Čtvrté cvičení

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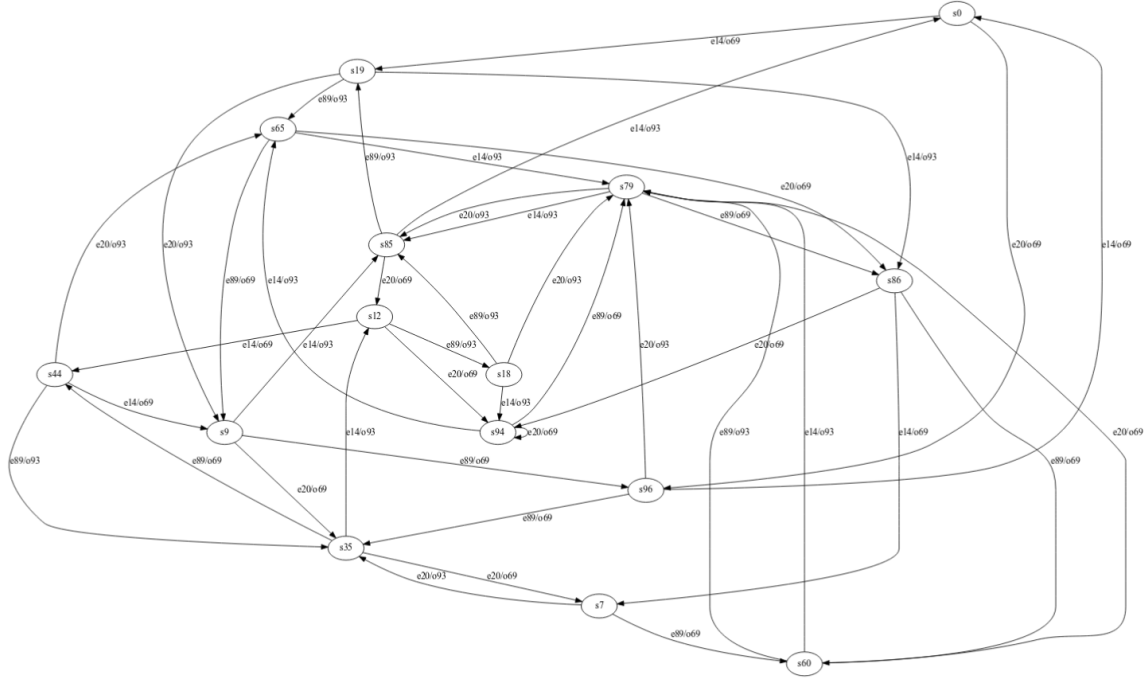### Testování konečných automatů

Zadání

Navrhněte charakterizační množinu pro následující konečný deterministický automat. Stavy jsou identifikovány prefixem "s", události prefixem "e", výstupní symboly prefixem "o". Nedosažitelné části automatu identifikujte jako chybu a při konstrukci charakterizační množiny nedosažitelné stavy neuvažujte. Jestliže přechod z nějakého stavu není pro danou událost určen, zůstává automat ve stejném stavu a na výstup pošle předdefinovaný výstupní symbol (default output).

```
entry node: s7
exit  node: s94
default output: o69
transition: s18 -> e20/o93 -> s79
transition: s96 -> e14/o69 -> s0
transition: s44 -> e89/o93 -> s35
transition: s96 -> e20/o93 -> s79
transition: s60 -> e89/o93 -> s79
transition: s86 -> e89/o69 -> s60
transition: s35 -> e20/o69 -> s7
transition: s19 -> e89/o93 -> s65
transition: s7 -> e20/o93 -> s35
transition: s85 -> e20/o69 -> s12
transition: s18 -> e89/o93 -> s85
transition: s18 -> e14/o93 -> s94
transition: s85 -> e14/o93 -> s0
transition: s65 -> e20/o69 -> s86
transition: s85 -> e89/o93 -> s19
transition: s35 -> e14/o93 -> s12
transition: s60 -> e14/o93 -> s79
transition: s60 -> e20/o69 -> s79
transition: s86 -> e20/o69 -> s94
transition: s7 -> e89/o69 -> s60
transition: s9 -> e20/o69 -> s35
transition: s12 -> e89/o93 -> s18
transition: s94 -> e14/o93 -> s65
transition: s12 -> e14/o69 -> s44
transition: s19 -> e14/o93 -> s86
transition: s94 -> e89/o69 -> s79
transition: s12 -> e20/o69 -> s94
transition: s79 -> e14/o93 -> s85
transition: s35 -> e89/o69 -> s44
transition: s0 -> e20/o69 -> s96
transition: s9 -> e14/o93 -> s85
transition: s79 -> e89/o69 -> s86
transition: s19 -> e20/o93 -> s9
transition: s0 -> e14/o69 -> s19
transition: s65 -> e14/o93 -> s79
transition: s94 -> e20/o69 -> s94
transition: s44 -> e14/o69 -> s9
transition: s9 -> e89/o69 -> s96
transition: s96 -> e89/o69 -> s35
```

```
transition: s65 -> e89/o69 -> s9
transition: s44 -> e20/o93 -> s65
transition: s86 -> e14/o69 -> s7
transition: s79 -> e20/o93 -> s85
```

