deletable, deletion of a production p from an instance sequence $L=(p_1,\bullet\bullet\bullet,p_k\ ,\ p\ ,p_l\ ,\bullet\bullet\bullet,p_n)$makes an instance sequence $(p_1,\bullet\bullet\bullet p_k\ ,\ p_l\ ,\ \bullet\bullet\bullet,p_n\ )$, which derives a graph D’n as follows.

1. Trace the derivation sequence Dn back to F

$$D0 \underset{\mathbf{p}1}{\overset{\omega 1\ H'p1}{\Rightarrow}} \cdots \underset{\mathbf{p}k}{\overset{\omega k\ H'k}{\Rightarrow}} F$$

2. Apply the production sequence $(p_l, \ldots, p_n)$ to F, and get the resultant graph D’n.

$$D0 \underset{\mathbf{p}1}{\overset{\omega 1\ H'p1}{\Rightarrow}} \cdots \underset{\mathbf{p}k}{\overset{\omega k\ H'k}{\Rightarrow}} F \underset{\mathbf{p}l}{\overset{\omega l\ H'l}{\Rightarrow}} \cdots \underset{\mathbf{p}n}{\overset{\omega n\ H'pn}{\Rightarrow}} D\ 'n$$

Definition

To <u>delete</u> a node *A* from a graph *H*

$\overset{def}{\Leftrightarrow}$

①A production *q* having a node *A* on the right hand side exists.

②The production *q* is deletable in the instance sequence for graph *H*.

③ *H*→ ••→*H* ’:

H' is the deleted graph which deletes the node *A* in the graph *H*.

3.4 Deletion of Blocked Items

Let D=(V_D,E_D,λ_D) be a graph.Let T⊆D be a subgraph.

Then, the deletion of the production about the derivation of T has been performed as follows.

1. D ’＝D
2. Let T⊆D' be a subgraph.
3. In derivation sequence D0⇒・・⇒D',

   q can be removed from the production in T.

   a) If q exists, the graph which removed q from the sequence, and then renew D' and return to 2.

   b) It is finished if q does not exist.

3.5 Property of Editing Method

Theorem 3.1

Deletion (insertion, block deletion) in HNGG is executed in linear time.

□

Theorem 3.2

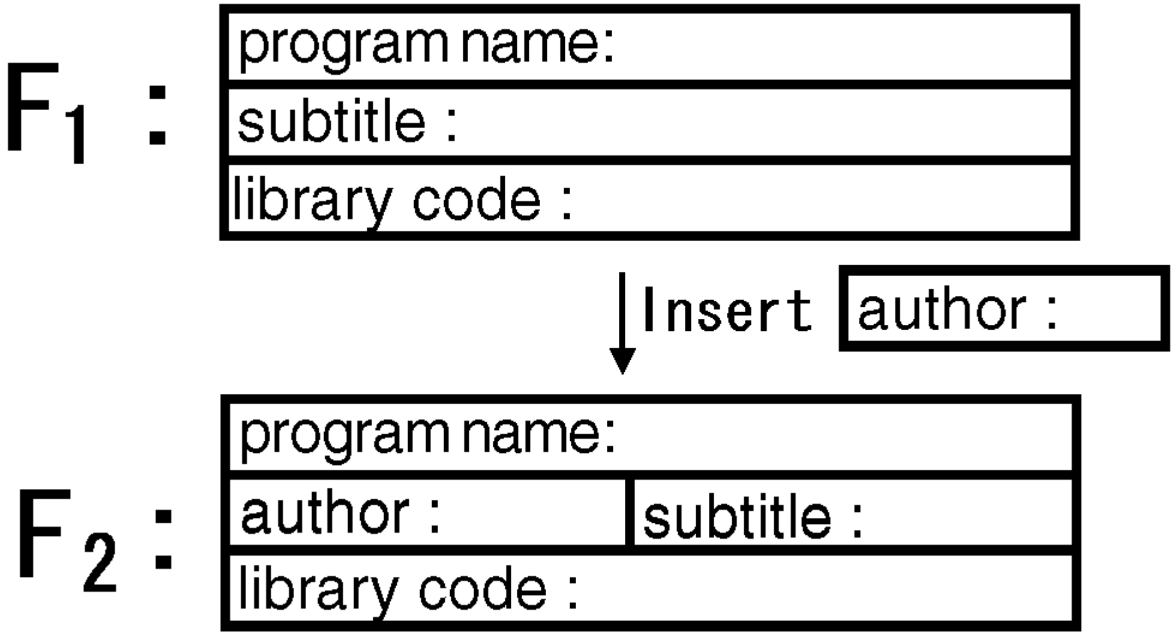
Let H be the graph obtained from G by the deletion of nodes a and b in this order, in HNGG.
Let H' be the graph obtained from G by the deletion of nodes b and a in this order, in HNGG.
Then, H=H'.

