Bevezetés a matematikába

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Ezek a programok csak szemléltetésre szolgálnak.

▶ 1. Halmazok

▶ 2. Természetes számok

▶ 3. A számfogalom bővítése

▶ 4. Véges halmazok

▶ 5. Végtelen halmazok

▶ 6. Számelmélet

▶ 7. Gráfelmélet

▶ 8. Algebra

▶ 9. Kódolás

▼ 10. Algoritmusok

▼ 10.1. Számítási modellek

```
> restart;
```

▶ *10.1.1. Számítási modellek*

▼ *10.1.2. Példa.*

```
> f:=proc();
  if nargs<2 then args else
    if nargs>2 then
      if args[3]=2 then
        if args[2]=0 then args[1] else args[1],args[2],3 fi;
```

```
      else args[2],args[1] mod args[2],2 fi;
    else args[1],args[2],2 fi;
  fi; end;
```

$f := \mathbf{proc}()$ (10.1.2.1)

```
    if nargs < 2 then
        args
    else
        if 2 < nargs then
            if args[3] = 2 then
                if args[2] = 0 then
                    args[1]
                else
                    args[1],
                    args[2], 3
                end if
            else
                args[2], mod(args[1],
                args[2]), 2
            end if
        else
            args[1], args[2], 2
        end if
    end if
end proc
```

```
> 172,62;f(%);f(%);f(%);f(%);f(%);f(%);f(%);f(%);f(%);f(%);f
  (%);f(%);f(%);
```

172, 62

172, 62, 2

172, 62, 3

62, 48, 2

62, 48, 3

48, 14, 2

48, 14, 3

14, 6, 2

14, 6, 3

6, 2, 2

6, 2, 3

2, 0, 2

2

10.1.3. Szimulálás.

10.1.4. Példa.

```
> f:=proc();
  if nargs=3 then args else
    if nargs<3 then args[1],1,0,args[2],0,1,0,2
    else
      if args[8]=2 then
        if args[4]=0 then args[1..3] else args[1..7],"3.1"
  fi;
      else
        if args[8]="3.1" then args[1..6],floor(args[1]/args
  [4]),"3.2"
        else args[4],args[5],args[6],args[1]-args[7]*args[4],
  args[2]-args[7]*args[5],args[3]-args[7]*args[6],args[7],2
  fi;
      fi;
    fi;
  fi; end;
>
```

(10.1.4.1)

```
f := proc()
    if nargs = 3 then
        args
    else
        if nargs < 3 then
            args[1], 1,
            0, args[2], 0, 1, 0, 2
        else
            if args[8] = 2 then
                if args[4] = 0 then
                    args[1..3]
                else
                    args[1..7], "3.1"
                end if
            else
                if args[8] = "3.1" then
                    args[1..6],
                    floor(args[1] / args[4]), "3.2"
                else
                    args[4],
```

```
                    args[5], args[6], args[1] − args[7]*args[4],
                    args[2] − args[7]*args[5],
                    args[3] − args[7]*args[6], args[7], 2
                end if
            end if
        end if
    end if
end proc
```

```
> 172,62;f(%);f(%);f(%);f(%);f(%);f(%);f(%);f(%);f(%);f(%);f(%);f(%);f(%);f(%);f(%);f(%);
```

172, 62

172, 1, 0, 62, 0, 1, 0, 2

172, 1, 0, 62, 0, 1, 0, "3.1"

172, 1, 0, 62, 0, 1, 2, "3.2"

62, 0, 1, 48, 1, −2, 2, 2

62, 0, 1, 48, 1, −2, 2, "3.1"

62, 0, 1, 48, 1, −2, 1, "3.2"

48, 1, −2, 14, −1, 3, 1, 2

48, 1, −2, 14, −1, 3, 1, "3.1"

48, 1, −2, 14, −1, 3, 3, "3.2"

14, −1, 3, 6, 4, −11, 3, 2

14, −1, 3, 6, 4, −11, 3, "3.1"

14, −1, 3, 6, 4, −11, 2, "3.2"

6, 4, −11, 2, −9, 25, 2, 2

6, 4, −11, 2, −9, 25, 2, "3.1"

6, 4, −11, 2, −9, 25, 3, "3.2"

2, −9, 25, 0, 31, −86, 3, 2

2, −9, 25

2, −9, 25 (10.1.4.2)

▶ ***10.1.5. Szimulációk sebességének összehasonlítása.***

▶ ***10.1.6. Ordó.***

▶ ***–>10.1.7. Feladat.***

▼ ***–>10.1.8. Feladat.***

▶ ***10.1.9. Feladat.***

▶ ***10.1.10. Algoritmus.***

10.1.11. Turing-gépek.

```
> T1:=proc(b,a) [h,a,"="] end; T1(h,"x");
```

$$T1 := \mathbf{proc}(b, a)\ [h, a, "="]\ \mathbf{end\ proc}$$

$$[h, "x", "="] \tag{10.1.11.1}$$

```
> T2:=proc(b,a) if b=h then [h,a,"="] else [b," ","<"] fi;
  end;
  T2("s","x");
```

$$T2 := \mathbf{proc}(b, a)$$
$$\quad \mathbf{if}\ b = h\ \mathbf{then}$$
$$\quad\quad [h, a, "="]$$
$$\quad \mathbf{else}$$
$$\quad\quad [b, " ", "<"]$$
$$\quad \mathbf{end\ if}$$
$$\mathbf{end\ proc}$$

$$["s", " ", "<"] \tag{10.1.11.2}$$

```
> T3:=proc(b,a) if b="h" then ["h",a,"="]
  elif a<>" " then ["s",a,"<"] else ["h",a,">"] fi; end;

  T3("s","1"); T3("s","2"); T3("s"," ");
```

$$T3 := \mathbf{proc}(b, a)$$
$$\quad \mathbf{if}\ b = "h"\ \mathbf{then}$$
$$\quad\quad ["h", a, "="]$$
$$\quad \mathbf{elif}\ a <> " "\ \mathbf{then}$$
$$\quad\quad ["s", a,$$
$$\quad\quad "<"]$$
$$\quad \mathbf{else}$$
$$\quad\quad ["h", a, ">"]$$
$$\quad \mathbf{end\ if}$$
$$\mathbf{end\ proc}$$

$$["s", "1", "<"]$$
$$["s", "2", "<"]$$
$$["h", " ", ">"] \tag{10.1.11.3}$$

10.1.12. Turing-gép, mint számítási eljárás; bemenet és kimenet.

```
> with(StringTools):
```

```
> space:=" ";start:="s";halt:="h";llength:=30;rlength:=30;
  Ts:=proc(T::procedure) global space,start,halt,llength,
  rlength;
  local k,i,L,LL,LLL,wl,wm,wr,w;
  if type(nargs,odd) or nargs<4 then
    error "odd number of words",nargs-2; fi;
  k:=(nargs-2)/2;L:=[args[2]];lprint(Fill(" ",llength+
  rlength));
  for i to k do
    wl:=args[2*i+1]; wr:=args[2*i+2];
    if length(wl)=0 then wm:=space; else wm:=wl[-1]; fi;
    while length(wl)>0 do
      if wl[1]<>space then break; else wl:=wl[2..-1]; fi;
    od;
    while length(wr)>0 do
      if wr[-1]<>space then break; else wr:=wr[1..-2]; fi;
    od;
    if length(wl)>llength then w:=wl[-llength..-1];
      else w:=cat(Fill(space,llength-length(wl)),wl); fi;
    if length(wr)>rlength then w:=cat(w,wr[1..rlength]);
      else w:=cat(w,wr,Fill(space,rlength-length(wr))); fi;
    lprint(w);
    L:=[op(L),wm];
  od;
  w:=cat(Fill(" ",llength-1),"^",L[1]);
  if length(L[1])<rlength then w:=cat(w,Fill(" ",rlength-
  length(L[1]))); fi; lprint(w);
  LL:=T(op(L)); LLL:=[T,LL[1]];
  for i to k do
    wl:=args[2*i+1]; wr:=args[2*i+2];
    if length(wl)>0 then wl:=wl[1..-2]; fi;
    if length(wr)>0 then wm:=wr[1]; wr:=wr[2..-1]; else wm:=
  space fi;
    if LL[k+1+i]="=" then wl:=cat(wl,LL[i+1]); wr:=cat(wm,wr)
  ; fi;
    if LL[k+1+i]="<" then wr:=cat(LL[i+1],wm,wr); fi;
    if LL[k+1+i]=">" then wl:=cat(wl,LL[i+1],wm); fi;
    LLL:=[op(LLL),wl,wr];
  od; op(LLL); end;
```

$$space := \text{" "}$$
$$start := \text{"s"}$$
$$halt := \text{"h"}$$
$$llength := 30$$
$$rlength := 30$$

$$Ts := \mathbf{proc}(T::procedure) \qquad (10.1.12.1)$$

$$\mathbf{local}\ k, i, L, LL, LLL, wl, wm, wr, w;$$

```
global space, start, halt, llength, rlength;
if type( nargs,
odd) or nargs < 4 then
    error "odd number of words",
    nargs - 2
end if;
k := 1 / 2 * nargs - 1;
L := [ args[ 2 ] ];
lprint( StringTools:-Fill( " ", llength + rlength) );
for i to k do
    wl := args[ 2 * i + 1 ];
    wr := args[ 2 * i + 2 ];
    if length( wl) = 0 then
        wm := space
    else
        wm := wl[ -1 ]
    end if;
    while 0 < length( wl) do
        if wl[ 1 ] <> space then
            break
        else
            wl := wl[ 2 .. -1 ]
        end if
    end do;
    while 0 < length( wr) do
        if wr[ -1 ] <> space then
            break
        else
            wr := wr[ 1 .. -2 ]
        end if
    end do;
    if llength < length( wl) then
        w := wl[ -llength .. -1 ]
    else
        w := cat( StringTools:-Fill( space, llength - length( wl) ),
            wl)
    end if;
    if rlength < length( wr) then
```

```
            w := cat(w,
            wr[1..rlength])
        else
            w := cat(w, wr,
            StringTools:-Fill(space, rlength - length(wr)))
        end if;
        lprint(w);
        L := [op(L), wm]
    end do;
    w := cat(StringTools:-Fill(" ", llength - 1), "^", L[1]);
    if length(L[1]) < rlength then
        w := cat(w, StringTools:-Fill(" ",
        rlength - length(L[1])))
    end if;
    lprint(w);
    LL := T(op(L));
    LLL := [T, LL[1]];
    for i to k do
        wl := args[2*i+1];
        wr := args[2*i+2];
        if 0 < length(wl) then
            wl := wl[1..-2]
        end if;
        if 0 < length(wr) then
            wm := wr[1];
            wr := wr[2..-1]
        else
            wm := space
        end if;
        if LL[k+1+i] = "=" then
            wl := cat(wl, LL[i+1]);
            wr := cat(wm, wr)
        end if;
        if LL[k+1+i] = "<" then
            wr := cat(LL[i+1], wm, wr)
        end if;
        if LL[k+1+i] = ">" then
            wl := cat(wl, LL[i+1], wm)
```

```
        end if;
        LLL := [op(LLL), wl, wr]
    end do;
    op(LLL)
end proc
```

```
> T3,"s","123","";Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):
                                T3, "s", "123", ""
"                                                                    "
"                                123                                 "
"                                  ^s                                "
"                                                                    "
"                                 123                                "
"                                  ^s                                "
"                                                                    "
"                                  123                               "
"                                  ^s                                "
"                                                                    "
"                                   123                              "
"                                  ^s                                "
"                                                                    "
"                                  123                               "
"                                  ^h                                "
"                                                                    "
"                                  123                               "
"                                  ^h                                "
```

