TIME-SENSITIVE PLANNING USING POINT-INTERVAL LOGIC

Student Paper

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Outline

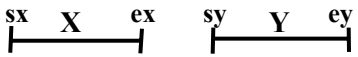
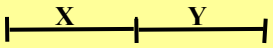
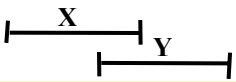
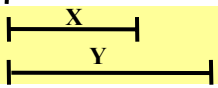
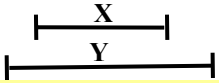
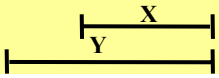
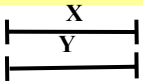
- Point-Interval Formalism
- Graphical Representation
- TEMPER – Temporal Programmer
- Application to Temporal Planning
- Conclusion

Point-Interval Formalism (PIL)

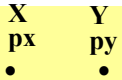
- Time Structure
  - Instantaneous Events – Points
    - Time Stamps
  - Duration Based Activities – Intervals
    - Time Stamps for the Start and End of an Activity
    - Length of Activities
- Temporal Relations
  - Quantitative
  - Qualitative

Point-Interval Formalism (PIL)

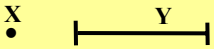
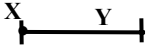
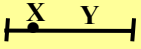
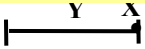
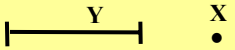
Case I— X and Y both intervals with non-zero lengths X = [sx, ex], Y = [sy , ey] with sx < ex and sy < ey

Before	X < Y	ex < sy		
Meets	X m Y	ex = sy		
Overlaps	X o Y	sx < sy;	sy < ex; ex < ey	
Starts	X s Y	sx = sy;	ex < ey	
During	X d Y	sx > sy;	ex < ey	
Finishes	X f Y	sy < sx;	ey = ex	
Equals	X = Y	sx = sy;	ex = ey	

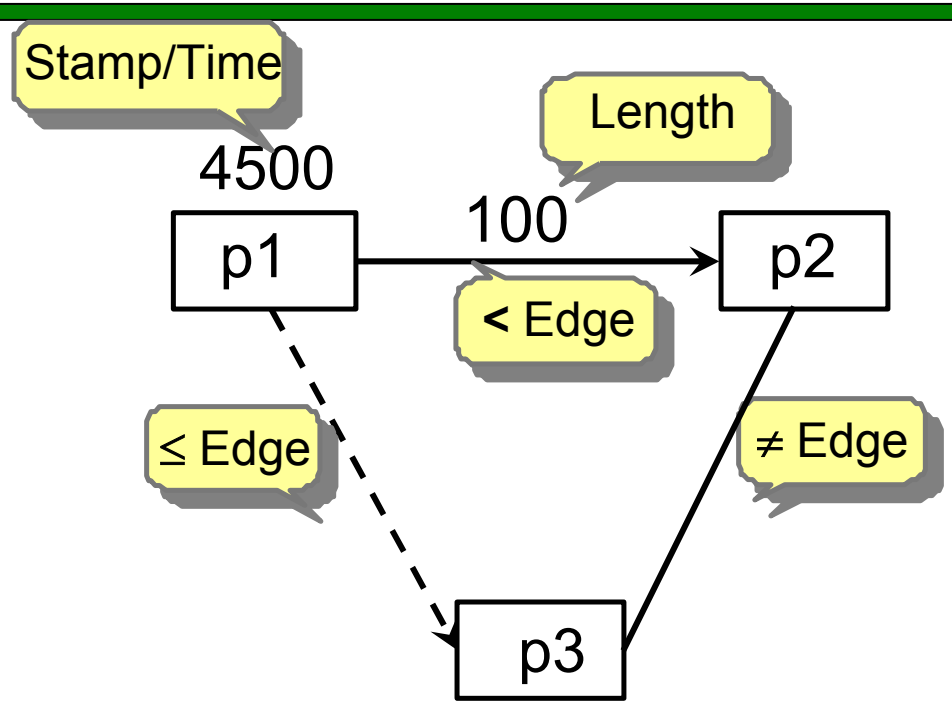
Case II —X and Y both points: X = [px] and Y = [py] with sx = ex = px and sy = ey = py

X < Y	px < py		
X = Y	px = py		

Case III—X is a point and Y is an interval: X = [px] and Y = [sy, ey] with px = sx = ex and sy < ey

X < Y	px < sy		
X s Y	px = sy		
X d Y	sy < px < ey		
X f Y	px = ey		
Y < X	ey < px		