□

4 Example： Insertion Process

4 Example: Insertion Process

Insertion of author : in the left side of 'subtitle' in form F_1



F_1 :

program name:

subtitle :

library code :

Insert author :

F_2 :

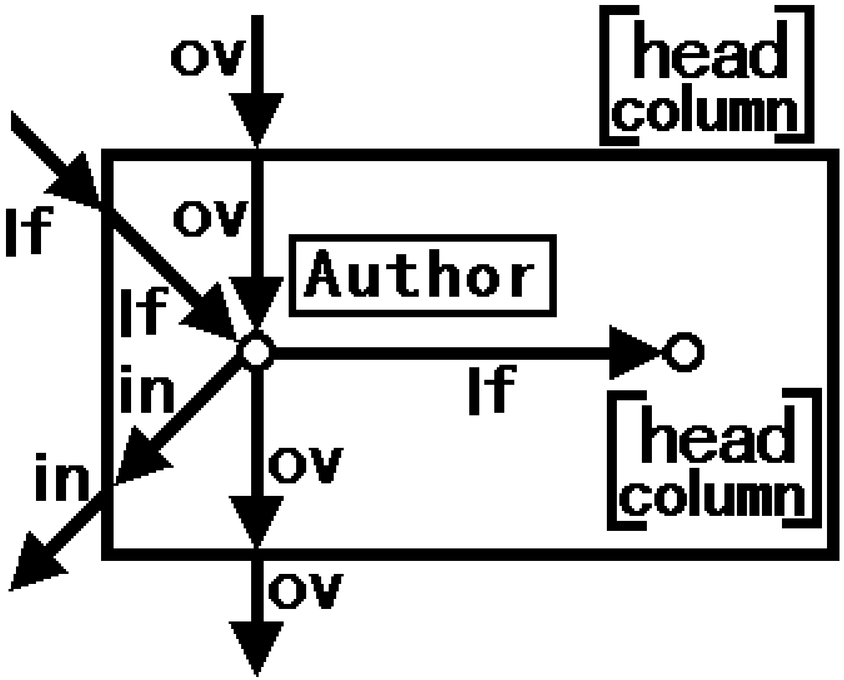
program name:

author : subtitle :

library code :

Step1. It makes the composite production copy for the use of the insertion.

$P_{Q} = P_{H5} \circ P_{H11}$

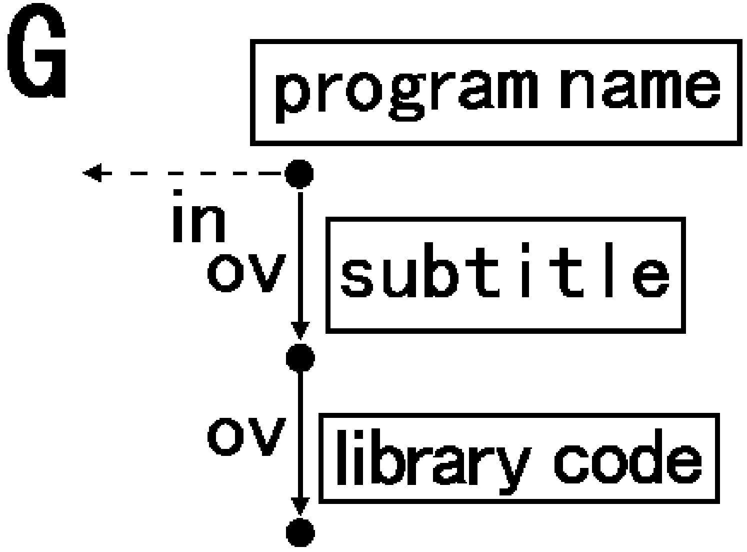


Step2. Construction of the Derivation D_1 of graph G for form F_1.