▶ *10.1.13. Megjegyzés.*

▼ *10.1.14. Példák.*

```
> T1,"h","abc","def";Ts(%):Ts(%):Ts(%):
                                T1, "h", "abc", "def"
"                                                                    "
"                                abcdef                              "
"                                  ^h                                "
"                                                                    "
"                                abcdef                              "
"                                  ^h                                "
"                                                                    "
"                                abcdef                              "
"                                  ^h                                "
> T2,"s","abc","def";Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):
                                T2, "s", "abc", "def"
"                                                                    "
"                                abcdef                              "
"                                  ^s                                "
```

```
"                                                                    "
"                                ab def                              "
"                                 ^s                                 "
"                                                                    "
"                                 a  def                             "
"                                 ^s                                 "
"                                                                    "
"                                     def                            "
"                                 ^s                                 "
"                                                                    "
"                                      def                           "
"                                 ^s                                 "
> T3,"s","123","";Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):
                              T3, "s", "123", ""
"                                                                    "
"                               123                                  "
"                                 ^s                                 "
"                                                                    "
"                                123                                 "
"                                 ^s                                 "
"                                                                    "
"                                 123                                "
"                                 ^s                                 "
"                                                                    "
"                                  123                               "
"                                 ^s                                 "
"                                                                    "
"                                 123                                "
"                                 ^h                                 "
"                                                                    "
"                                 123                                "
"                                 ^h                                 "
> T4:=proc(b,a) if b="s" then ["0","a",">"]
  elif b="0" then ["1","b",">"]
  elif b="1" then ["2","r",">"]
  elif b="2" then ["3","a",">"]
  elif b="3" then ["4","k",">"]
  elif b="4" then ["5","a",">"]
  elif b="5" then ["6","d",">"]
  elif b="6" then ["7","a",">"]
  elif b="7" then ["8","b",">"]
  elif b="8" then ["9","r",">"]
  elif b="9" then ["h","a","="]
  elif b="h" then ["h","a","="] fi; end;
```

$$T4 := \mathbf{proc}(b, a) \qquad (10.1.14.1)$$

$\mathbf{if}\ b = \text{"s"}\ \mathbf{then}$

$[\text{"0"}, \text{"a"}, \text{">"}]$

```
    elif b = "0" then
        ["1",
        "b", ">"]
    elif b = "1" then
        ["2", "r", ">"]
    elif b = "2" then
        ["3",
        "a", ">"]
    elif b = "3" then
        ["4", "k", ">"]
    elif b = "4" then
        ["5",
        "a", ">"]
    elif b = "5" then
        ["6", "d", ">"]
    elif b = "6" then
        ["7",
        "a", ">"]
    elif b = "7" then
        ["8", "b", ">"]
    elif b = "8" then
        ["9",
        "r", ">"]
    elif b = "9" then
        ["h", "a", "="]
    elif b = "h" then
        ["h",
        "a", "="]
    end if
end proc
```

```
> T4,"s","","";Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts
  (%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):
                                T4, "s", "", ""
"                                                                    "
"                                                                    "
"                                  ^s                                "
"                                                                    "
"                                a                                   "
"                                  ^0                                "
```

```
"                                                                    "
"                              ab                                    "
"                                ^1                                  "
"                                                                    "
"                             abr                                    "
"                                ^2                                  "
"                                                                    "
"                            abra                                    "
"                                ^3                                  "
"                                                                    "
"                           abrak                                    "
"                                ^4                                  "
"                                                                    "
"                          abraka                                    "
"                                ^5                                  "
"                                                                    "
"                         abrakad                                    "
"                                ^6                                  "
"                                                                    "
"                        abrakada                                    "
"                                ^7                                  "
"                                                                    "
"                       abrakadab                                    "
"                                ^8                                  "
"                                                                    "
"                      abrakadabr                                    "
"                                ^9                                  "
"                                                                    "
"                      abrakadabra                                   "
"                                ^h                                  "
"                                                                    "
"                      abrakadabra                                   "
"                                ^h                                  "
```

```
> T5:=proc(b,a1,a2)
  if b="s" then
    if a1<>" " then ["s",a1,a2,"<","="] else ["c",a1,a1,">",
  "<"] fi;
  elif b="c" then
    if a1<>" " then ["c",a1,a1,">","<"] else ["r",a1,a1,"<",
  ">"] fi;
  elif b="r" then
    if a2<>" " then ["r",a1,a2,"=",">"] else ["h",a1,a2,"=",
  "<"] fi;
  else ["h",a1,a2,"=","="] fi; end;
```

$$T5 := \mathbf{proc}(b, a1, a2) \tag{10.1.14.2}$$

```
    if b = "s" then
        if a1 <> " " then
```

```
            ["s", a1, a2,
            "<", "="]
        else
            ["c", a1, a1, ">", "<"]
        end if
    elif b = "c" then
        if a1 <> " " then
            ["c", a1, a1, ">", "<"]
        else
            ["r", a1, a1, "<", ">"]
        end if
    elif b = "r" then
        if a2 <> " " then
            ["r", a1, a2, "=", ">"]
        else
            ["h", a1, a2, "=", "<"]
        end if
    else
        ["h", a1, a2, "=", "="]
    end if
end proc
```

```
> T5,"s","abcd","","","":Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%)
  :Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts
  (%):Ts(%):
"                                                              "
"                              abcd                            "
"                                                              "
"                                ^s                            "
"                                                              "
"                               abcd                           "
"                                                              "
"                                ^s                            "
"                                                              "
"                               abcd                           "
"                                                              "
"                                ^s                            "
"                                                              "
"                                abcd                          "
"                                                              "
"                                ^s                            "
"                                                              "
"                                 abcd                         "
```

```
"                                                                    "
"                                  ^s                                "
"                                                                    "
"                                  abcd                              "
"                                                                    "
"                                  ^c                                "
"                                                                    "
"                                 abcd                               "
"                                   a                                "
"                                  ^c                                "
"                                                                    "
"                                abcd                                "
"                                   ba                               "
"                                  ^c                                "
"                                                                    "
"                               abcd                                 "
"                                   cba                              "
"                                  ^c                                "
"                                                                    "
"                              abcd                                  "
"                                   dcba                             "
"                                  ^c                                "
"                                                                    "
"                               abcd                                 "
"                                  dcba                              "
"                                  ^r                                "
"                                                                    "
"                               abcd                                 "
"                                 dcba                               "
"                                  ^r                                "
"                                                                    "
"                               abcd                                 "
"                                dcba                                "
"                                  ^r                                "
"                                                                    "
"                               abcd                                 "
"                               dcba                                 "
"                                  ^r                                "
"                                                                    "
"                               abcd                                 "
"                              dcba                                  "
"                                  ^r                                "
"                                                                    "
"                               abcd                                 "
"                               dcba                                 "
"                                  ^h                                "
"                                                                    "
"                               abcd                                 "
```

```
"                                dcba                                "
"                                   ^h                               "
```

```
> T63:=proc(b,a1,a2,a3)
  if b="s" then
    if a1="1" and a2="1" then ["c",a1,a2,"0","<","<","<"]
    elif a1="1" or a2="1" then ["s",a1,a2,"1","<","<","<"]
    elif a1="0" or a2="0" then ["s",a1,a2,"0","<","<","<"]
    else ["b",a1,a2,a3,"=","=",">"] fi;
  elif b="c" then
    if a1="1" and a2="1" then ["c",a1,a2,"1","<","<","<"]
    elif a1="1" or a2="1" then ["c",a1,a2,"0","<","<","<"]
    elif a1="0" or a2="0" then ["s",a1,a2,"1","<","<","<"]
    else ["b",a1,a2,"1","=","=",">"] fi;
  elif b="b" then
    if a3<>" " then ["b",a1,a2,a3,"=","=",">"]
    else ["h",a1,a2,a3,"=","=","<"] fi;
  else ["h",a1,a2,a3,"=","=","="] fi; end;
```