Graphical Representation

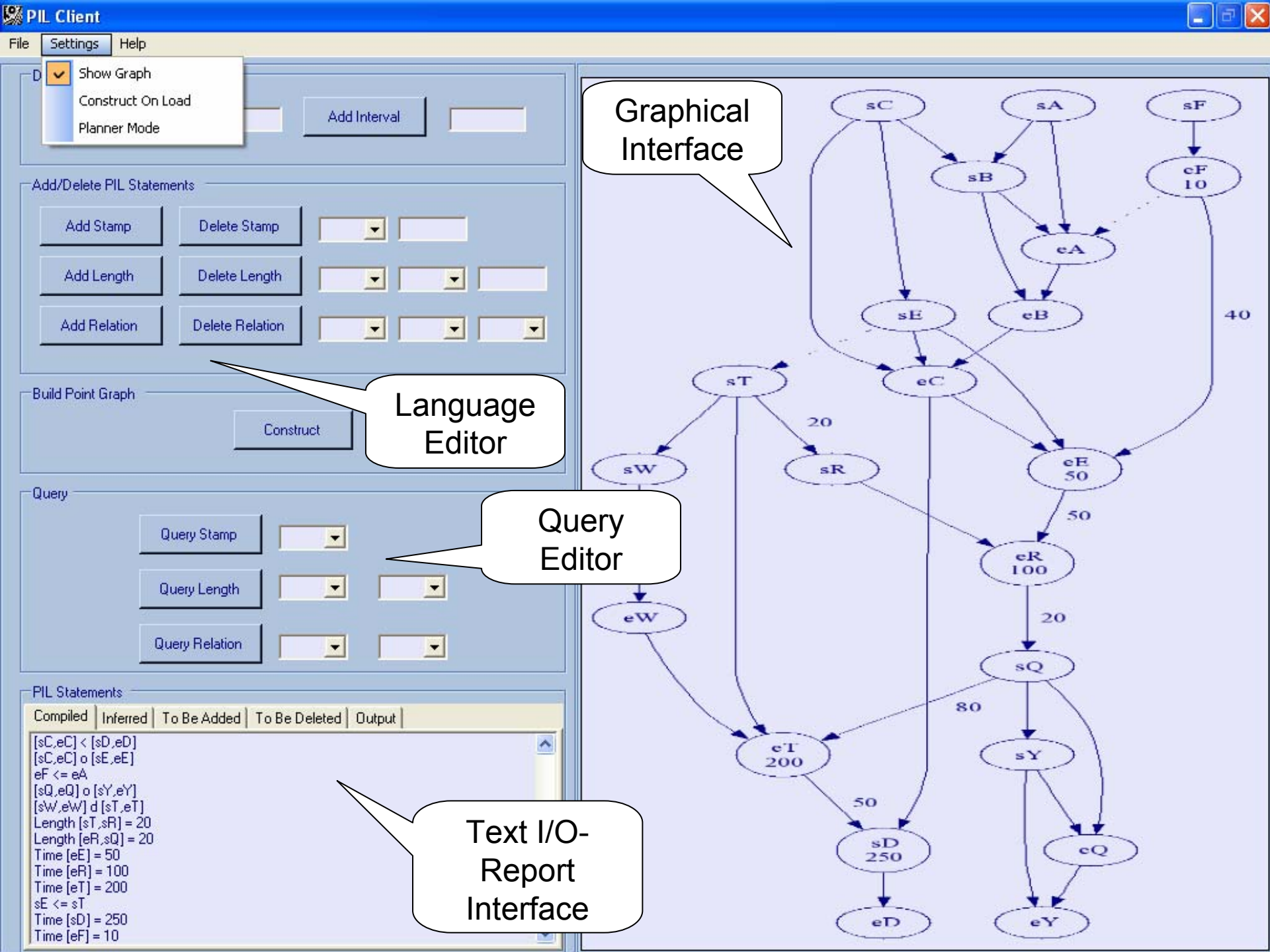


Stamp[p1] = 4500
p1 < p2
Length [p1, p2] = 100
P1 <= p3
P3 <> p2

TEMPER – Temporal Programmer

- Software Implementation of the Point-Interval Formalism
  - Language Interface
  - Graphical Interface
  - Inference Mechanism
  - Verification Mechanism
- Implementation of a Tractable Subclass of the General Temporal Problem
  - Polynomial Time Complexity for all Algorithms Implemented
- Available as an API at

  http://viking.gmu.edu/PILEngine.htm


PIL Client
File
Settings
Help
Show Graph
Construct On Load
Planner Mode
Add Interval
Add/Delete PIL Statements
Add Stamp
Delete Stamp
Add Length
Delete Length
Add Relation
Delete Relation
Build Point Graph
Construct
Language Editor
Query
Query Stamp
Query Length
Query Relation
Query Editor
PIL Statements
Compiled
Inferred
To Be Added
To Be Deleted
Output
[sC,eC] < [sD,eD]
[sC,eC] o [sE,eE]
eF <= eA
[sQ,eQ] o [sY,eY]
[sW,eW] d [sT,eT]
Length [sT,sR] = 20
Length [eR,sQ] = 20
Time [eE] = 50
Time [eR] = 100
Time [eT] = 200
sE <= sT
Time [sD] = 250
Time [eF] = 10
Text I/O-Report Interface
Graphical Interface
sC
sA
sF
sB
eF 10
eA
sE
eB
40
sT
eC
20
sW
sR
eE 50
50
eR 100
eW
20
sQ
80
eT 200
sY
50
sD 250
eQ
eD
eY

Illustration

Description	ID	PIL Statement
Weapon Platform Ingress to PGW Launch Point	A	Length A = 5
Weapon Platform Egress from PGW Launch Point	B	Length B = 5
Target Parameters are Uploaded into the PGW Navigation Processor	C	Length C = 5
PGW is Launched and Flies to the Target	D	Length D = 2
Local, On-site Activity Provides Navigation and Guidance Updates to PGW	E	Length E = 10
The Platform will not Loiter in the Area due to Threat Considerations		A m B (A Meets B)
The PGW is launched Immediately after the Target Parameters are Uploaded		C m D (C Meets D)
The PGW Launch Precedes the Egress		eC ≤ sB (C Precedes B)
Local, On-site Activity Must Cease Just Prior to Weapon Striking the Target		eE ≤ eD