$$D_1 : G_0 \xRightarrow[\mathbf{p}1]{\omega 1\ \mathrm{H'p1}} G_1 \xRightarrow[\mathbf{p}2]{\omega 2\ \mathrm{H'p2}} G_2 \xRightarrow[\mathbf{p}H1]{\omega H1\ \mathrm{H'pH1}} G_3 \xRightarrow[\mathbf{p}H2]{\omega H2\ \mathrm{H'pH2}} G_4 \xRightarrow[\mathbf{p}H4]{\omega H4\ \mathrm{H'pH4}} G_5 \xRightarrow[\mathbf{p}H6]{\omega H6\ \mathrm{H'pH6}} G_6 \xRightarrow[\mathbf{p}H7]{\omega H7\ \mathrm{H'pH7}}$$

$$G_7 \xRightarrow[\mathbf{p}H2]{\omega H2\ \mathrm{H'pH2}} G_8 \xRightarrow[\mathbf{p}H4]{\omega H4\ \mathrm{H'pH4}} G_9 \xRightarrow[\mathbf{p}H6]{\omega H6\ \mathrm{H'pH6}} G_{10} \xRightarrow[\mathbf{p}H8]{\omega H8\ \mathrm{H'pH8}} G_{11} \xRightarrow[\mathbf{p}H3]{\omega H3\ \mathrm{H'pH3}} G_{12} \xRightarrow[\mathbf{p}H4]{\omega H4\ \mathrm{H'pH4}} G_{13}$$

$$\xRightarrow[\mathbf{p}H6]{\omega H6\ \mathrm{H'pH6}} G14 \xRightarrow[\mathbf{p}H9]{\omega H9\ \mathrm{H'pH9}} G$$

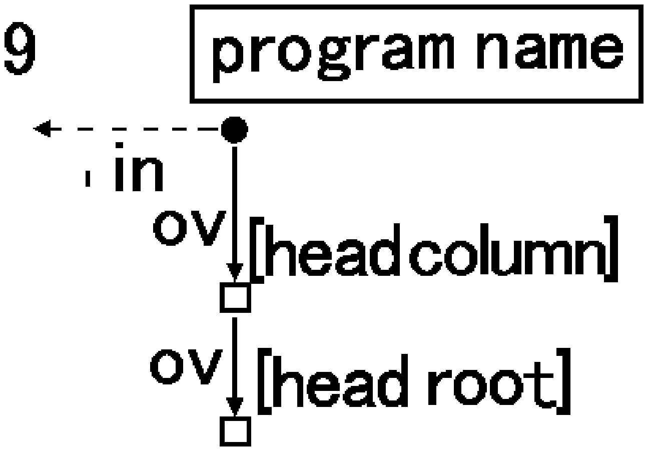


Step3. Find a target graph G_9 by Insertion Point in G Find a subderivation D_{11} to generate G_9 in D_1.

$$D_{11} : G_0 \overset{\omega 1\ H'p1}{\underset{\mathbf{p}1}{\Rightarrow}} G_1 \overset{\omega 2\ H'p2}{\underset{\mathbf{p}2}{\Rightarrow}} G_2 \overset{\omega H1\ H'pH1}{\underset{\mathbf{p}H1}{\Rightarrow}} G_3 \overset{\omega H2\ H'pH2}{\underset{\mathbf{p}H2}{\Rightarrow}} G_4 \overset{\omega H4\ H'pH4}{\underset{\mathbf{p}H4}{\Rightarrow}} G_5 \overset{\omega H6\ H'pH6}{\underset{\mathbf{p}H6}{\Rightarrow}} G_6$$

$$\overset{\omega H7\ H'pH7}{\underset{\mathbf{p}H7}{\Rightarrow}} G_7 \overset{\omega H2\ H'pH2}{\underset{\mathbf{p}H2}{\Rightarrow}} G_8 \overset{\omega H4\ H'pH4}{\underset{\mathbf{p}H4}{\Rightarrow}} G_9$$