$$T63 := \mathbf{proc}(b, a1, a2, a3) \qquad (10.1.14.3)$$

```
if b = "s" then
    if a1 = "1" and a2 = "1" then
        ["c", a1, a2, "0", "<", "<", "<"]
    elif a1 = "1" or a2 = "1" then
        ["s", a1, a2, "1", "<", "<",
        "<"]
    elif a1 = "0" or a2 = "0" then
        ["s", a1, a2, "0", "<",
        "<", "<"]
    else
        ["b", a1, a2, a3, "=", "=", ">"]
    end if
elif b = "c" then
    if a1 = "1" and a2 = "1" then
        ["c", a1, a2,
        "1", "<", "<", "<"]
    elif a1 = "1" or a2 = "1" then
        ["c", a1,
        a2, "0", "<", "<", "<"]
    elif a1 = "0" or a2 = "0" then
        ["s",
        a1, a2, "1", "<", "<", "<"]
    else
```

```
            ["b", a1, a2, "1", "=", "=",
            ">"]
        end if
    elif b = "b" then
        if a3 <> " " then
            ["b", a1, a2,
            a3, "=", "=", ">"]
        else
            ["h", a1, a2, a3, "=", "=", "<"]
        end if
    else
        ["h", a1, a2, a3, "=", "=", "="]
    end if
end proc
```

```
> T63,"s","10111","","1011","","","":Ts(%):Ts(%):Ts(%):Ts(%)
  :Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts
  (%):
"                                                              "
"                          10111                               "
"                           1011                               "
"                                                              "
"                              ^s                              "
"                                                              "
"                          10111                               "
"                           1011                               "
"                              0                               "
"                             ^c                               "
"                                                              "
"                          10111                               "
"                           1011                               "
"                             10                               "
"                             ^c                               "
"                                                              "
"                          10111                               "
"                           1011                               "
"                            010                               "
"                             ^c                               "
"                                                              "
"                          10111                               "
"                           1011                               "
"                           0010                               "
"                             ^c                               "
"                                                              "
"                            10111                             "
```

```
"                                1011                                "
"                               00010                                "
"                              ^c                                    "
"                                                                    "
"                               10111                                "
"                                1011                                "
"                              100010                                "
"                              ^b                                    "
"                                                                    "
"                               10111                                "
"                                1011                                "
"                             100010                                 "
"                              ^b                                    "
"                                                                    "
"                               10111                                "
"                                1011                                "
"                           100010                                   "
"                              ^b                                    "
"                                                                    "
"                               10111                                "
"                                1011                                "
"                            100010                                  "
"                              ^b                                    "
"                                                                    "
"                               10111                                "
"                                1011                                "
"                          100010                                    "
"                              ^b                                    "
"                                                                    "
"                               10111                                "
"                                1011                                "
"                        100010                                      "
"                              ^b                                    "
"                                                                    "
"                               10111                                "
"                                1011                                "
"                         100010                                     "
"                              ^h                                    "
"                                                                    "
"                               10111                                "
"                                1011                                "
"                         100010                                     "
"                              ^h                                    "
```

```
> T62:=proc(b,a1,a2)
  if b="s" then
    if a1="1" and a2="1" then ["c",a1,"0","<","<"]
    elif a1="1" or a2="1" then ["s",a1,"1","<","<"]
    elif a1="0" or a2="0" then ["s",a1,"0","<","<"]
```

```
    else ["b",a1,a2,"=",">"] fi;
  elif b="c" then
    if a1="1" and a2="1" then ["c",a1,"1","<","<"]
    elif a1="1" or a2="1" then ["c",a1,"0","<","<"]
    elif a1="0" or a2="0" then ["s",a1,"1","<","<"]
    else ["b",a1,"1","=",">"] fi;
  elif b="b" then
    if a2<>" " then ["b",a1,a2,"=",">"]
    else ["h",a1,a2,"=","<"] fi;
  else ["h",a1,a2,"=","="] fi; end;
```

```
T62 := proc(b, a1, a2)                                    (10.1.14.4)
    if b = "s" then
        if a1 = "1" and a2 = "1" then
            ["c", a1, "0", "<", "<"]
        elif a1 = "1" or a2 = "1" then
            ["s", a1,
            "1", "<", "<"]
        elif a1 = "0" or a2 = "0" then
            ["s", a1, "0",
            "<", "<"]
        else
            ["b", a1, a2, "=", ">"]
        end if
    elif b = "c" then
        if a1 = "1" and a2 = "1" then
            ["c", a1, "1",
            "<", "<"]
        elif a1 = "1" or a2 = "1" then
            ["c", a1, "0", "<",
            "<"]
        elif a1 = "0" or a2 = "0" then
            ["s", a1, "1", "<", "<"]
        else
            ["b", a1, "1", "=", ">"]
        end if
    elif b = "b" then
        if a2 <> " " then
            ["b", a1, a2, "=", ">"]
        else
            ["h", a1, a2, "=", "<"]
```

```
        end if
    else
        ["h", a1, a2, "=", "="]
    end if
end proc
```

```
> T62,"s","11","","11","":Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%)
  :Ts(%):Ts(%):
"                                                                    "
"                                11                                  "
"                                11                                  "
"                                 ^s                                 "
"                                                                    "
"                                 11                                 "
"                                 10                                 "
"                                 ^c                                 "
"                                                                    "
"                                  11                                "
"                                  10                                "
"                                 ^c                                 "
"                                                                    "
"                                  11                                "
"                                110                                 "
"                                 ^b                                 "
"                                                                    "
"                                  11                                "
"                              110                                   "
"                                 ^b                                 "
"                                                                    "
"                                  11                                "
"                              110                                   "
"                                 ^b                                 "
"                                                                    "
"                                  11                                "
"                              110                                   "
"                                 ^h                                 "
"                                                                    "
"                                  11                                "
"                              110                                   "
"                                 ^h                                 "
```

▶ ***->10.1.15. Feladat.***

▼ ***->10.1.16. Feladat.***

▼ ***->10.1.17. Feladat.***

▼ ***10.1.18. Feladat.***

▼ ***10.1.19. Feladat.***

10.1.20. Feladat.

10.1.21. Turing-gép szimulálása csökkentett jelkészlettel.

```
> T3unary:=proc(b,a)
  if b="s" then
    if a=" " then ["sb",a,"<"] else ["sI",a,"<"] fi;
  elif b="sb" then
    if a=" " then ["s0"," ",">"] else ["s2","I",">"] fi;
  elif b="sI" then
    if a=" " then ["s1"," ",">"] else ["s3","I",">"] fi;
  elif b="s0" then ["s0>"," ",">"]
  elif b="s1" then ["s1<","I","<"]
  elif b="s2" then ["s2<"," ","<"]
  elif b="s3" then ["s3<","I","<"]
  elif b="s0>" then ["h",a,">"]
  elif b="s1<" then ["s",a,"<"]
  elif b="s2<" then ["s",a,"<"]
  elif b="s3<" then ["s",a,"<"]
  else ["h",a,"="] fi; end;
```

$$T3unary := \mathbf{proc}(b, a) \tag{10.1.21.1}$$

```
    if b = "s" then
        if a = " " then
            ["sb", a, "<"]
        else
            ["sI", a, "<"]
        end if
    elif b = "sb" then
        if a = " " then
            ["s0", " ", ">"]
        else
            ["s2", "I", ">"]
        end if
    elif b = "sI" then
        if a = " " then
            ["s1", " ", ">"]
        else
            ["s3", "I", ">"]
        end if
    elif b = "s0" then
        ["s0>", " ", ">"]
    elif b = "s1" then
```

```
        ["s1<",
       "I", "<"]
    elif b = "s2" then
        ["s2<", " ", "<"]
    elif b = "s3" then
        ["s3<", "I", "<"]
    elif b = "s0>" then
        ["h", a, ">"]
    elif b = "s1<" then
        ["s", a, "<"]
    elif b = "s2<" then
        ["s", a,
       "<"]
    elif b = "s3<" then
        ["s", a, "<"]
    else
        ["h", a, "="]
    end if
end proc
```

```
> T3unary,"s"," II II","":Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%)
  :Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts
  (%):Ts(%):Ts(%):
"                                                              "
"                          II II                               "
"                             ^s                               "
"                                                              "
"                           II II                              "
"                              ^sI                             "
"                                                              "
"                          II II                               "
"                             ^s3                              "
"                                                              "
"                           II II                              "
"                              ^s3<                            "
"                                                              "
"                            II II                             "
"                              ^s                              "
"                                                              "
"                               II II                          "
"                                ^sb                           "
"                                                              "
"                            II II                             "
"                              ^s2                             "
```

```
"                                                                    "
"                              II II                                 "
"                               ^s2<                                 "
"                                                                    "
"                               II II                                "
"                               ^s                                   "
"                                                                    "
"                                II II                               "
"                               ^sI                                  "
"                                                                    "
"                               II II                                "
"                               ^s1                                  "
"                                                                    "
"                                II II                               "
"                               ^s1<                                 "
"                                                                    "
"                                 II II                              "
"                               ^s                                   "
"                                                                    "
"                                  II II                             "
"                               ^sb                                  "
"                                                                    "
"                                 II II                              "
"                               ^s0                                  "
"                                                                    "
"                                II II                               "
"                               ^s0>                                 "
"                                                                    "
"                               II II                                "
"                               ^h                                   "
"                                                                    "
"                               II II                                "
"                               ^h                                   "
```

10.1.22. Feladat.

10.1.23. Példák.

```
> T01:=proc(b,a)
  if b="s" then
    if a<>" " then ["sb",a,"<"] else ["r",a,">"] fi;
  elif b="sb" then
    if a<>" " then [cat("s",a)," ","<"] else ["bb"," ",">"]
  fi;
  elif b="b" then
    if a<>" " then ["b",a,">"] else ["bb",a,">"] fi;
  elif b="bb" then [cat("b",a),a,"<"]
  elif b[1]="b" then ["s",b[2],"<"]
```

```
  elif b="r" then
    if a<>" " then ["r",a,">"] else ["h",a,"<"] fi;
  elif b="h" then ["h",a,"="]
  else if a<>" " then [cat("s",a),b[2],"<"] else ["b",b[2],
  ">"] fi; fi;
  end;
```

