Designing Neural Networks Using Gene Expression Programming

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PLAN

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2. GEP genes
3. Multigenic chromosomes
4. Representing ANNs in GEP
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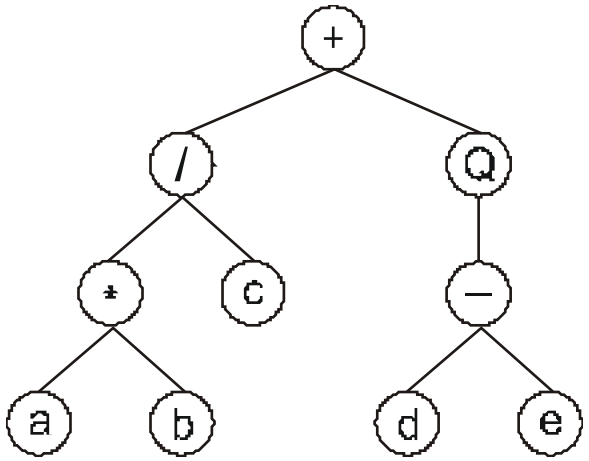
Representing Trees in GEP

$$\frac{a \cdot b}{c} + \sqrt{d - e}$$

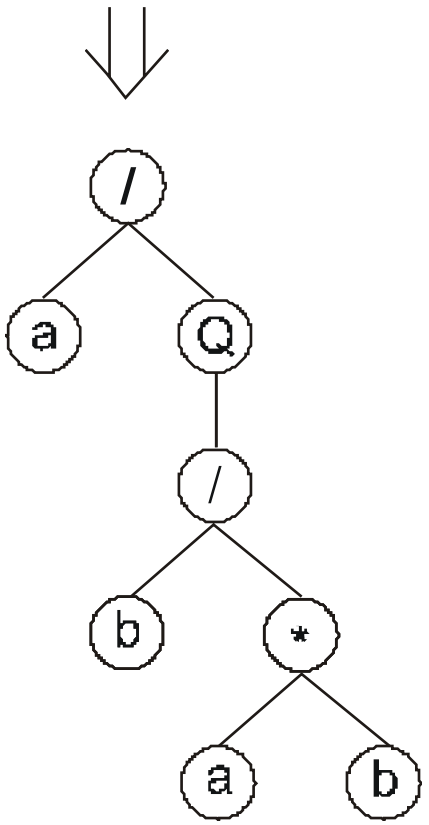



```
0123456789
+/Q*c-abde
```

GEP Genes

```
012345678901234567890123456789 0
/aQ/b*ab/Qa*b*-ababaababbabbbba
```

head tail



$t = h\,(n\text{-}1) + 1$

h - head length
t - tail length
n - max arity

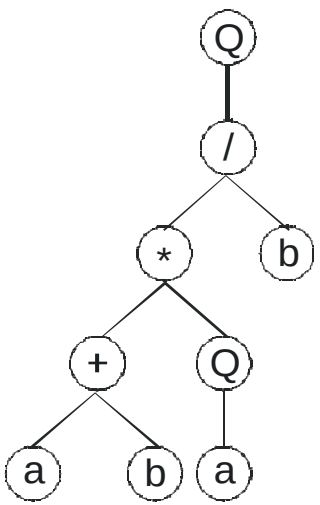
MULTIGENIC CHROMOSOMES

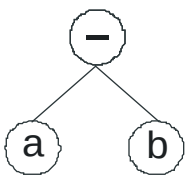
```
012345678901234012345678901234012345678901234
Q/*b+Qababaabaa-abQ/*+bababbab**-*bb/babaaaab
```