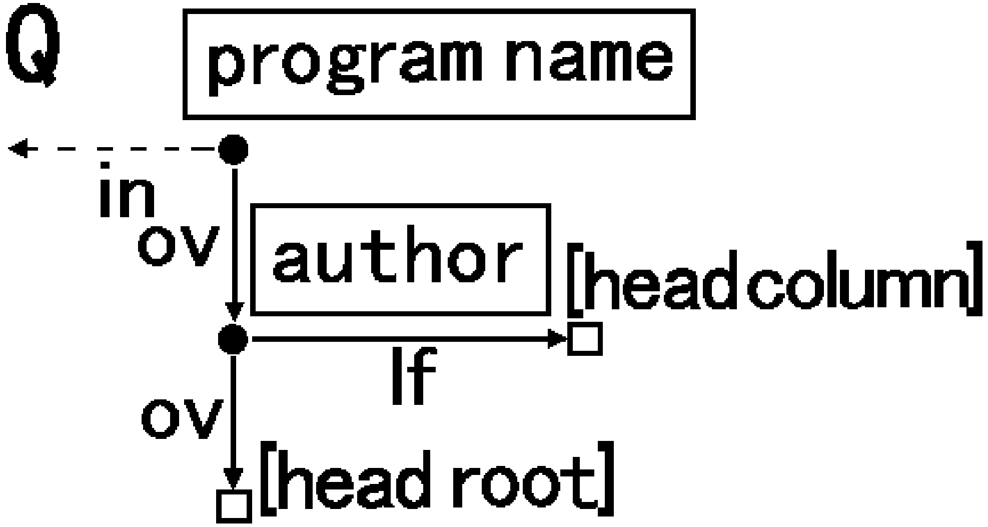
G_9



Step4. Apply P_Q to G_9 and obtain G_Q.