PIL Client

File Settings Help

Declare Variables

Add Point | Add Interval

Add/Delete PIL Statements

Add Stamp | Delete Stamp

Add Length | Delete Length

Add Relation | Delete Relation

Build Point Graph

Construct

Query

Query Stamp

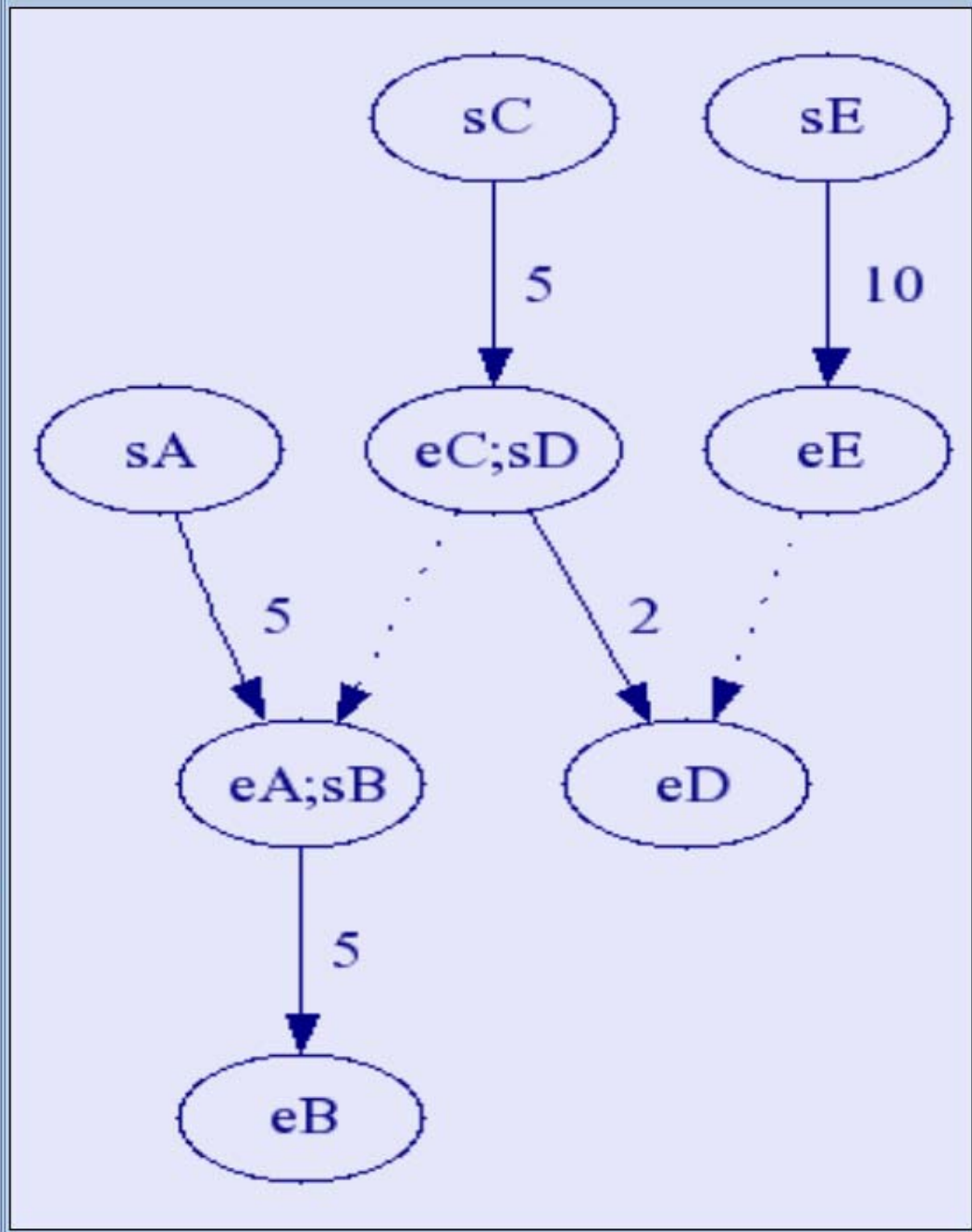
Query Length

Query Relation

PIL Statements

Compiled | Inferred | To Be Added | To Be Deleted | Output

```
sA < eA
sC < eC
sD < eD
sE < eE
sB < eB
Length [sA,eA] = 5
Length [sB,eB] = 5
Length [sC,eC] = 5
Length [sE,eE] = 10
[sA,eA] m [sB,eB]
[sC,eC] m [sD,eD]
eC <= sB
eE <= eD
```



Verification

- **THEOREM (for cases without the ≠ constraint)**

  A set of PIL statements is inconsistent iff

  (a) the graphical representation of the set contains self-loops and/or cycles. *or*

  (b) for a point p1, the system calculates two different stamps. *or*

  (c) for some points p1 and p2, the system can determine two different lengths for the interval [p1, p2]

PIL Client

File Settings Help

Declare Variables

Add Point | Add Interval

Error

The point graph contains inconsistent Paths:
sC eC;sD eD
sC sE eE eD

OK

Construct

Query

Query Stamp

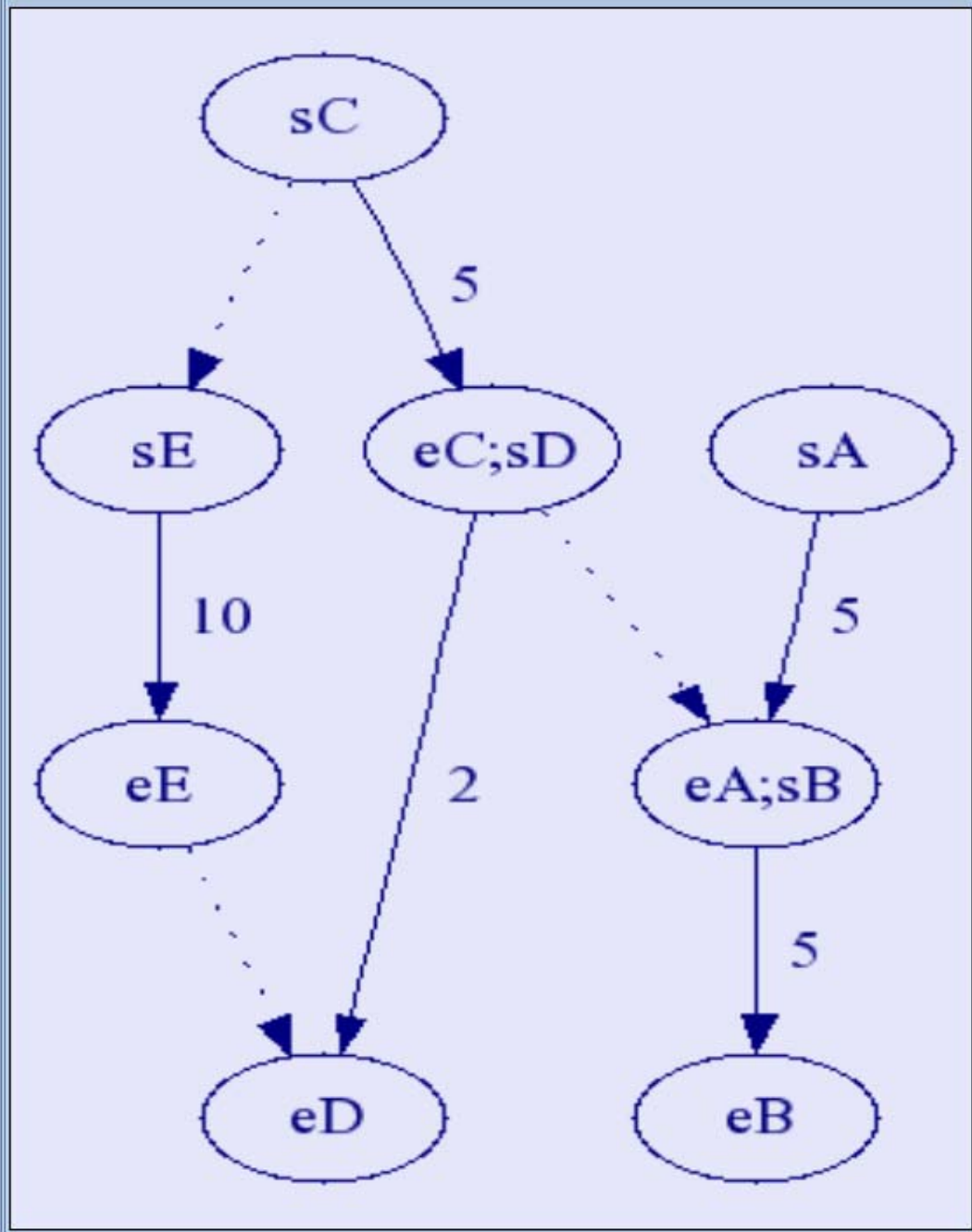
Query Length

Query Relation

PIL Statements

Compiled | Inferred | To Be Added | To Be Deleted | Output

sD < eD
sE < eE
sB < eB
Length [sA,eA] = 5
Length [sB,eB] = 5
Length [sC,eC] = 5
Length [sE,eE] = 10
[sA,eA] m [sB,eB]
[sC,eC] m [sD,eD]
eC <= sB
eE <= eD
Lengt
Delete
sC <= sE