$$TO1 := \mathbf{proc}(b, a) \tag{10.1.23.1}$$

```
if b = "s" then
    if a <> " " then
        ["sb", a, "<"]
    else
        ["r", a, ">"]
    end if
elif b = "sb" then
    if a <> " " then
        [cat("s",
        a), " ", "<"]
    else
        ["bb", " ", ">"]
    end if
elif b = "b" then
    if a <> " " then
        ["b", a, ">"]
    else
        ["bb", a, ">"]
    end if
elif b = "bb" then
    [cat("b", a), a, "<"]
elif b[1] = "b" then
    ["s", b[2], "<"]
elif b = "r" then
    if a <> " " then
        ["r", a, ">"]
    else
        ["h", a, "<"]
    end if
elif b = "h" then
    ["h", a, "="]
else
```

```
        if a<>" " then
            [cat("s", a), b[2], "<"]
        else
            ["b", b[2], ">"]
        end if
    end if
end proc
```

```
> T01,"s","123","":Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%)
  :Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts
  (%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%)
  :Ts(%):Ts(%):
"                                                          "
"                          123                             "
"                            ^s                            "
"                                                          "
"                           123                            "
"                            ^sb                           "
"                                                          "
"                            1 3                           "
"                            ^s2                           "
"                                                          "
"                             2 3                          "
"                            ^s1                           "
"                                                          "
"                           12 3                           "
"                            ^b                            "
"                                                          "
"                          12 3                            "
"                            ^b                            "
"                                                          "
"                         12 3                             "
"                            ^bb                           "
"                                                          "
"                           12 3                           "
"                            ^b3                           "
"                                                          "
"                           1233                           "
"                            ^s                            "
"                                                          "
"                            1233                          "
"                            ^sb                           "
"                                                          "
"                              233                         "
"                            ^s1                           "
"                                                          "
"                           1 233                          "
```

```
"                    ^b                                    "
"                                                          "
"                  1 233                                   "
"                    ^bb                                   "
"                                                          "
"                   1 233                                  "
"                    ^b2                                   "
"                                                          "
"                    12233                                 "
"                    ^s                                    "
"                                                          "
"                     12233                                "
"                    ^sb                                   "
"                                                          "
"                    12233                                 "
"                    ^bb                                   "
"                                                          "
"                     12233                                "
"                    ^b1                                   "
"                                                          "
"                     112233                               "
"                    ^s                                    "
"                                                          "
"                    112233                                "
"                    ^r                                    "
"                                                          "
"                   112233                                 "
"                    ^r                                    "
"                                                          "
"                  112233                                  "
"                    ^r                                    "
"                                                          "
"                 112233                                   "
"                    ^r                                    "
"                                                          "
"                112233                                    "
"                    ^r                                    "
"                                                          "
"               112233                                     "
"                    ^r                                    "
"                                                          "
"              112233                                      "
"                    ^r                                    "
"                                                          "
"               112233                                     "
"                    ^h                                    "
"                                                          "
"               112233                                     "
```

```
"                                    ^h                                    "
> TO2:=proc(b,a)
  if b="s" then
    if a<>" " then [cat("s",a)," ",">"] else [">",a,">"] fi;
  elif b=">" then
    if a<>" " then [">",a,">"] else ["h",a,"<"] fi;
  elif b="h" then ["h",a,"="]
  elif length(b)=2 then
    if a=" " then [cat(b,"<"),b[2],"<"] else [b,a,">"] fi;
  else
    if a=" " then ["s",b[2],"<"] else [b,a,"<"] fi;
  fi; end;
```

$$TO2 := \mathbf{proc}(b, a) \tag{10.1.23.2}$$

```
if b = "s" then
    if a <> " " then
        [cat("s", a), " ",
        ">"]
    else
        [">", a, ">"]
    end if
elif b = ">" then
    if a <> " " then
        [">", a, ">"]
    else
        ["h", a, "<"]
    end if
elif b = "h" then
    ["h", a, "="]
elif length(b) = 2 then
    if a = " " then
        [cat(b, "<"), b[2], "<"]
    else
        [b, a, ">"]
    end if
else
    if a = " " then
        ["s", b[2], "<"]
    else
        [b, a, "<"]
    end if
```

```
    end if
end proc
> T02,"s","123","":Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%)
  :Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts
  (%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%)
  :Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):
"                                                            "
"                             123                            "
"                               ^s                           "
"                                                            "
"                            12                              "
"                               ^s3                          "
"                                                            "
"                             12 3                           "
"                               ^s3<                         "
"                                                            "
"                              1233                          "
"                               ^s                           "
"                                                            "
"                             1 33                           "
"                               ^s2                          "
"                                                            "
"                            1 33                            "
"                               ^s2                          "
"                                                            "
"                           1 33                             "
"                               ^s2                          "
"                                                            "
"                            1 332                           "
"                               ^s2<                         "
"                                                            "
"                             1 332                          "
"                               ^s2<                         "
"                                                            "
"                              1 332                         "
"                               ^s2<                         "
"                                                            "
"                                 12332                      "
"                                 ^s                         "
"                                                            "
"                                 2332                       "
"                                 ^s1                        "
"                                                            "
"                                2332                        "
"                                 ^s1                        "
"                                                            "
"                             2332                           "
"                               ^s1                          "
```

```
"                                                                                  "
"                                  2332                                            "
"                                     ^s1                                          "
"                                                                                  "
"                                 2332                                             "
"                                     ^s1                                          "
"                                                                                  "
"                                  23321                                           "
"                                     ^s1<                                         "
"                                                                                  "
"                                   23321                                          "
"                                     ^s1<                                         "
"                                                                                  "
"                                    23321                                         "
"                                     ^s1<                                         "
"                                                                                  "
"                                     23321                                        "
"                                     ^s1<                                         "
"                                                                                  "
"                                      23321                                       "
"                                     ^s1<                                         "
"                                                                                  "
"                                      123321                                      "
"                                     ^s                                           "
"                                                                                  "
"                                     123321                                       "
"                                     ^>                                           "
"                                                                                  "
"                                    123321                                        "
"                                     ^>                                           "
"                                                                                  "
"                                   123321                                         "
"                                     ^>                                           "
"                                                                                  "
"                                  123321                                          "
"                                     ^>                                           "
"                                                                                  "
"                                 123321                                           "
"                                     ^>                                           "
"                                                                                  "
"                                123321                                            "
"                                     ^>                                           "
"                                                                                  "
"                               123321                                             "
"                                     ^>                                           "
"                                                                                  "
"                                123321                                            "
"                                     ^h                                           "
```

```
"                                                                    "
"                          123321                                    "
"                               ^h                                   "
```

```
> TO3:=proc(b,a)
  if b="s" then
    if a<>" " then ["l",a,"<"] else ["h",a,"="] fi;
  elif b="l" then
    if a=" " then ["h",a,">"] else ["r",a,"="] fi;
  elif b[1]="r" and b<>"r" then
    if a=" " then [cat(">",b[2],"-")," ",">"]
    else [cat(">",b[2],"+"),a,">"] fi;
  elif b[1]=">" then
    if a=" " then [b,a,">"] else [cat("w",b[2..-1]),a,">"]
  fi;
  elif b[1]="w" then
    if a<>" " then [b,a,">"]
    elif b[3]="+" then ["<",b[2],"<"]
    else ["h",b[2],"="] fi;
  elif b="h" then ["h",a,"="]
  elif b="<" then
    if a<>" " then ["<",a,"<"] else ["r",a,"<"] fi;
  else
    if a=" " then ["r",a,"<"] else [cat("r",a)," ","<"] fi;
  fi; end;
```

$$TO3 := \mathbf{proc}(b, a) \tag{10.1.23.3}$$

```
if b = "s" then
    if a <> " " then
        ["l", a, "<"]
    else
        ["h", a, "="]
    end if
elif b = "l" then
    if a = " " then
        ["h", a, ">"]
    else
        ["r", a, "="]
    end if
elif b[1] = "r" and b <> "r" then
    if a = " " then
        [cat(">", b[2], "-"), " ", ">"]
    else
        [cat(">", b[2],
        "+"), a, ">"]
```

```
        end if
    elif b[1] = ">" then
        if a = " " then
            [b,
            a, ">"]
        else
            [cat("w", b[2..-1]), a, ">"]
        end if
    elif b[1] = "w" then
        if a <> " " then
            [b, a, ">"]
        elif b[3] = "+" then
            ["<", b[2], "<"]
        else
            ["h", b[2], "="]
        end if
    elif b = "h" then
        ["h", a, "="]
    elif b = "<" then
        if a <> " " then
            ["<", a, "<"]
        else
            ["r", a, "<"]
        end if
    else
        if a = " " then
            ["r", a, "<"]
        else
            [cat("r", a), " ", "<"]
        end if
    end if
end proc
> T03,"s","123","":Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%)
  :Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts
  (%):Ts(%):
"                                                            "
"                          123                               "
"                            ^s                              "
"                                                            "
```

```
"                    123                                    "
"                     ^l                                    "
"                                                           "
"                    123                                    "
"                     ^r                                    "
"                                                           "
"                     1 3                                   "
"                     ^r2                                   "
"                                                           "
"                    1 3                                    "
"                     ^>2+                                  "
"                                                           "
"                   1 3                                     "
"                     ^>2+                                  "
"                                                           "
"                  1 3                                      "
"                     ^w2+                                  "
"                                                           "
"                   1 32                                    "
"                     ^<                                    "
"                                                           "
"                    1 32                                   "
"                     ^<                                    "
"                                                           "
"                     1 32                                  "
"                     ^r                                    "
"                                                           "
"                        32                                 "
"                     ^r1                                   "
"                                                           "
"                       32                                  "
"                     ^>1-                                  "
"                                                           "
"                      32                                   "
"                     ^>1-                                  "
"                                                           "
"                     32                                    "
"                     ^>1-                                  "
"                                                           "
"                    32                                     "
"                     ^w1-                                  "
"                                                           "
"                   32                                      "
"                     ^w1-                                  "
"                                                           "
"                   321                                     "
"                     ^h                                    "
"                                                           "
```

```
"                                  321                                  "
"                                    ^h                                 "
```

```
> TO4:=proc(b,a)
  if b="s" then
    if a<>" " then ["=",a,">"] else ["h",a,"="] fi;
  elif b="=" then ["==",a,"<"]
  elif b="==" then ["1"," ","<"]
  elif b="1" then
    if a<>" " then ["0",a,"<"] else [">1",a,">"] fi;
  elif b="0" then
    if a<>" " then ["1",a,"<"] else [">0","1",">"] fi;
  elif b=">0" or b=">1" then
    if a=" " then [cat("=",b[2]),a,">"] else [b,a,">"] fi;
  elif b="=0" or b="=1" then ["?",b[2],"<"]
  elif b="?" then ["??",a,"<"]
  elif b="??" then
    if a=" " then [">>",a,">"] else ["d1"," ","<"] fi;
  elif b=">>" then [">",a,">"]
  elif b=">" then
    if a<>" " then [">",a,">"] else ["h",a,"<"] fi;
  elif b="d1" then ["d0",a,"<"]
  elif b="d0" then
    if a<>" " then ["d1"," ","<"] else ["t",a,">"] fi;
  elif b="t" then ["t>"," ",">"]
  elif b="t>" then
    if a<>" " then ["t>",a,">"] else ["t=","1",">"] fi;
  elif b="t=" then
    if a=" " then ["=",a,"="] else ["t<",a,"<"] fi;
  elif b="t<" then
    if a<>" " then ["t<",a,"<"] else ["t",a,">"] fi;
  else ["h",a,"="] fi; end;
```