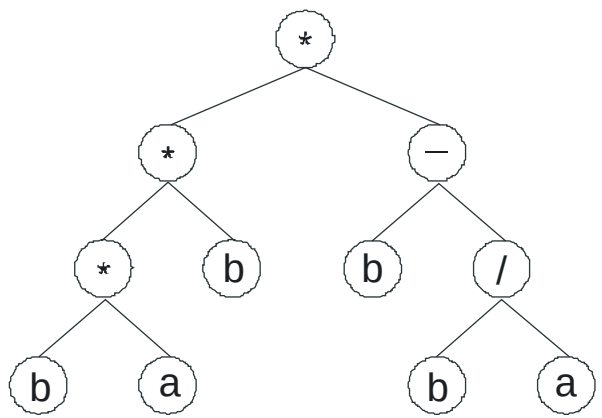
Sub-ET$_1$

Sub-ET$_2$

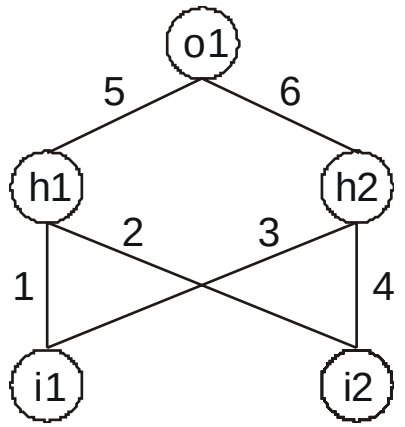
Sub-ET$_3$

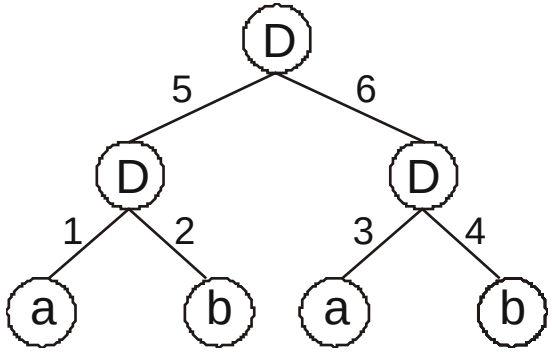


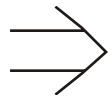




Representing ANNs in GEP







head **Dw**

012345678901 2

DDDabab654321

tail

Evolving the Neural Network Architecture

Genetic Operators:

- » Mutation
- » Transposition
  - » IS Transposition
  - » RIS Transposition
  - » Gene Transposition
- » Recombination
  - » One-point Recombination
  - » Intragenic Two-point Recombination

EXAMPLE: INTRAGENIC TWO-POINT RECOMBINATION

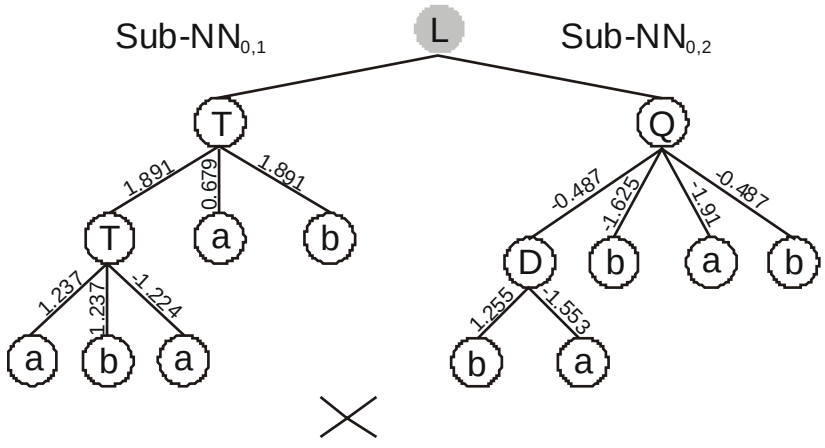
a)

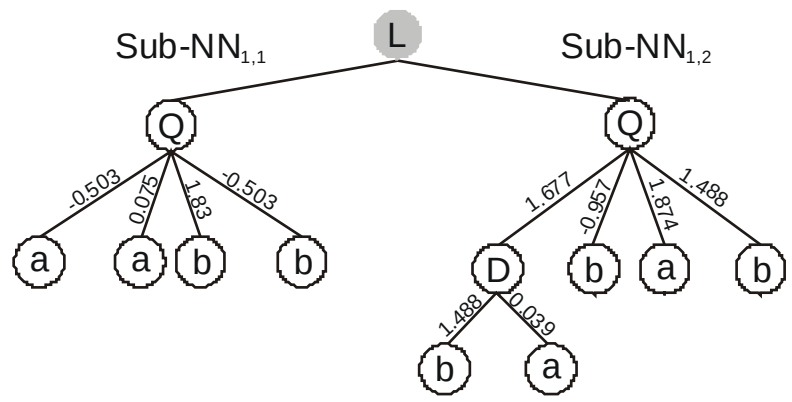
```
01234567890123456012345678901234 56
TTababaab14393255QDbabbabb96369304-[0]
Qaabbbabb97872192QDbabbaaa81327963-[1]

01234567890123456012345678901234 56
Taabbbabb978 93255QDbabbabb96369304-[0]
QTababaab143 72192QDbabbaaa81327963-[1]
```