Application to Temporal Planning

- **Existing Approaches**
  - **Mathematical Programming**
  - **Graph Based Critical Path Methods**
    - **Activities with Duration**
    - **Only One Temporal Relation Between Activities, e.g, "A Precedes B" (eA $\leq$ sB)**
- **PIL Approach**
  - **Allows Activities With or Without Duration**
  - **Allows Partial Relations Between Activities, e.g., "sA $\leq$ sB", "sA $\leq$ eB", and "eA $\leq$ eB"**
  - **Identifies Critical Activities/Paths**
  - **Calculates Time Slacks (Earliest, Late, Latest Occurrences) for Non-Critical Activities**
  - **Offers a Graphical Interface and an Inference Mechanism for Analysis**

Illustration

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The Platform will not Loiter in the Area due to Threat Considerations		A m B (A Meets B)
The PGW is launched Immediately after the Target Parameters are Uploaded		C m D (C Meets D)
The PGW Launch Precedes the Egress		eC ≤ sB (C Precedes B)
Local, On-site Activity Must Cease Just Prior to Weapon Striking the Target		eE ≤ eD

The Approach

- Input Temporal Planning Requirements as PIL Statements
- Run Verification Algorithm on the Input
- Run *Forward-Reverse** Algorithm to Calculate Earliest Occurrence Times of the Nodes in the Graph
- Run *Reverse-Forward** Algorithm to Calculate Late/Latest Occurrence Times of the Nodes in the Graph
- Identify Critical Activities/Paths
- Calculate Time Slacks, e.g., Total and Free Floats, for Non-Critical Activities
- Report Results

PIL Client

File | Settings | Help

Show Graph
Construct On Load
Planner Mode

Planner Mode

Add/Delete PIL Statements

Add Stamp | Delete Stamp
Add Length | Delete Length
Add Relation | Delete Relation

Build Point Graph

Construct

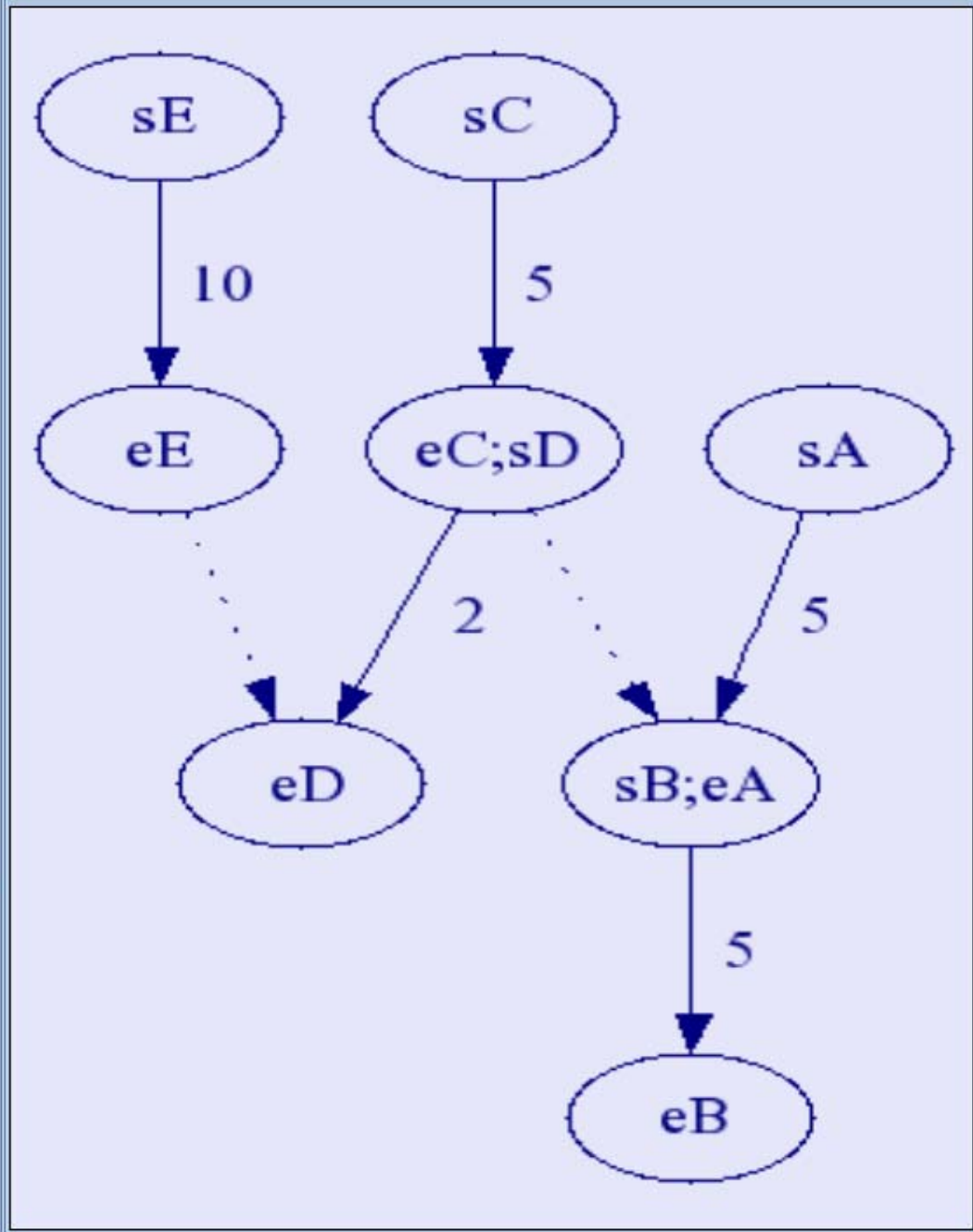
Query

Query Stamp
Query Length
Query Relation

PIL Statements

Compiled | Inferred | To Be Added | To Be Deleted | Output

```
sA < eA
sC < eC
sD < eD
sE < eE
sB < eB
Length [sA,eA] = 5
Length [sB,eB] = 5
Length [sC,eC] = 5
Length [sE,eE] = 10
[sA,eA] m [sB,eB]
[sC,eC] m [sD,eD]
eC <= sB
eE <= eD
```