$$TO4 := \mathbf{proc}(b, a) \qquad (10.1.23.4)$$

```
    if b = "s" then
        if a <> " " then
            ["=", a, ">"]
        else
            ["h", a, "="]
        end if
    elif b = "=" then
        ["==", a, "<"]
    elif b = "==" then
        ["1", " ", "<"]
    elif b = "1" then
        if a <> " " then
```

```
            ["0", a, "<"]
        else
            [">1", a, ">"]
        end if
    elif b = "0" then
        if a <> " " then
            ["1", a, "<"]
        else
            [">0", "1",
           ">"]
        end if
    elif b = ">0" or b = ">1" then
        if a = " " then
            [cat("=", b[2]), a, ">"]
        else
            [b, a, ">"]
        end if
    elif b = "=0" or b = "=1" then
        ["?", b[2], "<"]
    elif b = "?" then
        ["??", a, "<"]
    elif b = "??" then
        if a = " " then
            [">>", a, ">"]
        else
            ["d1", " ", "<"]
        end if
    elif b = ">>" then
        [">", a, ">"]
    elif b = ">" then
        if a <> " " then
            [">", a, ">"]
        else
            ["h", a, "<"]
        end if
    elif b = "d1" then
        ["d0", a, "<"]
    elif b = "d0" then
```

```
        if a<>" " then
            ["d1", " ", "<"]
        else
            ["t", a,
           ">"]
        end if
    elif b = "t" then
        ["t>", " ", ">"]
    elif b = "t>" then
        if a<>" " then
            ["t>", a, ">"]
        else
            ["t=",
           "1", ">"]
        end if
    elif b = "t=" then
        if a = " " then
            ["=", a,
           "="]
        else
            ["t<", a, "<"]
        end if
    elif b = "t<" then
        if a<>" " then
            ["t<", a, "<"]
        else
            ["t", a, ">"]
        end if
    else
        ["h",
       a, "="]
    end if
end proc
```

```
> T04,"s","11111","":Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts
  (%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%)
  :Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts
  (%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%)
  :Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts
  (%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%)
```

```
:Ts(%):Ts(%):Ts(%):
"                                                                    "
"                          11111                                     "
"                              ^s                                    "
"                                                                    "
"                         11111                                      "
"                              ^=                                    "
"                                                                    "
"                          11111                                     "
"                              ^==                                   "
"                                                                    "
"                           1111                                     "
"                              ^1                                    "
"                                                                    "
"                            1111                                    "
"                              ^0                                    "
"                                                                    "
"                             1111                                   "
"                              ^1                                    "
"                                                                    "
"                              1111                                  "
"                              ^0                                    "
"                                                                    "
"                               1111                                 "
"                              ^1                                    "
"                                                                    "
"                              1111                                  "
"                              ^>1                                   "
"                                                                    "
"                             1111                                   "
"                              ^>1                                   "
"                                                                    "
"                            1111                                    "
"                              ^>1                                   "
"                                                                    "
"                           1111                                     "
"                              ^>1                                   "
"                                                                    "
"                          1111                                      "
"                              ^>1                                   "
"                                                                    "
"                         1111                                       "
"                              ^=1                                   "
"                                                                    "
"                          1111 1                                    "
"                              ^?                                    "
"                                                                    "
"                           1111 1                                   "
```

```
"                                  ^??                                  "
"                                                                       "
"                                111  1                                 "
"                                  ^d1                                  "
"                                                                       "
"                                 111  1                                "
"                                  ^d0                                  "
"                                                                       "
"                                  1 1  1                               "
"                                  ^d1                                  "
"                                                                       "
"                                   1 1  1                              "
"                                  ^d0                                  "
"                                                                       "
"                                  1 1  1                               "
"                                  ^t                                   "
"                                                                       "
"                                   1  1                                "
"                                  ^t>                                  "
"                                                                       "
"                                 11  1                                 "
"                                  ^t=                                  "
"                                                                       "
"                                  11  1                                "
"                                  ^t<                                  "
"                                                                       "
"                                   11  1                               "
"                                  ^t<                                  "
"                                                                       "
"                                  11  1                                "
"                                  ^t                                   "
"                                                                       "
"                                  1  1                                 "
"                                  ^t>                                  "
"                                                                       "
"                                 1  1                                  "
"                                  ^t>                                  "
"                                                                       "
"                                11 1                                   "
"                                  ^t=                                  "
"                                                                       "
"                                11 1                                   "
"                                  ^=                                   "
"                                                                       "
"                                 11 1                                  "
"                                  ^==                                  "
"                                                                       "
"                                  1  1                                 "
```

```
"                                ^1                                "
"                                                                  "
"                                 1  1                             "
"                                ^0                                "
"                                                                  "
"                               11  1                              "
"                                ^>0                               "
"                                                                  "
"                              11  1                               "
"                                ^>0                               "
"                                                                  "
"                             11  1                                "
"                                ^=0                               "
"                                                                  "
"                              11 01                               "
"                                ^?                                "
"                                                                  "
"                               11 01                              "
"                                ^??                               "
"                                                                  "
"                                1  01                             "
"                                ^d1                               "
"                                                                  "
"                                 1  01                            "
"                                ^d0                               "
"                                                                  "
"                                1  01                             "
"                                ^t                                "
"                                                                  "
"                                  01                              "
"                                ^t>                               "
"                                                                  "
"                               1 01                               "
"                                ^t=                               "
"                                                                  "
"                               1 01                               "
"                                ^=                                "
"                                                                  "
"                                1 01                              "
"                                ^==                               "
"                                                                  "
"                                   01                             "
"                                ^1                                "
"                                                                  "
"                                  01                              "
"                                ^>1                               "
"                                                                  "
"                                 01                               "
```

```
"                                ^=1                                "
"                                                                   "
"                                 101                               "
"                                ^?                                 "
"                                                                   "
"                                  101                              "
"                                ^??                                "
"                                                                   "
"                                 101                               "
"                                ^>>                                "
"                                                                   "
"                                101                                "
"                                ^>                                 "
"                                                                   "
"                               101                                 "
"                                ^>                                 "
"                                                                   "
"                             101                                   "
"                               ^>                                  "
"                                                                   "
"                           101                                     "
"                             ^>                                    "
"                                                                   "
"                            101                                    "
"                              ^h                                   "
"                                                                   "
"                            101                                    "
"                              ^h                                   "
> TO5:=proc(b,a)
  if b="s" then
    if a=" " then ["h",a,"="] else ["s<",a,"<"] fi;
  elif b="s<" then
    if a=" " then ["??",a,">"] else [b,a,"<"] fi;
  elif b="??" then
    if a=" " then ["==",a,"<"] else ["=",a,"<"] fi;
  elif b="==" then ["h",a,"<"]
  elif b="=" then ["d",a,"<"]
  elif b="d" then
    if a=" " then [">",a,">"] else ["dd",a,"<"] fi;
  elif b="dd" then
    if a=" " then [">","1",">"] else ["d<"," ","<"] fi;
  elif b="d<" then
    if a<>" " then [b,a,"<"] else ["d>","1",">"] fi;
  elif b="d>" then
    if a<>" " then [b,a,">"] else ["d","1","<"] fi;
  elif b=">" then
    if a<>" " then [b,a,">"] else ["?","1",">"] fi;
  elif b="?" then
```

```
    if a="1" then ["??"," ",">"] else ["0<"," ","<"] fi;
  elif b="0<" then
    if a<>" " then [b,a,"<"] else ["0=",a,">"] fi;
  elif b="0=" then ["0>"," ",">"]
  elif b="0>" then
    if a<>" " then [b,a,">"] else ["??",a,">"] fi;
  else ["h",a,"="] fi end;
```