Graf automatu

Pokrytí stavů

```
[['e89', 'e14', 'e89', 'e20', 'e14', 'e89'],
 ['e89', 'e14', 'e89', 'e20', 'e14', 'e89', 'e89', 'e14', 'e14'],
 ['e89', 'e14', 'e14', 'e20', 'e89'],
 ['e89', 'e14', 'e89', 'e20', 'e14', 'e89', 'e89', 'e14'],
 ['e89', 'e14', 'e14', 'e20'],
 ['e89', 'e14'],
 ['e20'],
 ['e89', 'e14', 'e89', 'e20', 'e14', 'e89', 'e89'],
 ['e89', 'e14', 'e89'],
 ['e89', 'e14', 'e89', 'e20'],
 ['e89', 'e14', 'e14', 'e20', 'e14'],
 ['e89', 'e14', 'e89', 'e20', 'e14'],
 ['e89'],
 ['e89', 'e14', 'e14']]
```

Pokrytí přechodů

```
[['e89', 'e14', 'e89', 'e20', 'e14', 'e89'],
 ['e89', 'e14', 'e89', 'e20', 'e14', 'e89', 'e89', 'e14', 'e14'],
 ['e89', 'e14', 'e14', 'e20', 'e89'],
 ['e89', 'e14', 'e89', 'e20', 'e14', 'e89', 'e89', 'e14'],
 ['e89', 'e14', 'e14', 'e20'],
 ['e89', 'e14'],
 ['e20'],
 ['e89', 'e14', 'e89', 'e20', 'e14', 'e89', 'e89'],
 ['e89', 'e14', 'e89'],
 ['e89', 'e14', 'e89', 'e20'],
 ['e89', 'e14', 'e14', 'e20', 'e14'],
 ['e89', 'e14', 'e89', 'e20', 'e14'],
```

```
      ['e89'],
      ['e89', 'e14', 'e14'],
      ['e89', 'e14', 'e89', 'e20', 'e14', 'e89', 'e89', 'e14', 'e20'],
      ['e89', 'e14', 'e89', 'e20', 'e14', 'e89', 'e89', 'e14', 'e14', 'e89'],
      ['e20', 'e14'],
      ['e89', 'e14', 'e89', 'e89'],
      ['e89', 'e14', 'e14', 'e14'],
      ['e89', 'e14', 'e89', 'e20', 'e14', 'e89', 'e89', 'e14', 'e89'],
      ['e89', 'e14', 'e89', 'e20', 'e14', 'e89', 'e89', 'e20'],
      ['e89', 'e20'],
      ['e89', 'e14', 'e89', 'e20', 'e14', 'e89', 'e89', 'e14', 'e14', 'e20'],
      ['e89', 'e14', 'e89', 'e20', 'e20'],
      ['e89', 'e14', 'e89', 'e20', 'e14', 'e89', 'e14'],
      ['e89', 'e14', 'e89', 'e20', 'e14', 'e14'],
      ['e89', 'e14', 'e89', 'e20', 'e14', 'e20'],
      ['e89', 'e14', 'e89', 'e20', 'e14', 'e89', 'e89', 'e89'],
      ['e89', 'e14', 'e89', 'e14'],
      ['e89', 'e14', 'e14', 'e20', 'e89', 'e89'],
      ['e89', 'e14', 'e14', 'e20', 'e89', 'e20'],
      ['e89', 'e14', 'e14', 'e20', 'e14', 'e20'],
      ['e89', 'e14', 'e89', 'e20', 'e14', 'e89', 'e20'],
      ['e89', 'e14', 'e89', 'e20', 'e14', 'e89', 'e89', 'e14', 'e14', 'e14'],
      ['e89', 'e14', 'e14', 'e20', 'e14', 'e89'],
      ['e89', 'e14', 'e14', 'e20', 'e20'],
      ['e89', 'e89'],
      ['e89', 'e14', 'e14', 'e20', 'e14', 'e14'],
      ['e89', 'e14', 'e14', 'e20', 'e89', 'e14', 'e14'],
      ['e14'],
      ['e89', 'e14', 'e14', 'e20', 'e89', 'e14', 'e14'],
      ['e20', 'e89'],
      ['e89', 'e14', 'e89', 'e20', 'e89'],
      ['e20', 'e20'],
      ['e89', 'e14', 'e20'],
      ['e89', 'e14', 'e14', 'e89']]
```