$W_{0,1}$ = {-0.78, -0.521, -1.224, 1.891, 0.554, 1.237, -0.444, 0.472, 1.012, 0.679}
$W_{0,2}$ = {-1.553, 1.425, -1.606, -0.487, 1.255, -0.253, -1.91, 1.427, -0.103, -1.625}

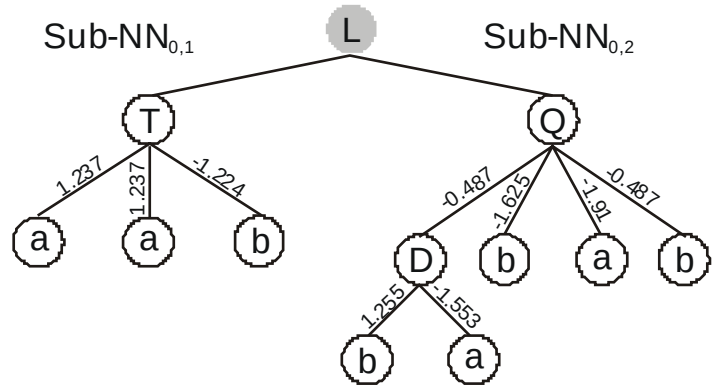
$W_{1,1}$ = {-0.148, 1.83, -0.503, -1.786, 0.313, -0.302, 0.768, -0.947, 1.487, 0.075}
$W_{1,2}$ = {-0.256, -0.026, 1.874, 1.488, -0.8, -0.804, 0.039, -0.957, 0.462, 1.677}

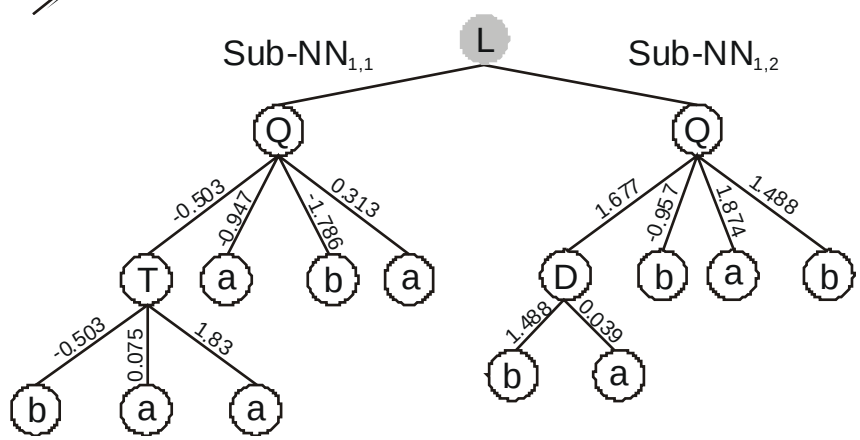
b)





c)





Fine-tuning the Weights/Thresholds

Genetic Operators:

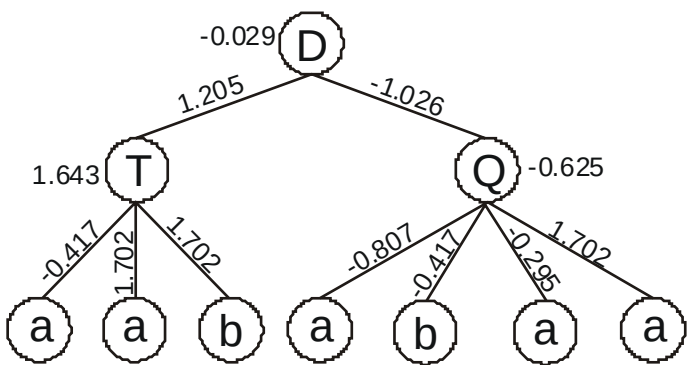
- » Domain-specific Mutation
- » Domain-specific Transposition
- » Direct Mutation of Weights/Thresholds