$TO5 := \mathbf{proc}(b, a)$ (10.1.23.5)

```
if b = "s" then
    if a = " " then
        ["h", a, "="]
    else
        ["s<", a, "<"]
    end if
elif b = "s<" then
    if a = " " then
        ["??", a,
       ">"]
    else
        [b, a, "<"]
    end if
elif b = "??" then
    if a = " " then
        ["==", a, "<"]
    else
        ["=", a, "<"]
    end if
elif b = "==" then
    ["h", a, "<"]
elif b = "=" then
    ["d", a, "<"]
elif b = "d" then
    if a = " " then
        [">", a, ">"]
    else
        ["dd", a, "<"]
    end if
elif b = "dd" then
    if a = " " then
```

```
            [">", "1", ">"]
        else
            ["d<",
            " ", "<"]
        end if
    elif b = "d<" then
        if a <> " " then
            [b, a,
            "<"]
        else
            ["d>", "1", ">"]
        end if
    elif b = "d>" then
        if a <> " " then
            [b, a, ">"]
        else
            ["d", "1", "<"]
        end if
    elif b = ">" then
        if a <> " " then
            [b, a, ">"]
        else
            ["?", "1", ">"]
        end if
    elif b = "?" then
        if a = "1" then
            ["??", " ", ">"]
        else
            ["0<", " ", "<"]
        end if
    elif b = "0<" then
        if a <> " " then
            [b,
            a, "<"]
        else
            ["0=", a, ">"]
        end if
    elif b = "0=" then
```

```
        ["0>",
       " ", ">"]
    elif b = "0>" then
        if a <> " " then
            [b, a, ">"]
        else
            ["??", a, ">"]
        end if
    else
        ["h", a, "="]
    end if
end proc
```

```
> T05,"s","0101","":Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%)
  :Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts
  (%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%)
  :Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts
  (%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%)
  :Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):
"                                                              "
"                          0101                                "
"                            ^s                                "
"                                                              "
"                           0101                               "
"                             ^s<                              "
"                                                              "
"                            0101                              "
"                             ^s<                              "
"                                                              "
"                              0101                            "
"                             ^s<                              "
"                                                              "
"                               0101                           "
"                             ^s<                              "
"                                                              "
"                              0101                            "
"                             ^??                              "
"                                                              "
"                               0101                           "
"                             ^=                               "
"                                                              "
"                                 0101                         "
"                             ^d                               "
"                                                              "
"                               0101                           "
"                             ^>                               "
```

```
"                                                                                  "
"                                  10101                                           "
"                                   ^?                                             "
"                                                                                  "
"                                   1  101                                         "
"                                   ^0<                                            "
"                                                                                  "
"                                    1  101                                        "
"                                   ^0<                                            "
"                                                                                  "
"                                   1  101                                         "
"                                   ^0=                                            "
"                                                                                  "
"                                    101                                           "
"                                   ^0>                                            "
"                                                                                  "
"                                   101                                            "
"                                   ^??                                            "
"                                                                                  "
"                                    101                                           "
"                                   ^=                                             "
"                                                                                  "
"                                     101                                          "
"                                   ^d                                             "
"                                                                                  "
"                                    101                                           "
"                                   ^>                                             "
"                                                                                  "
"                                  1101                                            "
"                                   ^?                                             "
"                                                                                  "
"                                 1  01                                            "
"                                   ^??                                            "
"                                                                                  "
"                                  1  01                                           "
"                                   ^=                                             "
"                                                                                  "
"                                   1  01                                          "
"                                   ^d                                             "
"                                                                                  "
"                                    1  01                                         "
"                                   ^dd                                            "
"                                                                                  "
"                                  11  01                                          "
"                                   ^>                                             "
"                                                                                  "
"                                 11  01                                           "
"                                   ^>                                             "
```

```
"                                                                                  "
"                                  11101                                           "
"                                     ^?                                           "
"                                                                                  "
"                                   111 1                                          "
"                                     ^0<                                          "
"                                                                                  "
"                                    111 1                                         "
"                                     ^0<                                          "
"                                                                                  "
"                                     111 1                                        "
"                                     ^0<                                          "
"                                                                                  "
"                                      111 1                                       "
"                                     ^0<                                          "
"                                                                                  "
"                                     111 1                                        "
"                                     ^0=                                          "
"                                                                                  "
"                                     11 1                                         "
"                                     ^0>                                          "
"                                                                                  "
"                                    11 1                                          "
"                                     ^0>                                          "
"                                                                                  "
"                                   11 1                                           "
"                                     ^0>                                          "
"                                                                                  "
"                                  11 1                                            "
"                                     ^??                                          "
"                                                                                  "
"                                   11 1                                           "
"                                     ^=                                           "
"                                                                                  "
"                                    11 1                                          "
"                                     ^d                                           "
"                                                                                  "
"                                     11 1                                         "
"                                     ^dd                                          "
"                                                                                  "
"                                       1 1                                        "
"                                     ^d<                                          "
"                                                                                  "
"                                    1 1 1                                         "
"                                     ^d>                                          "
"                                                                                  "
"                                     111 1                                        "
"                                     ^d                                           "
```

```
"                                                                    "
"                              111 1                                 "
"                             ^dd                                    "
"                                                                    "
"                            1111 1                                  "
"                             ^>                                     "
"                                                                    "
"                           1111 1                                   "
"                             ^>                                     "
"                                                                    "
"                          1111 1                                    "
"                             ^>                                     "
"                                                                    "
"                         1111 1                                     "
"                             ^>                                     "
"                                                                    "
"                        111111                                      "
"                             ^?                                     "
"                                                                    "
"                       11111                                        "
"                             ^??                                    "
"                                                                    "
"                        11111                                       "
"                             ^==                                    "
"                                                                    "
"                         11111                                      "
"                             ^h                                     "
"                                                                    "
"                         11111                                      "
"                             ^h                                     "
```

```
> TO6:=proc(b,a)
  if b="s" then
    if a=" " then ["h",a,"="] else ["s>",a,">"] fi;
  elif b="s>" then ["ss"," ",">"]
  elif b="ss" then ["s<","I","<"]
  elif b="s<" then ["d"," ","<"]
  elif b="d" then ["d<"," ","<"]
  elif b="d<" then
    if a<>" " then [b,a,"<"] else ["d<<",a,"<"] fi;
  elif b="d<<" then
    if a<>" " then [b,a,"<"] else ["d>","I",">"] fi;
  elif b="d>" then
    if a<>" " then [b,a,">"] else ["d?",a,">"] fi;
  elif b="d?" then
    if a<>" " then ["d>>",a,">"] else ["r","I",">"] fi;
  elif b="d>>" then
    if a<>" " then [b,a,">"] else ["d",a,"<"] fi;
  elif b="r" then
```

```
    if a=" " then [b,"I",">"] else ["ds"," ","<"] fi;
  elif b="ds" then ["m<"," ","<"]
  elif b="m<" then
    if a<>" " then [b,a,"<"] else ["a",a,"<"] fi;
  elif b="a" then ["a<"," ","<"]
  elif b="a<" then
    if a<>" " then [b,a,"<"] else ["a<<",a,"<"] fi;
  elif b="a<<" then
    if a<>" " then [b,a,"<"] else ["a>","I",">"] fi;
  elif b="a>" then
    if a<>" " then [b,a,">"] else ["a?",a,">"] fi;
  elif b="a?" then
    if a<>" " then ["a>>",a,">"] else ["ra","I",">"] fi;
  elif b="a>>" then
    if a<>" " then [b,a,">"] else ["a",a,"<"] fi;
  elif b="ra" then
    if a=" " then [b,"I",">"] else ["rr",a,"<"] fi;
  elif b="rr" then ["m>"," ",">"]
  elif b="m>" then
    if a<>" " then [b,a,">"] else ["md",a,"<"] fi;
  elif b="md" then ["m?"," ","<"]
  elif b="m?" then
    if a<>" " then ["m<",a,"<"] else ["ad"," ","<"] fi;
  elif b="ad" then
    if a<>" " then [b," ","<"] else ["h",a,"<"] fi;
  else ["h",a,"="] fi; end;
```

$TO6 := \mathbf{proc}(b, a)$ (10.1.23.6)

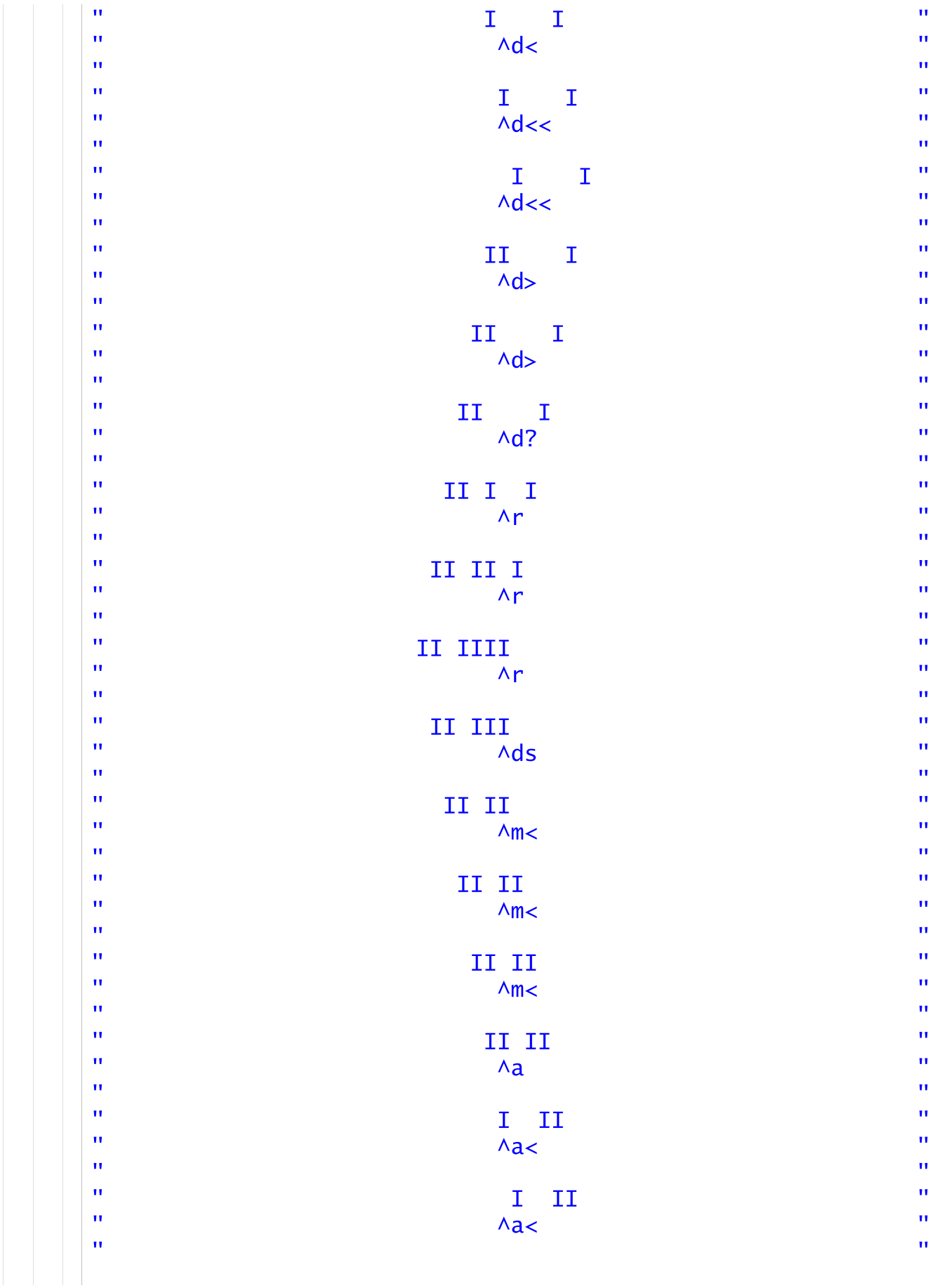
```
if b = "s" then
    if a = " " then
        ["h", a, "="]
    else
        ["s>", a, ">"]
    end if
elif b = "s>" then
    ["ss", " ", ">"]
elif b = "ss" then
    ["s<", "I", "<"]
elif b = "s<" then
    ["d", " ",
    "<"]
elif b = "d" then
    ["d<", " ", "<"]
elif b = "d<" then
```