Charakterizační množina

```
[('e14',), ('e14', 'e14'), ('e14', 'e20'), ('e14', 'e89'), ('e20',), ('e89',)]
```

Výstup na char. množinu

```
s09:  [('o93',), ('o93', 'o93'), ('o93', 'o69'), ('o93', 'o93'), ('o69',), ('o69',)]
s19:  [('o93',), ('o93', 'o69'), ('o93', 'o69'), ('o93', 'o69'), ('o93',), ('o93',)]
s18:  [('o93',), ('o93', 'o93'), ('o93', 'o69'), ('o93', 'o69'), ('o93',), ('o93',)]
s00:  [('o69',), ('o69', 'o93'), ('o69', 'o93'), ('o69', 'o93'), ('o69',), ('o69',)]
s12:  [('o69',), ('o69', 'o69'), ('o69', 'o93'), ('o69', 'o93'), ('o69',), ('o93',)]
s79:  [('o93',), ('o93', 'o93'), ('o93', 'o69'), ('o93', 'o93'), ('o93',), ('o69',)]
s07:  [('o69',), ('o69', 'o69'), ('o69', 'o93'), ('o69', 'o69'), ('o93',), ('o69',)]
s44:  [('o69',), ('o69', 'o93'), ('o69', 'o69'), ('o69', 'o69'), ('o93',), ('o93',)]
s35:  [('o93',), ('o93', 'o69'), ('o93', 'o69'), ('o93', 'o93'), ('o69',), ('o69',)]
s96:  [('o69',), ('o69', 'o69'), ('o69', 'o69'), ('o69', 'o69'), ('o93',), ('o69',)]
s86:  [('o69',), ('o69', 'o69'), ('o69', 'o93'), ('o69', 'o69'), ('o69',), ('o69',)]
s94:  [('o93',), ('o93', 'o93'), ('o93', 'o69'), ('o93', 'o69'), ('o69',), ('o69',)]
s65:  [('o93',), ('o93', 'o93'), ('o93', 'o93'), ('o93', 'o69'), ('o69',), ('o69',)]
s60:  [('o93',), ('o93', 'o93'), ('o93', 'o93'), ('o93', 'o69'), ('o69',), ('o93',)]
s85:  [('o93',), ('o93', 'o69'), ('o93', 'o69'), ('o93', 'o69'), ('o69',), ('o93',)]
```