PIL Client

File Settings Planner Help

Declare Variables

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Add/Delete PIL Statements

Add Stamp | Delete Stamp

Add Length | Delete Length

Add Relation | Delete Relation

Build Point Graph

Construct

Query

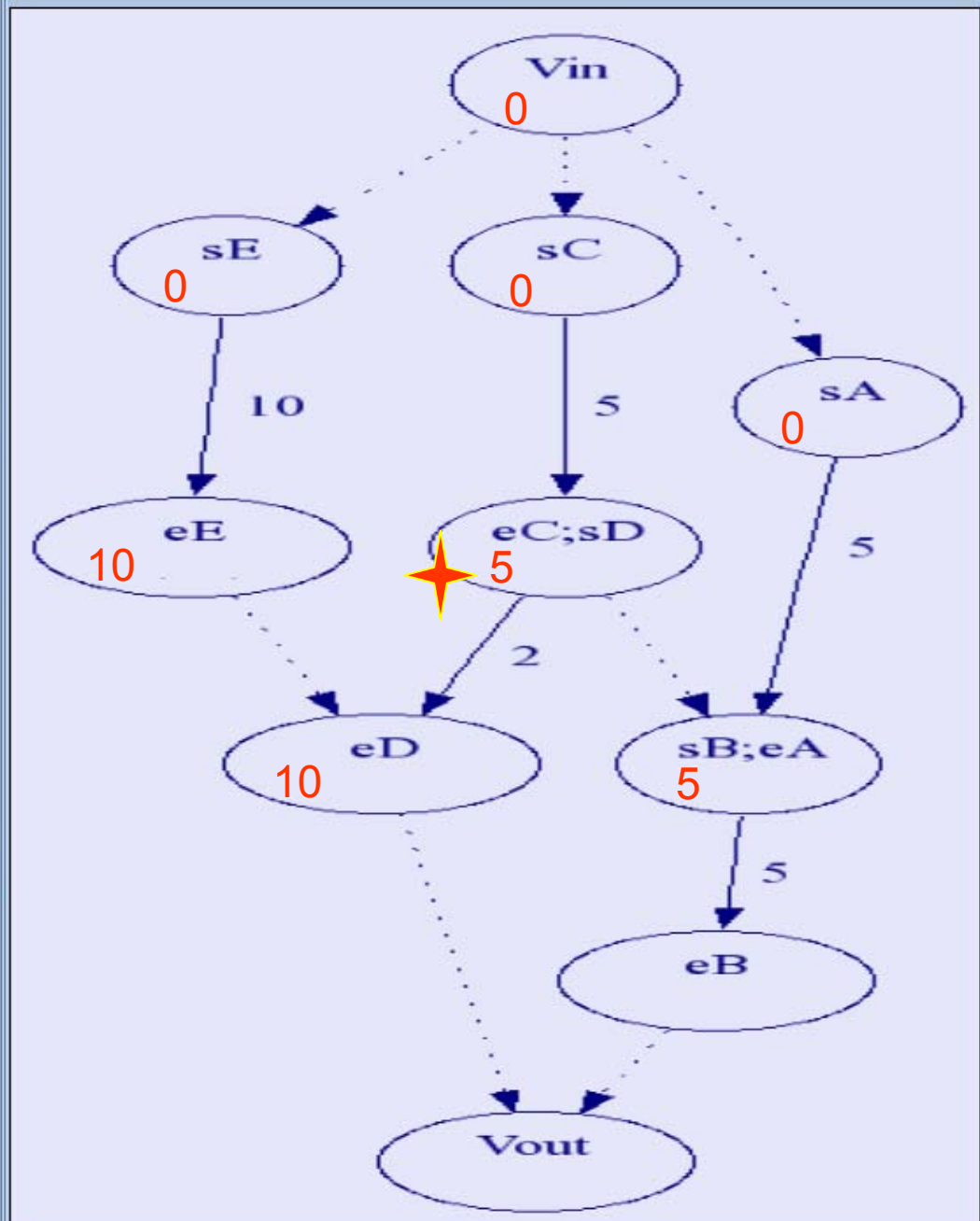
Query Stamp

Query Length

Query Relation

PIL Statements

Compiled | Inferred | To Be Added | To Be Deleted | Output



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Build Point Graph

Construct

Query

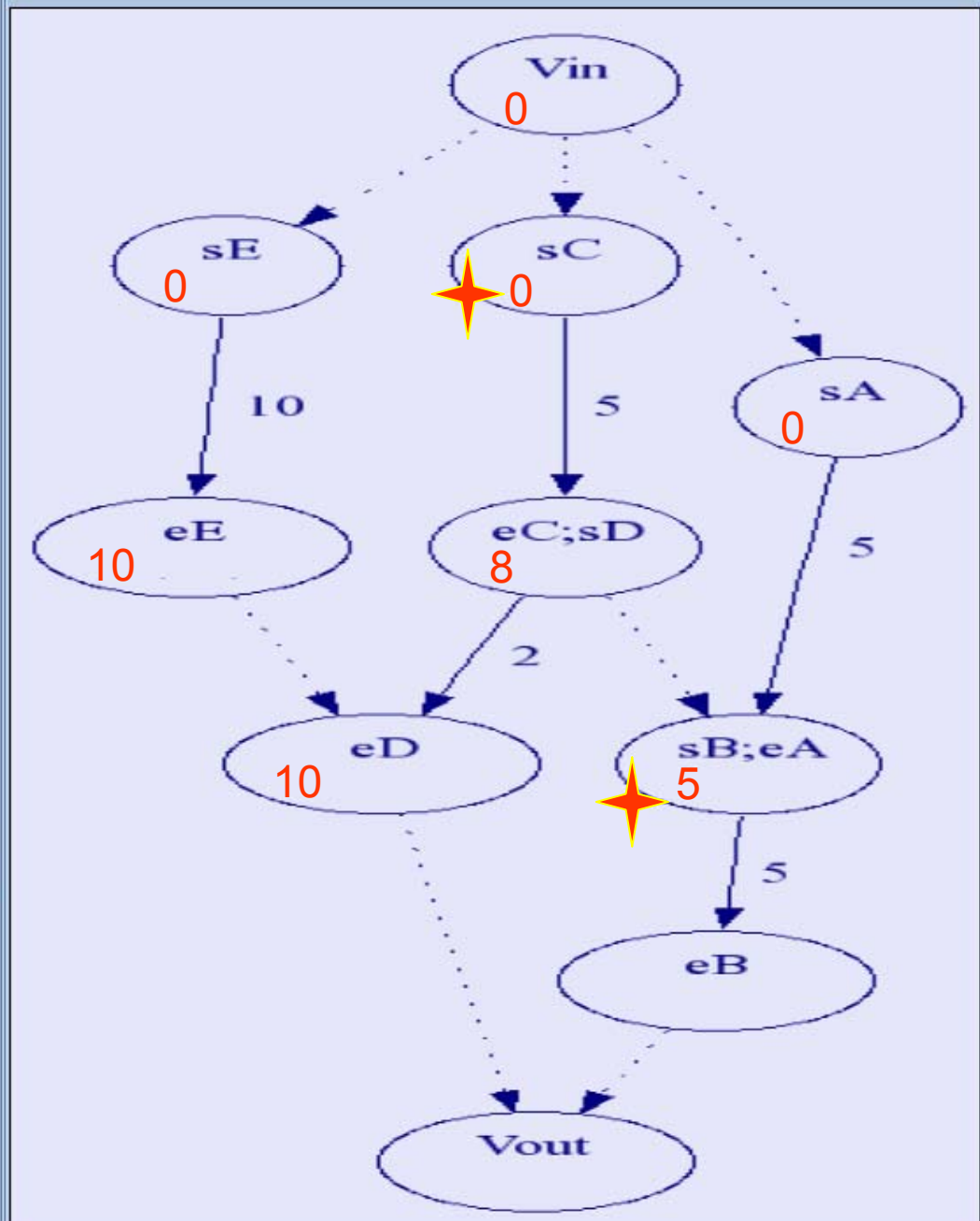
Query Stamp

Query Length

Query Relation

PIL Statements

Compiled | Inferred | To Be Added | To Be Deleted | Output



PIL Client

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Add Stamp | Delete Stamp

Add Length | Delete Length

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Build Point Graph

Construct