EXAMPLE: DOMAIN-SPECIFIC TRANSPOSITION

012345678901234567890123456789012345678
DTQaababaabbaabba057174573628466828672

W_m = {-1.64, -1.834, -0.295, 1.205, -0.807, 0.856, 1.702, -1.026, -0.417, -1.061}

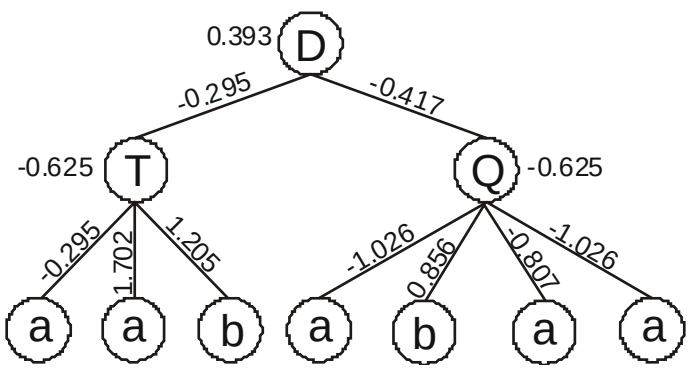
T_m = {-1.14, 1.177, -1.179, -0.74, 0.393, 1.135, -0.625, 1.643, -0.029, -1.639}



012345678901234567890123456789012345678
DTQaababaabbaabba057146682745736284668

W_d = {-1.64, -1.834, -0.295, 1.205, -0.807, 0.856, 1.702, -1.026, -0.417, -1.061}

T_d = {-1.14, 1.177, -1.179, -0.74, 0.393, 1.135, -0.625, 1.643, -0.029, -1.639}



XOR: Parameters and Performance

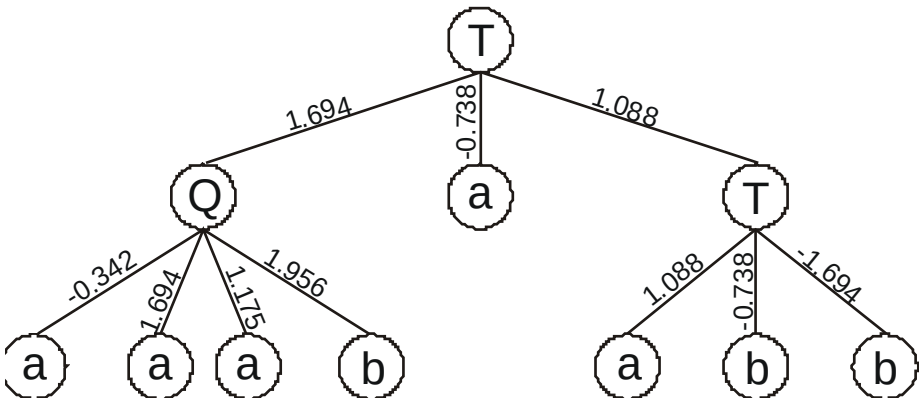
	Redundant System	Compact System
Number of runs	100	100
Number of generations	50	50
Population size	30	30
Number of fitness cases	4	4
Function set	D T Q	D T Q
Terminal set	a b	a b
Weights array length	10	10
Weights range	[-2, 2]	[-2, 2]
Head length	4	2
Number of genes	1	1
Chromosome length	33	17
Mutation rate	0.061	0.118
One-point recombination rate	0.7	0.7
IS transposition rate	0.1	--
IS elements length	1	--
RIS transposition rate	0.1	--
RIS elements length	1	--
Dw specific transposition rate	0.1	0.1
Dw specific IS elements length	2,3,5	2,3,5
Success rate	77%	30%

XOR: Two Perfect Solutions

1.

```
012345678901234567890123456789012
TQaTaaababbbabaaa6085977238275036
```

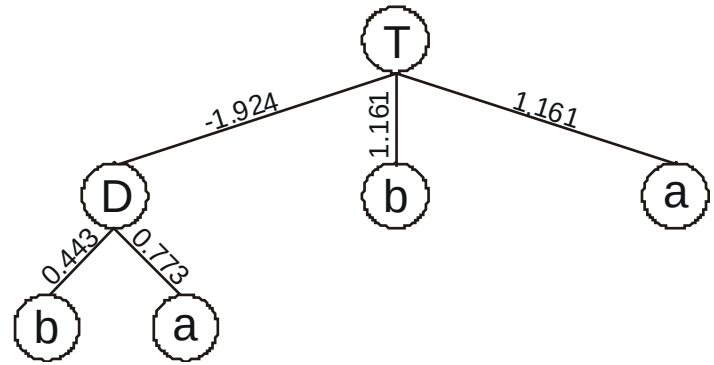
W = {1.175, 0.315, -0.738, 1.694, -1.215, 1.956,
-0.342, 1.088, -1.694, 1.288}