Tabulka nejmenších poř. čísel rozl. sekvencí

```
(s09, s19): 1 − ('e14', 'e14')        − ['o93', 'o93']        − ['o93', 'o69']
(s09, s18): 3 − ('e14', 'e89')        − ['o93', 'o93']        − ['o93', 'o69']
(s09, s00): 0 − ('e14',)              − ['o93']               − ['o69']
(s09, s12): 0 − ('e14',)              − ['o93']               − ['o69']
```

```
(s09, s79): 4 − ('e20',)              − ['o93']              − ['o93']
(s09, s07): 0 − ('e14',)              − ['o93']              − ['o69']
(s09, s44): 0 − ('e14',)              − ['o93']              − ['o69']
(s09, s35): 1 − ('e14', 'e14')        − ['o93', 'o93']       − ['o93', 'o69']
(s09, s96): 0 − ('e14',)              − ['o93']              − ['o69']
(s09, s86): 0 − ('e14',)              − ['o93']              − ['o69']
(s09, s94): 3 − ('e14', 'e89')        − ['o93', 'o93']       − ['o93', 'o69']
(s09, s65): 2 − ('e14', 'e20')        − ['o93', 'o69']       − ['o93', 'o93']
(s09, s60): 2 − ('e14', 'e20')        − ['o93', 'o69']       − ['o93', 'o93']
(s09, s85): 1 − ('e14', 'e14')        − ['o93', 'o93']       − ['o93', 'o69']
(s19, s18): 1 − ('e14', 'e14')        − ['o93', 'o69']       − ['o93', 'o93']
(s19, s00): 0 − ('e14',)              − ['o93']              − ['o69']
(s19, s12): 0 − ('e14',)              − ['o93']              − ['o69']
(s19, s79): 1 − ('e14', 'e14')        − ['o93', 'o69']       − ['o93', 'o93']
(s19, s07): 0 − ('e14',)              − ['o93']              − ['o69']
(s19, s44): 0 − ('e14',)              − ['o93']              − ['o69']
(s19, s35): 3 − ('e14', 'e89')        − ['o93', 'o69']       − ['o93', 'o93']
(s19, s96): 0 − ('e14',)              − ['o93']              − ['o69']
(s19, s86): 0 − ('e14',)              − ['o93']              − ['o69']
(s19, s94): 1 − ('e14', 'e14')        − ['o93', 'o69']       − ['o93', 'o93']
(s19, s65): 1 − ('e14', 'e14')        − ['o93', 'o69']       − ['o93', 'o93']
(s19, s60): 1 − ('e14', 'e14')        − ['o93', 'o69']       − ['o93', 'o93']
(s19, s85): 4 − ('e20',)              − ['o93']              − ['o69']
(s18, s00): 0 − ('e14',)              − ['o93']              − ['o69']
(s18, s12): 0 − ('e14',)              − ['o93']              − ['o69']
(s18, s79): 3 − ('e14', 'e89')        − ['o93', 'o69']       − ['o93', 'o93']
(s18, s07): 0 − ('e14',)              − ['o93']              − ['o69']
(s18, s44): 0 − ('e14',)              − ['o93']              − ['o69']
(s18, s35): 1 − ('e14', 'e14')        − ['o93', 'o93']       − ['o93', 'o69']
(s18, s96): 0 − ('e14',)              − ['o93']              − ['o69']
(s18, s86): 0 − ('e14',)              − ['o93']              − ['o69']
(s18, s94): 4 − ('e20',)              − ['o93']              − ['o69']
(s18, s65): 2 − ('e14', 'e20')        − ['o93', 'o69']       − ['o93', 'o93']
(s18, s60): 2 − ('e14', 'e20')        − ['o93', 'o69']       − ['o93', 'o93']
(s18, s85): 1 − ('e14', 'e14')        − ['o93', 'o93']       − ['o93', 'o69']
(s00, s12): 1 − ('e14', 'e14')        − ['o69', 'o93']       − ['o69', 'o69']
(s00, s79): 0 − ('e14',)              − ['o69']              − ['o93']
(s00, s07): 1 − ('e14', 'e14')        − ['o69', 'o93']       − ['o69', 'o69']
(s00, s44): 2 − ('e14', 'e20')        − ['o69', 'o93']       − ['o69', 'o69']
(s00, s35): 0 − ('e14',)              − ['o69']              − ['o93']
(s00, s96): 1 − ('e14', 'e14')        − ['o69', 'o93']       − ['o69', 'o69']
(s00, s86): 1 − ('e14', 'e14')        − ['o69', 'o93']       − ['o69', 'o69']
(s00, s94): 0 − ('e14',)              − ['o69']              − ['o93']
(s00, s65): 0 − ('e14',)              − ['o69']              − ['o93']
(s00, s60): 0 − ('e14',)              − ['o69']              − ['o93']
(s00, s85): 0 − ('e14',)              − ['o69']              − ['o93']
(s12, s79): 0 − ('e14',)              − ['o69']              − ['o93']
(s12, s07): 3 − ('e14', 'e89')        − ['o69', 'o93']       − ['o69', 'o69']
(s12, s44): 1 − ('e14', 'e14')        − ['o69', 'o69']       − ['o69', 'o93']