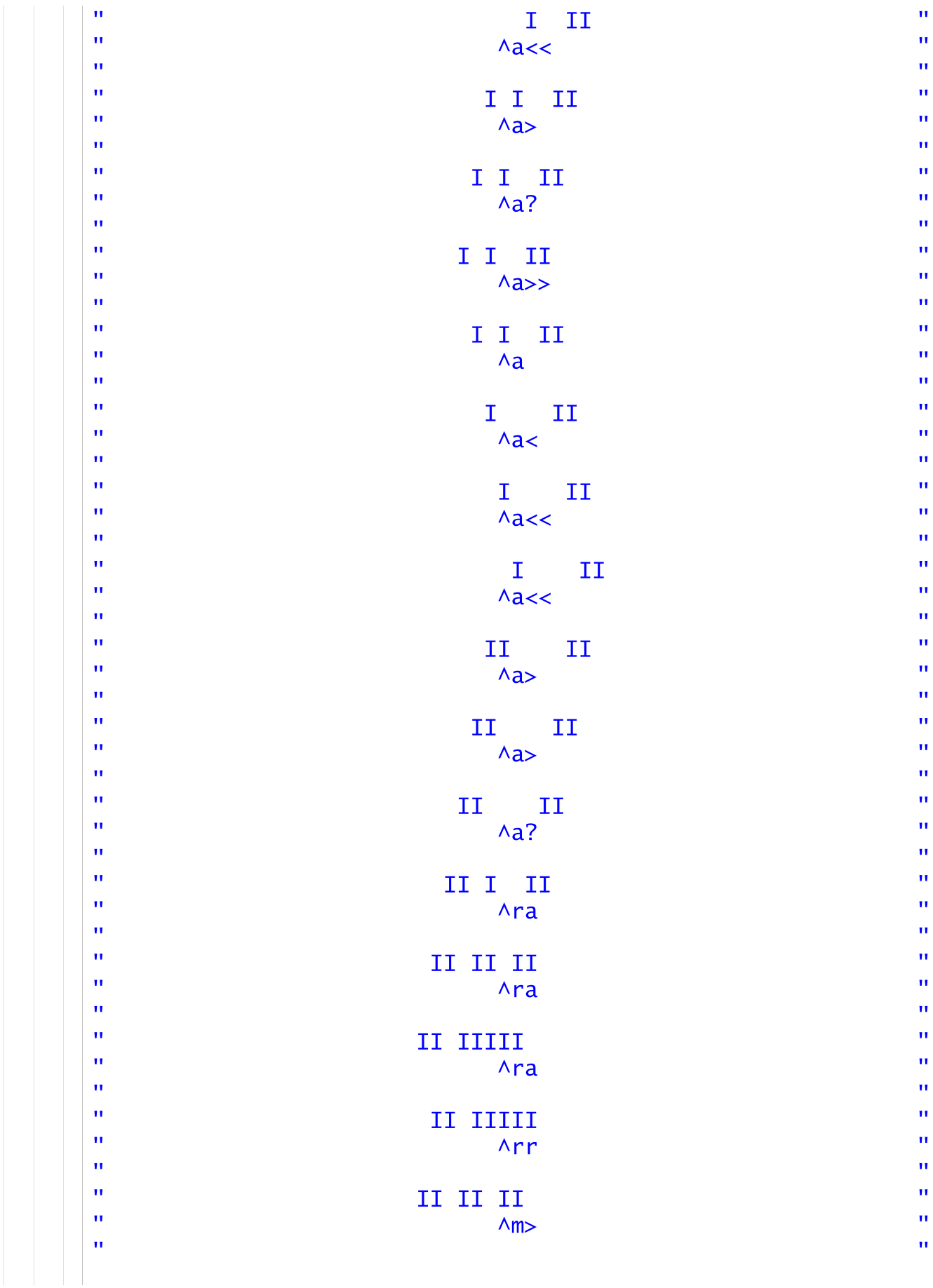
```
        if a <> " " then
            [b, a, "<"]
        else
            ["d<<", a, "<"]
        end if
    elif b = "d<<" then
        if a <> " " then
            [b, a, "<"]
        else
            ["d>",
            "I", ">"]
        end if
    elif b = "d>" then
        if a <> " " then
            [b, a,
            ">"]
        else
            ["d?", a, ">"]
        end if
    elif b = "d?" then
        if a <> " " then
            ["d>>", a, ">"]
        else
            ["r", "I", ">"]
        end if
    elif b = "d>>" then
        if a <> " " then
            [b, a, ">"]
        else
            ["d", a,
            "<"]
        end if
    elif b = "r" then
        if a = " " then
            [b, "I", ">"]
        else
            ["ds", " ", "<"]
        end if
```

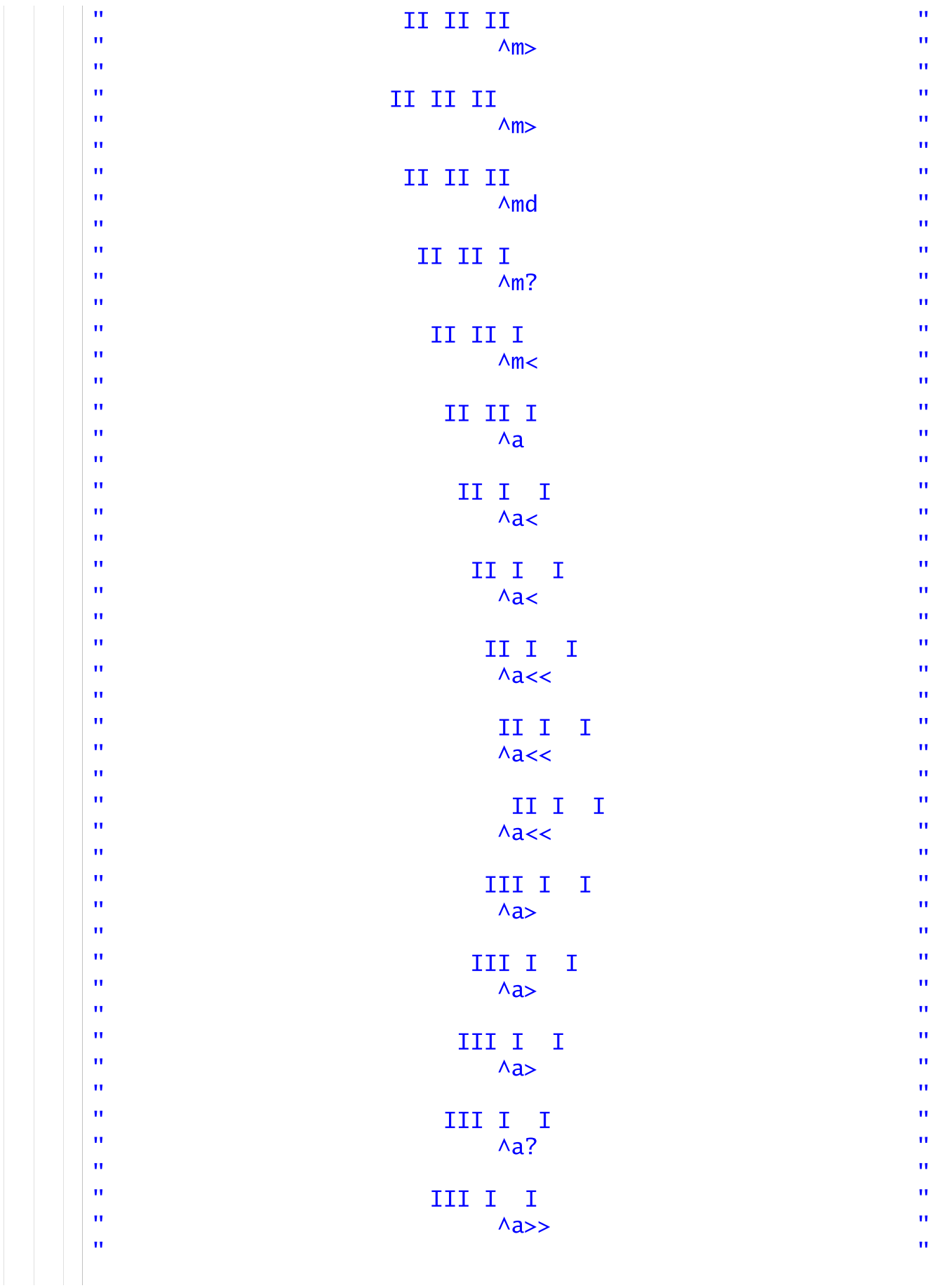
```
elif b = "ds" then
    ["m<", " ", "<"]
elif b = "m<" then
    if a <> " " then
        [b, a, "<"]
    else
        ["a", a,
       "<"]
    end if
elif b = "a" then
    ["a<", " ", "<"]
elif b = "a<" then
    if a <> " " then
        [b, a, "<"]
    else
        ["a<<", a,
      "<"]
    end if
elif b = "a<<" then
    if a <> " " then
        [b, a, "<"]
    else
        ["a>", "I", ">"]
    end if
elif b = "a>" then
    if a <> " " then
        [b, a, ">"]
    else
        ["a?", a, ">"]
    end if
elif b = "a?" then
    if a <> " " then
        ["a>>", a, ">"]
    else
        ["ra",
      "I", ">"]
    end if
elif b = "a>>" then
```