2.

```
01234567890123456
TDbabaabb88399837
```

W = {0.713, -0.774, -0.221, 0.773, -0.789, 1.792, -1.77,
0.443, -1.924, 1.161}



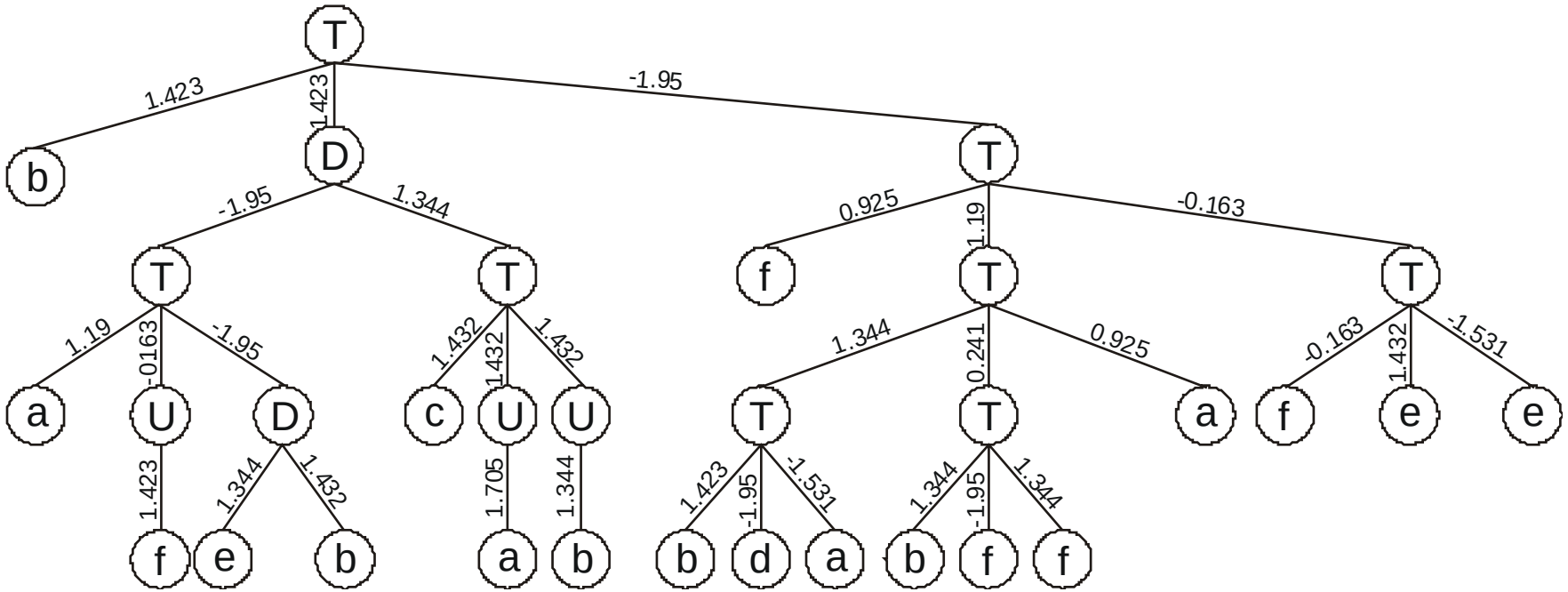
6-Multiplexer: Parameters and Performance