Query

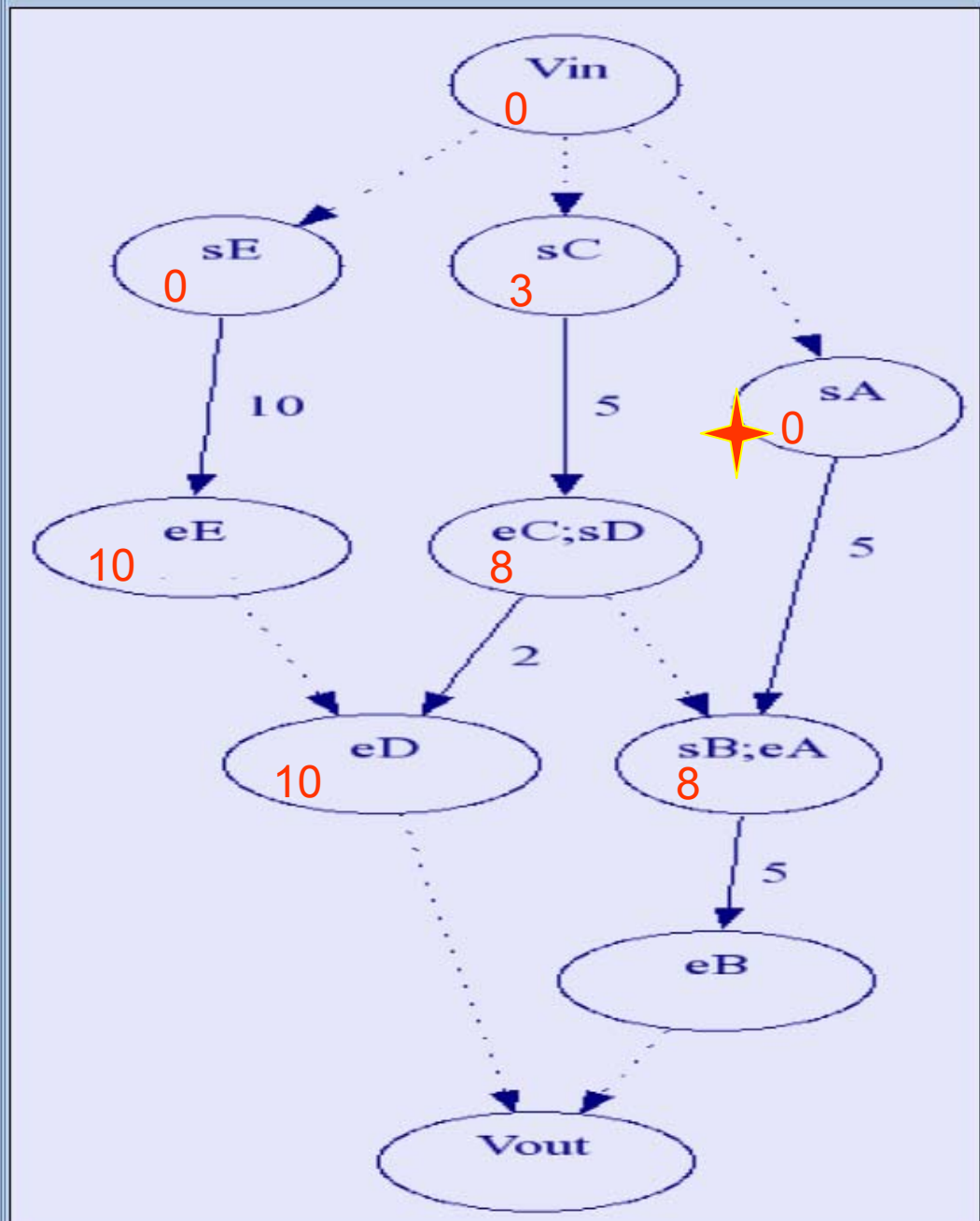
Query Stamp

Query Length

Query Relation

PIL Statements

Compiled | Inferred | To Be Added | To Be Deleted | Output



PIL Client

File Settings Planner Help

Declare Variables

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Add Length | Delete Length

Add Relation | Delete Relation

Build Point Graph

Construct

Query

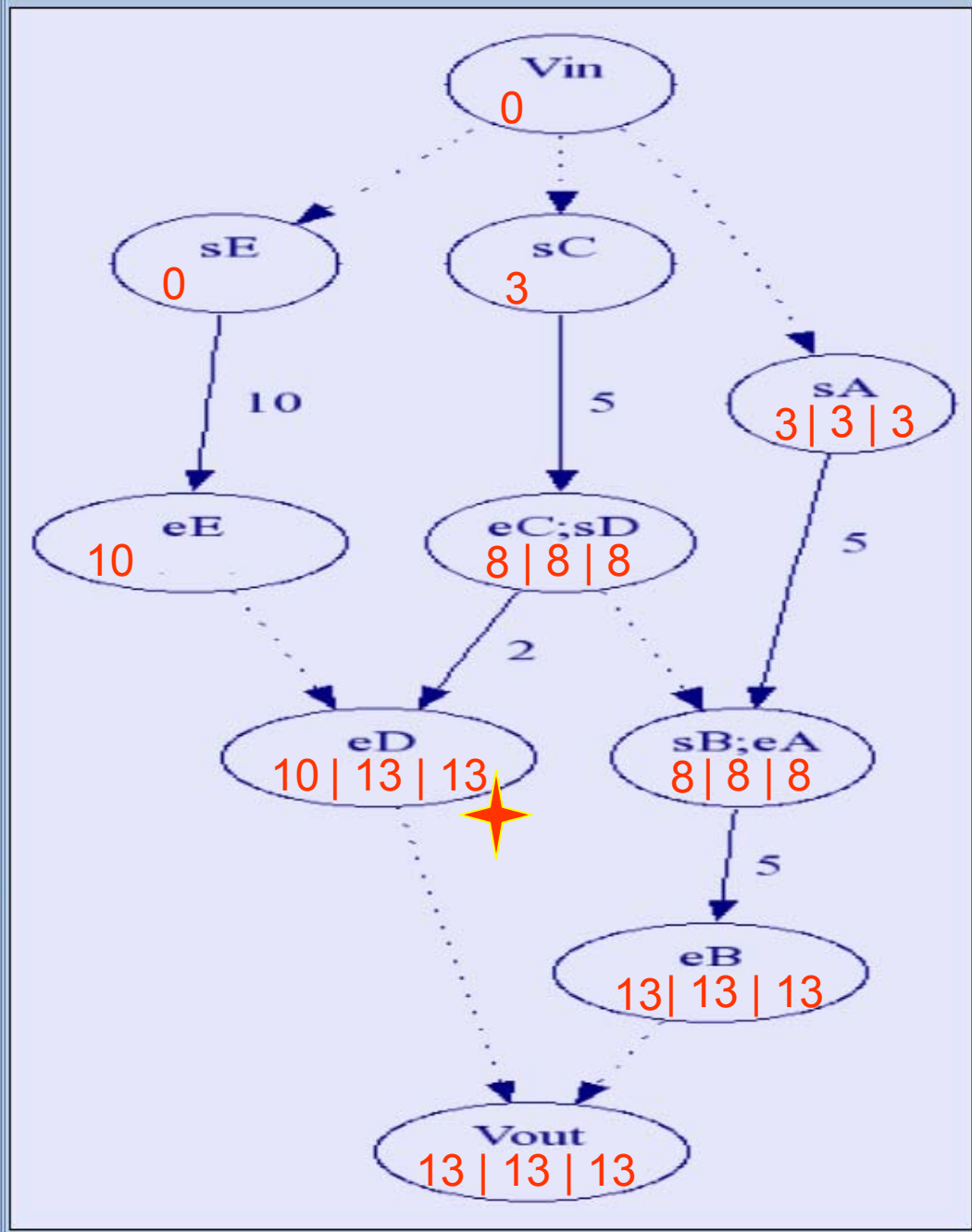
Query Stamp

Query Length

Query Relation

PIL Statements

Compiled | Inferred | To Be Added | To Be Deleted | Output



PIL Client

File Settings Planner Help

Declare Variables

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Add/Delete PIL Statements

Add Stamp | Delete Stamp

Add Length | Delete Length

Add Relation | Delete Relation

Build Point Graph

Construct

Query

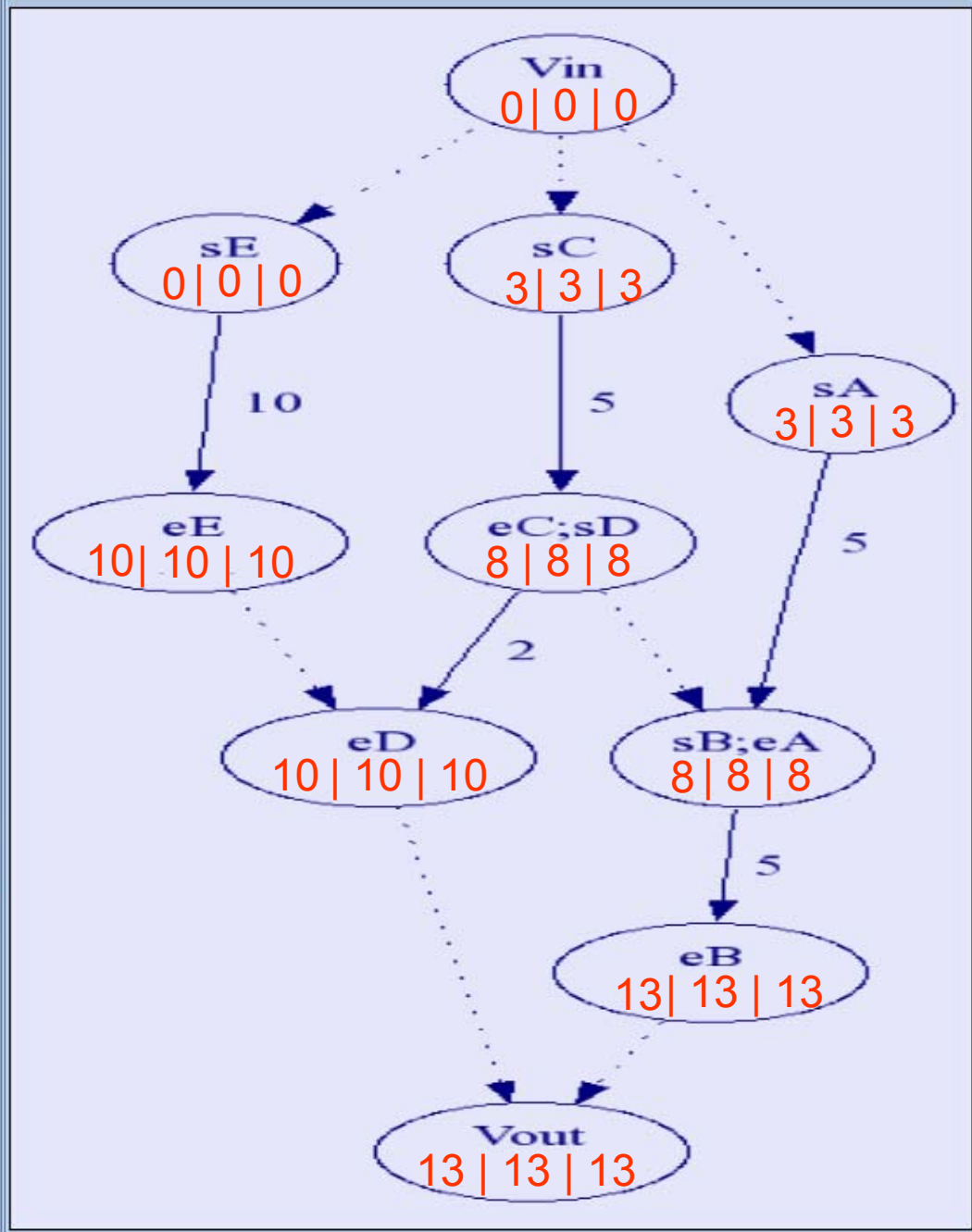
Query Stamp

Query Length

Query Relation