$$G_9 \overset{\omega QH'pQ}{\underset{\mathbf{p}Q}{\Rightarrow}} G_Q$$

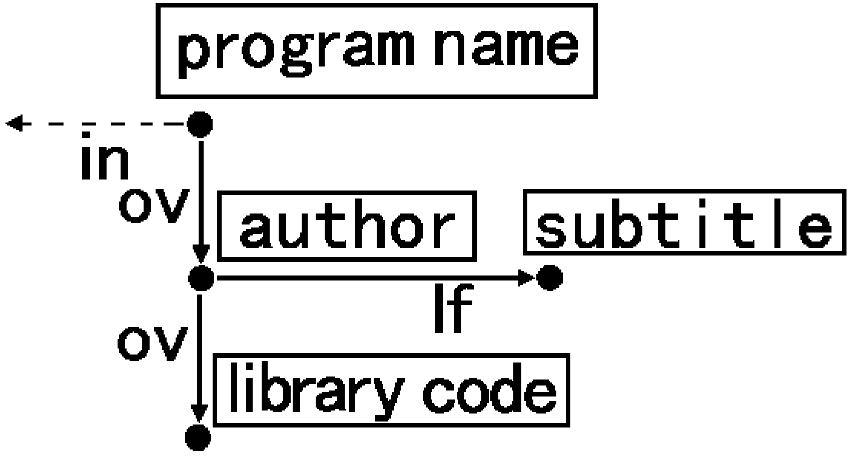
G_Q



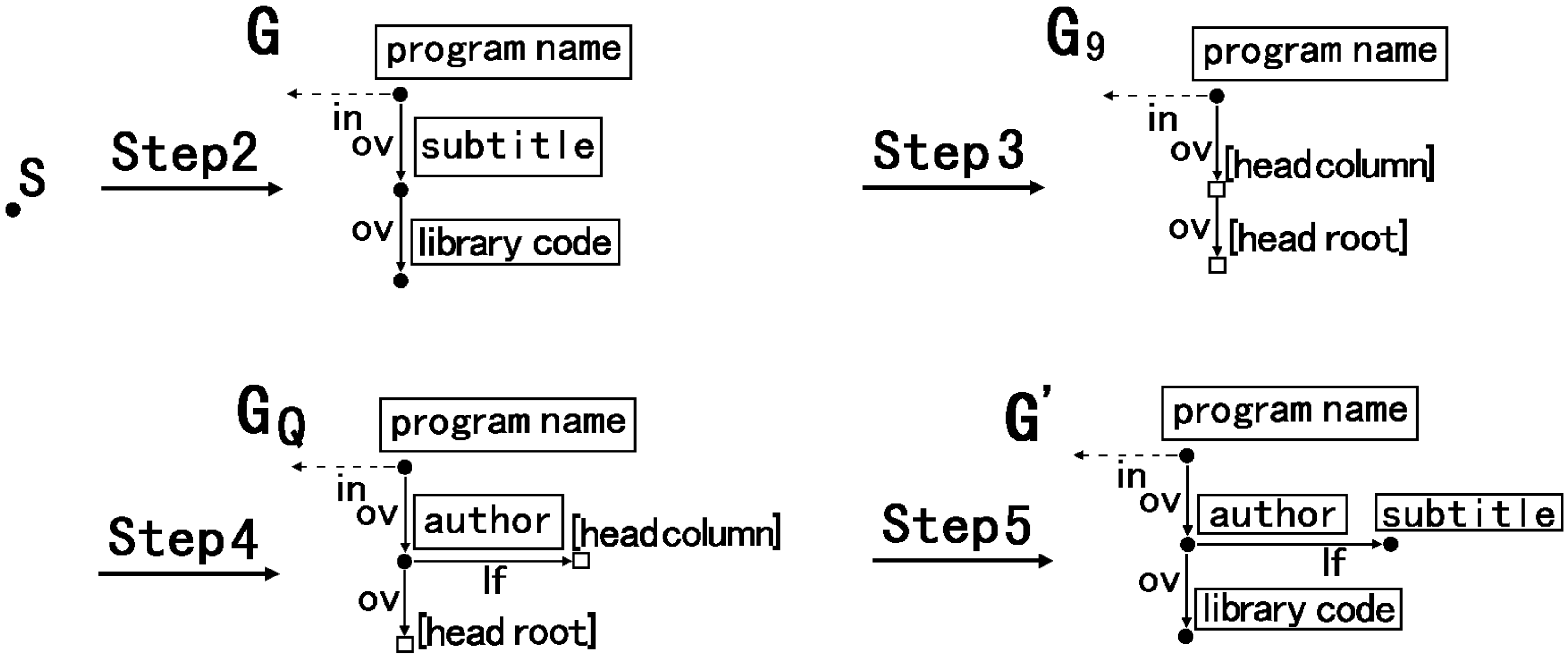
Step5. Apply the latter part of D_1 to G_Q.

$$G'_Q \overset{\omega H6\,\mathrm{H'pH6}}{\underset{\mathbf{p}H6}{\Rightarrow}} G'_{10} \overset{\omega H8\,\mathrm{H'pH8}}{\underset{\mathbf{p}H8}{\Rightarrow}} G'_{11} \overset{\omega H3\,\mathrm{H'pH3}}{\underset{\mathbf{p}H3}{\Rightarrow}} G'_{12} \overset{\omega H4\,\mathrm{H'pH4}}{\underset{\mathbf{p}H4}{\Rightarrow}} G'_{13} \overset{\omega H6\,\mathrm{H'pH6}}{\underset{\mathbf{p}H6}{\Rightarrow}} G'_{14} \overset{\omega H9\,\mathrm{H'pH9}}{\underset{\mathbf{p}H9}{\Rightarrow}} G'$$

G'



G' is a graph for form F_2.



Insertion process

6.Conclusion

- We proposed editing methods for tabular forms, based on the attribute edNCE graph grammar.
- Examples to apply editor methods were shown.

Future works.

- Detailed algorithm of editing methods.
- Other edit manipulations representing a division manipulation, a combination manipulation and so on.
- We are now developing a tabular form editor system utilizing this approach.