(s12, s35): 0 − ('e14',)              − ['o69']              − ['o93']
(s12, s96): 2 − ('e14', 'e20')        − ['o69', 'o93']       − ['o69', 'o69']
(s12, s86): 3 − ('e14', 'e89')        − ['o69', 'o93']       − ['o69', 'o69']
(s12, s94): 0 − ('e14',)              − ['o69']              − ['o93']
(s12, s65): 0 − ('e14',)              − ['o69']              − ['o93']
(s12, s60): 0 − ('e14',)              − ['o69']              − ['o93']
(s12, s85): 0 − ('e14',)              − ['o69']              − ['o93']
(s79, s07): 0 − ('e14',)              − ['o93']              − ['o69']
(s79, s44): 0 − ('e14',)              − ['o93']              − ['o69']
(s79, s35): 1 − ('e14', 'e14')        − ['o93', 'o93']       − ['o93', 'o69']
(s79, s96): 0 − ('e14',)              − ['o93']              − ['o69']
(s79, s86): 0 − ('e14',)              − ['o93']              − ['o69']
```

```
(s79 , s94 ): 3 − ('e14', 'e89')        − ['o93', 'o93']         − ['o93', 'o69']
(s79 , s65 ): 2 − ('e14', 'e20')        − ['o93', 'o69']         − ['o93', 'o93']
(s79 , s60 ): 2 − ('e14', 'e20')        − ['o93', 'o69']         − ['o93', 'o93']
(s79 , s85 ): 1 − ('e14', 'e14')        − ['o93', 'o93']         − ['o93', 'o69']
(s07 , s44 ): 1 − ('e14', 'e14')        − ['o69', 'o69']         − ['o69', 'o93']
(s07 , s35 ): 0 − ('e14',)              − ['o69']               − ['o93']
(s07 , s96 ): 2 − ('e14', 'e20')        − ['o69', 'o93']         − ['o69', 'o69']
(s07 , s86 ): 4 − ('e20',)              − ['o93']               − ['o69']
(s07 , s94 ): 0 − ('e14',)              − ['o69']               − ['o93']
(s07 , s65 ): 0 − ('e14',)              − ['o69']               − ['o93']
(s07 , s60 ): 0 − ('e14',)              − ['o69']               − ['o93']
(s07 , s85 ): 0 − ('e14',)              − ['o69']               − ['o93']
(s44 , s35 ): 0 − ('e14',)              − ['o69']               − ['o93']
(s44 , s96 ): 1 − ('e14', 'e14')        − ['o69', 'o93']         − ['o69', 'o69']
(s44 , s86 ): 1 − ('e14', 'e14')        − ['o69', 'o93']         − ['o69', 'o69']
(s44 , s94 ): 0 − ('e14',)              − ['o69']               − ['o93']
(s44 , s65 ): 0 − ('e14',)              − ['o69']               − ['o93']
(s44 , s60 ): 0 − ('e14',)              − ['o69']               − ['o93']
(s44 , s85 ): 0 − ('e14',)              − ['o69']               − ['o93']
(s35 , s96 ): 0 − ('e14',)              − ['o93']               − ['o69']
(s35 , s86 ): 0 − ('e14',)              − ['o93']               − ['o69']
(s35 , s94 ): 1 − ('e14', 'e14')        − ['o93', 'o69']         − ['o93', 'o93']
(s35 , s65 ): 1 − ('e14', 'e14')        − ['o93', 'o69']         − ['o93', 'o93']
(s35 , s60 ): 1 − ('e14', 'e14')        − ['o93', 'o69']         − ['o93', 'o93']
(s35 , s85 ): 3 − ('e14', 'e89')        − ['o93', 'o93']         − ['o93', 'o69']
(s96 , s86 ): 2 − ('e14', 'e20')        − ['o69', 'o69']         − ['o69', 'o93']
(s96 , s94 ): 0 − ('e14',)              − ['o69']               − ['o93']
(s96 , s65 ): 0 − ('e14',)              − ['o69']               − ['o93']
(s96 , s60 ): 0 − ('e14',)              − ['o69']               − ['o93']
(s96 , s85 ): 0 − ('e14',)              − ['o69']               − ['o93']
(s86 , s94 ): 0 − ('e14',)              − ['o69']               − ['o93']
(s86 , s65 ): 0 − ('e14',)              − ['o69']               − ['o93']
(s86 , s60 ): 0 − ('e14',)              − ['o69']               − ['o93']
(s86 , s85 ): 0 − ('e14',)              − ['o69']               − ['o93']
(s94 , s65 ): 2 − ('e14', 'e20')        − ['o93', 'o69']         − ['o93', 'o93']
(s94 , s60 ): 2 − ('e14', 'e20')        − ['o93', 'o69']         − ['o93', 'o93']
(s94 , s85 ): 1 − ('e14', 'e14')        − ['o93', 'o93']         − ['o93', 'o69']
(s65 , s60 ): 5 − ('e89',)              − ['o69']               − ['o93']
(s65 , s85 ): 1 − ('e14', 'e14')        − ['o93', 'o93']         − ['o93', 'o69']
(s60 , s85 ): 1 − ('e14', 'e14')        − ['o93', 'o93']         − ['o93', 'o69']
```