PIL Statements

Compiled | Inferred | To Be Added | To Be Deleted | Output



PIL Client

File Settings Planner Help

Declare Variables

Add Point | Add Interval

Add/Delete PIL Statements

Add Stamp | Delete Stamp

Add Length | Delete Length

Add Relation | Delete Relation

Build Point Graph

Construct

Query

Query Stamp

Query Length

Query Relation

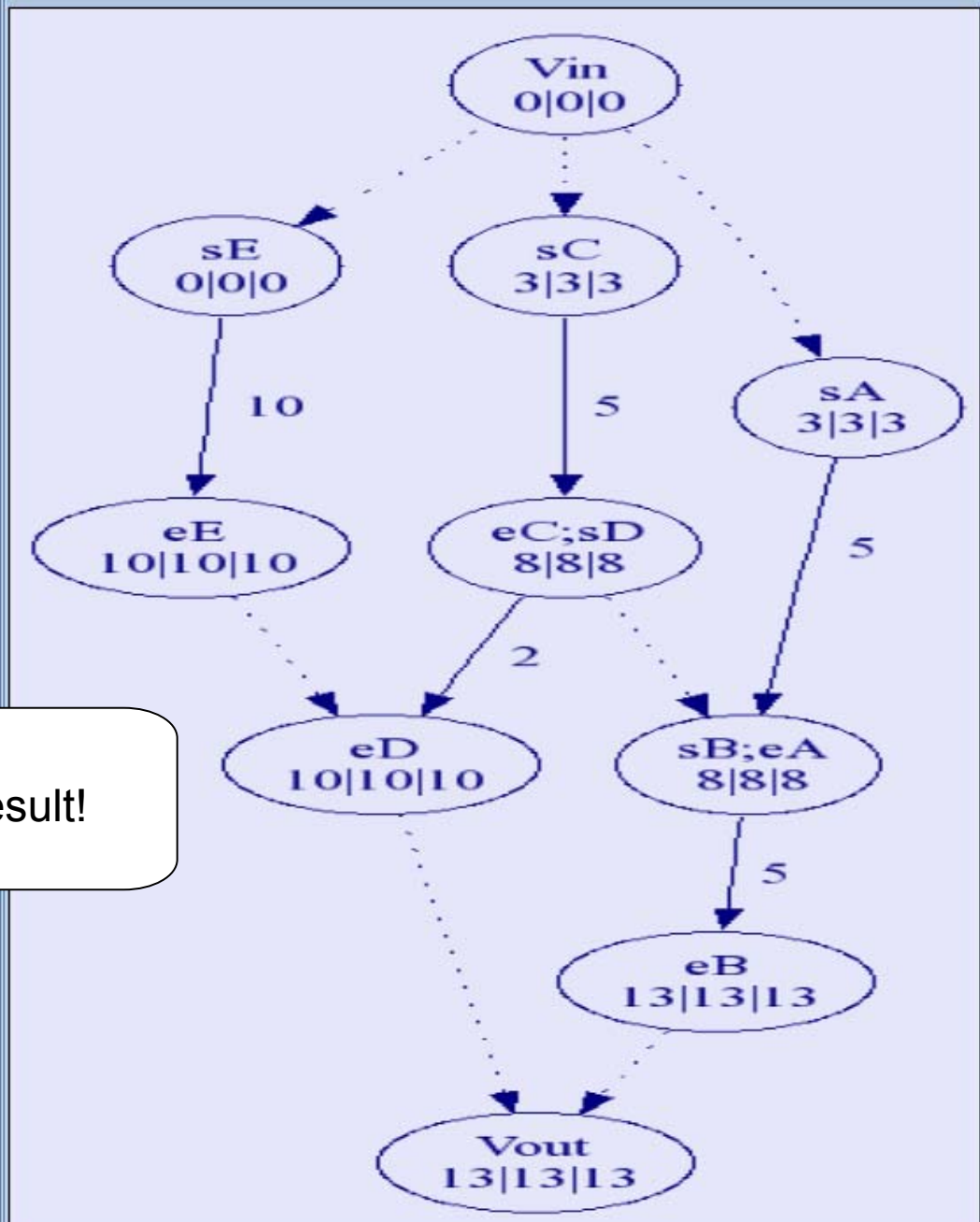
PIL Statements

Compiled | Inferred | To Be Added | To Be Deleted | Output

Point Graph has been successfully constructed
Point Graph has been successfully constructed

Activity, Duration, Earliest Start Time, Latest End Time, Critical, Total Float, Free Float, Stretch Float
A, 5, 3, 8, True, 0, 0, 0
C, 5, 3, 8, True, 0, 0, 0
D, 2, 8, 10, True, 0, 0, 0
E, 10, 0, 10, True, 0, 0, 0
B, 5, 8, 13, True, 0, 0, 0

Result!



Result

Activity	Duration	Earliest Start Time	Latest End Time	Critical	Total Float	Free Float
A	5	3	8	yes	0	0
B	5	8	13	yes	0	0
C	5	3	8	yes	0	0
D	2	8	10	yes	0	0
E	10	0	10	yes	0	0

Conclusion

- A Temporal Formalism with Provisions for:
  - Point (Event) and Interval Activities
  - Qualitative and Quantitative Temporal Relations Among Events/Activities
  - Partially Specified Temporal Relations Among Interval Activities
  - Verification of Planning Requirements Prior to Solving the Problem
  - An Inference Mechanism for Analysis
- An Implementation of the Formalism that offers:
  - An Interface for Specifying Temporal Requirements
  - A Graphical Interface for Temporal Knowledge Representation
  - A Planning Tool that Can be Used by Mission Planners and Project Managers to Plan Temporal Events/Activities and for Analysis of Planned Activities
  - An API for Integration With other Applications

http://viking.gmu.edu/PILEngine.htm