	Unigenic System	Multigenic System
Number of runs	100	100
Number of generations	2000	2000
Population size	50	50
Number of fitness cases	64	64
Function set	3U 3D 3T	3U 3D 3T
Terminal set	a b c d d e f	a b c d d e f
Linking function	--	O
Weights array length	10	10
Weights range	[-2, 2]	[-2, 2]
Head length	17	5
Number of genes	1	4
Chromosome length	103	124
Mutation rate	0.044	0.044
Intragenic two-point recombination rate	0.6	0.6
Gene recombination rate	--	0.1
Gene transposition rate	--	0.1
IS transposition rate	0.1	0.1
IS elements length	1,2,3	1,2,3
RIS transposition rate	0.1	0.1
RIS elements length	1,2,3	1,2,3
Weights mutation rate	0.002	0.002
Dw specific transposition rate	0.1	0.1
Dw specific IS elements length	2,3,5	2,3,5
Success rate	4%	6%

6-Multiplexer: A Perfect Unigenic Solution

```
TbDTTTfTTaUDcUUTTafeefebabbdabffddfcfeeeabcabfabdcfe...
   ...709761631479459597193997465381760511137453583952159
```

W = {0.241, 1.432, 1.705, -1.95, 1.19, 1.344, 0.925, -0.163, -1.531, 1.423}

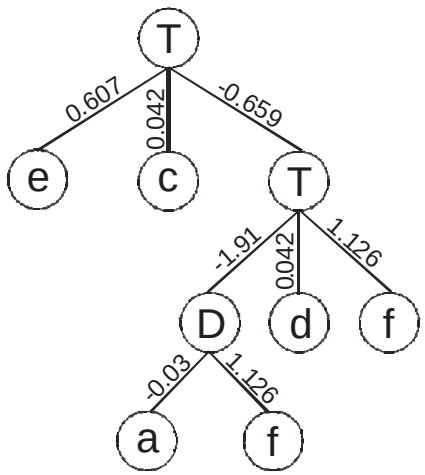


6-Multiplexer: A Perfect Multigenic Solution

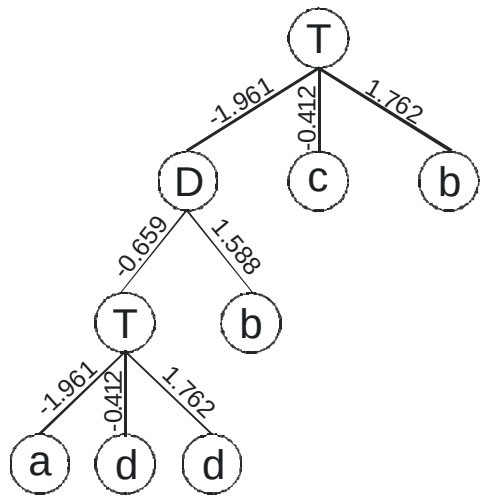
```
TecTDdfafabdddfa487674791701403
TDcbTbadddfceacc501702156029560
TfTTUbadbcdffdce593993321226318
TDTbaceaaeeacacd072636270049968
```

W_1 = {1.126, 0.042, 1.588, -0.03, -1.91, 1.83, -0.412, 0.607, -0.294, -0.659}
W_2 = {-1.961, 1.161, 1.588, -0.03, -1.91, 1.762, -0.412, -0.121, -0.294, -0.659}
W_3 = {1.558, -0.69, 0.921, 0.134, 0.468, -1.534, 0.966, 1.399, 0.023, 0.915}
W_4 = {1.558, 0.767, 0.076, 0.071, 0.468, -1.534, 1.387, -1.857, -1.88, 0.331}

Sub-NN_1

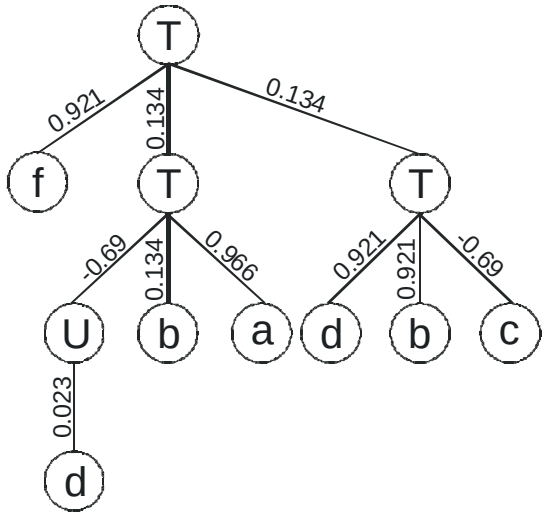


Sub-NN_2



Note:
Sub-NNs linked by OR

Sub-NN_3



Sub-NN_4