Testy skrytých stavů

```
set ([('e14', 'e14'),
      ('e14', 'e14', 'e14'),
      ('e14', 'e14', 'e20'),
      ('e14', 'e14', 'e89'),
      ('e14', 'e20'),
      ('e14', 'e89'),
      ('e20', 'e14'),
      ('e20', 'e14', 'e14'),
      ('e20', 'e14', 'e20'),
      ('e20', 'e14', 'e89'),
      ('e20', 'e20'),
      ('e20', 'e89'),
      ('e89', 'e14'),
      ('e89', 'e14', 'e14'),
      ('e89', 'e14', 'e20'),
      ('e89', 'e14', 'e89'),
      ('e89', 'e20'),
      ('e89', 'e89')])
```

Nestandardní kroky

Pokrytí přechodů bylo vytvořeno, narozdíl od postupu doporučeného v přednášce, pomocí rozšíření pokrytí stavů o posloupnosti přechodů pokrývající pokrytím stavů nepokryté přechody tak, že posloupnost přechodů pokrývající počáteční stav nepokrytého přechodu byla prodloužena o příslušný nepokrytý přechod. Nalezené pokrytí bylo menší než pokrytí nalezené pomocí doporučené metody.

Událost (`'e14',`) lze z charakterizační množiny samozřejmě odstranit, neboť každé dva stavy rozlišené touto událostí jsou rozlišené také každou posloupností začínající touto událostí.

Kód byl okomentován a napsán s důrazem na přehlednost znovupoužitelnost. Pokus o ověření validity pokrytí stavů, hran i charakterizační množiny byl proveden pomocí testovacích metod.

V tabulce nejmenších pořadových čísel rozlišovacích sekvencí z charakterizační množiny je pro přehlednost přímo uvedena příslušná sekvence a příslušné výstupy.

Zde jsou pro zajímavost uvedeny rozdělovací tabulky a tabulka nejmenších pořadových čísel rozdělovacích tabulek, ve kterých byla příslušná dvojice stavů poprvé v rozdílných třídách:

```
[{0: ['s44'], 1: ['s12'], 2: ['s09', 's35', 's94', 's65'], 3: ['s60', 's85'],
  4: ['s19', 's18'], 5: ['s00', 's86'], 6: ['s07', 's96'], 7: ['s79']},
 {0: ['s44'], 1: ['s94'], 2: ['s09'], 3: ['s79'], 4: ['s18'], 5: ['s85'], 6: ['s60'],
  7: ['s00'], 8: ['s35'], 9: ['s07', 's86'], 10: ['s96'], 11: ['s19'], 12: ['s12'],
  13: ['s65']},
 {0: ['s60'], 1: ['s86'], 2: ['s07'], 3: ['s44'], 4: ['s79'], 5: ['s19'], 6: ['s09'],
  7: ['s18'], 8: ['s35'], 9: ['s94'], 10: ['s00'], 11: ['s12'], 12: ['s65'],
  13: ['s85'], 14: ['s96']}]

{('s00', 's07'): 0,
 ('s00', 's12'): 0,
 ('s00', 's35'): 0,
 ('s00', 's44'): 0,
 ('s00', 's60'): 0,
 ('s00', 's65'): 0,
 ('s00', 's79'): 0,
 ('s00', 's85'): 0,
 ('s00', 's86'): 1,
 ('s00', 's94'): 0,
 ('s00', 's96'): 0,
 ('s07', 's35'): 0,
 ('s07', 's44'): 0,
 ('s07', 's60'): 0,
 ('s07', 's65'): 0,
 ('s07', 's85'): 0,
 ('s07', 's86'): 0,
 ('s07', 's94'): 0,
 ('s07', 's96'): 1,
 ('s09', 's00'): 0,
 ('s09', 's07'): 0,
 ('s09', 's12'): 0,
 ('s09', 's18'): 0,
 ('s09', 's19'): 0,
 ('s09', 's35'): 1,
 ('s09', 's44'): 0,
 ('s09', 's60'): 0,
 ('s09', 's65'): 1,
 ('s09', 's79'): 0,
 ('s09', 's85'): 0,
 ('s09', 's86'): 0,
 ('s09', 's94'): 1,
 ('s09', 's96'): 0,
 ('s12', 's07'): 0,
 ('s12', 's35'): 0,
 ('s12', 's44'): 0,
 ('s12', 's60'): 0,
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