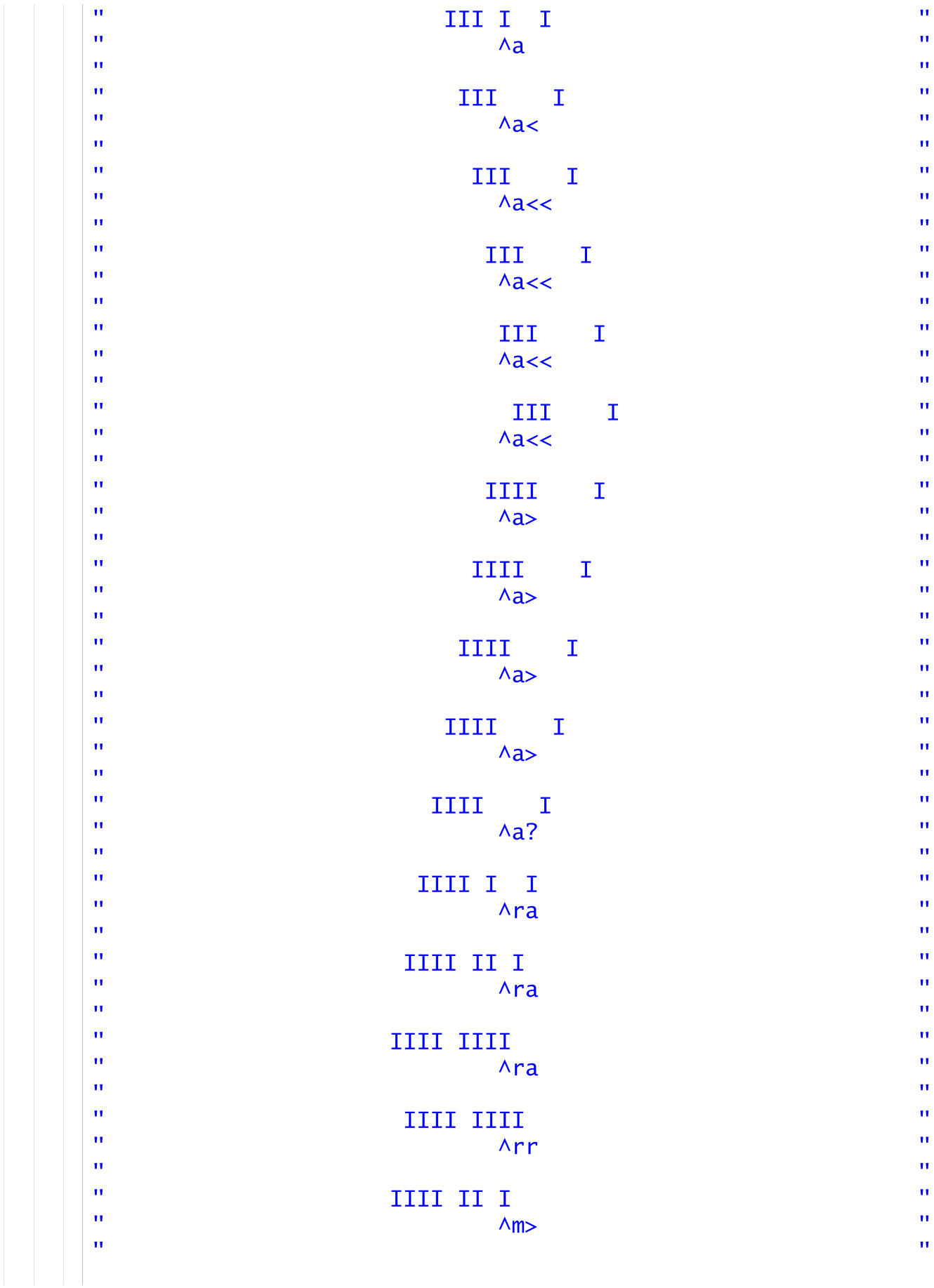
```
        if a <> " " then
            [b, a,
           ">"]
        else
            ["a", a, "<"]
        end if
    elif b = "ra" then
        if a = " " then
            [b, "I", ">"]
        else
            ["rr", a, "<"]
        end if
    elif b = "rr" then
        ["m>", " ", ">"]
    elif b = "m>" then
        if a <> " " then
            [b, a, ">"]
        else
            ["md", a, "<"]
        end if
    elif b = "md" then
        ["m?", " ", "<"]
    elif b = "m?" then
        if a <> " " then
            ["m<", a, "<"]
        else
            ["ad", " ", "<"]
        end if
    elif b = "ad" then
        if a <> " " then
            [b, " ", "<"]
        else
            ["h", a,
           "<"]
        end if
    else
        ["h", a, "="]
    end if
```

```
end proc
> TO6,"s","II","":Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%)
  :Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts
  (%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%)
  :Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts
  (%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%)
  :Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts
  (%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%)
  :Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts
  (%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%)
  :Ts(%):Ts(%):
"                                                              "
"                            II                                "
"                             ^s                               "
"                                                              "
"                           II                                 "
"                             ^s>                              "
"                                                              "
"                          II                                  "
"                             ^ss                              "
"                                                              "
"                           II I                               "
"                             ^s<                              "
"                                                              "
"                            II I                              "
"                             ^d                               "
"                                                              "
"                             I  I                             "
"                             ^d<                              "
"                                                              "
"                              I  I                            "
"                             ^d<                              "
"                                                              "
"                                I  I                          "
"                             ^d<<                             "
"                                                              "
"                            I I  I                            "
"                             ^d>                              "
"                                                              "
"                           I I  I                             "
"                             ^d?                              "
"                                                              "
"                          I I  I                              "
"                             ^d>>                             "
"                                                              "
"                           I I  I                             "
"                             ^d                               "
"                                                              "
```


I I
^d<
I I
^d<<
I I
^d<<
II I
^d>
II I
^d>
II I
^d?
II I I
^r
II II I
^r
II IIII
^r
II III
^ds
II II
^m<
II II
^m<
II II
^m<
II II
^a
I II
^a<
I II
^a<


I II
^a<<
I I II
^a>
I I II
^a?
I I II
^a>>
I I II
^a
I II
^a<
I II
^a<<
I II
^a<<
II II
^a>
II II
^a>
II II
^a?
II I II
^ra
II II II
^ra
II IIIII
^ra
II IIIII
^rr
II II II
^m>


II II II
^m>
II II II
^m>
II II II
^md
II II I
^m?
II II I
^m<
II II I
^a
II I I
^a<
II I I
^a<
II I I
^a<<
II I I
^a<<
II I I
^a<<
III I I
^a>
III I I
^a>
III I I
^a>
III I I
^a?
III I I
^a>>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IIII IIII
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"                             ^h                                "
```

```
> TO7:=proc(b,a)
  if b="s" then
    if a=" " then ["h",a,"="] else ["s<",a,"<"] fi;
  elif b="s<" then
    if a<>" " then [b,a,"<"] else ["ss"," ","<"] fi;
  elif b="ss" then ["d","I","="]
  elif b="d" then ["d<"," ","<"]
  elif b="d<" then
    if a<>" " then [b,a,"<"] else ["d<<",a,"<"] fi;
  elif b="d<<" then
    if a<>" " then [b,a,"<"] else ["d>","I",">"] fi;
  elif b="d>" then
    if a<>" " then [b,a,">"] else ["d?",a,">"] fi;
  elif b="d?" then
    if a<>" " then ["d>>",a,">"] else ["r","I",">"] fi;
  elif b="d>>" then
    if a<>" " then [b,a,">"] else ["d",a,"<"] fi;
  elif b="r" then
    if a=" " then [b,"I",">"] else ["mm",a,"<"] fi;
  elif b="mm" then ["m<"," ","<"]
  elif b="m<" then
    if a<>" " then [b,a,"<"] else ["a",a,"<"] fi;
```

```
    elif b="a" then ["a<"," ","<"]
    elif b="a<" then
      if a<>" " then [b,a,"<"] else ["a<<",a,"<"] fi;
    elif b="a<<" then
      if a<>" " then [b,a,"<"] else ["a>","I",">"] fi;
    elif b="a>" then
      if a<>" " then [b,a,">"] else ["a?",a,">"] fi;
    elif b="a?" then
      if a<>" " then ["a>>",a,">"] else ["ra","I",">"] fi;
    elif b="a>>" then
      if a<>" " then [b,a,">"] else ["a",a,"<"] fi;
    elif b="ra" then
      if a=" " then [b,"I",">"] else ["rr",a,"<"] fi;
    elif b="rr" then ["m>"," ",">"]
    elif b="m>" then
      if a<>" " then [b,a,">"] else ["md",a,"<"] fi;
    elif b="md" then ["m?"," ","<"]
    elif b="m?" then
      if a<>" " then ["m<",a,"<"] else ["rm"," ",">"] fi;
    elif b="rm" then
      if a=" " then [b,"I",">"] else ["rrm",a,"<"] fi;
    elif b="rrm" then ["c<<"," ","<"]
    elif b="c<<" then
      if a<>" " then [b,a,"<"] else ["c<<<",a,"<"] fi;
    elif b="c<<<" then
      if a<>" " then [b,a,"<"] else ["c<<<<",a,"<"] fi;
    elif b="c<<<<" then
      if a<>" " then [b,a,"<"] else ["cd",a,">"] fi;
    elif b="cd" then ["c?"," ",">"]
    elif b="c?" then
      if a<>" " then ["c>",a,">"] else ["i>",a,">"] fi;
    elif b="c>" then
      if a<>" " then [b,a,">"] else ["c>>",a,">"] fi;
    elif b="c>>" then
      if a<>" " then [b,a,">"] else ["c>>>",a,">"] fi;
    elif b="c>>>" then
      if a<>" " then [b,a,">"] else ["c>>>>"," ",">"] fi;
    elif b="c>>>>" then
      if a=" " then [b,a,">"] else ["c??"," ",">"] fi;
    elif b="c??" then
      if a<>" " then ["c<",a,"<"] else ["h<",a,"<"] fi;
    elif b="c<" then
      if a=" " then [b,a,"<"] else ["c<<",a,"<"] fi;
    elif b="h<" then
      if a=" " then [b,a,"<"] else ["h<<",a,"<"] fi;
    elif b="h<<" then
      if a<>" " then [b,a,"<"] else ["h<<<",a,"<"] fi;
    elif b="h<<<" then
```

```
    if a<>" " then [b,a,"<"] else ["h<<<<",a,"<"] fi;
  elif b="h<<<<" then
    if a<>" " then [b,a,"<"] else ["h>",a,">"] fi;
  elif b="h>" then
    if a<>" " then [b," ",">"] else ["h>>",a,">"] fi;
  elif b="h>>" then
    if a<>" " then [b," ",">"] else ["hd",a,">"] fi;
  elif b="hd" then ["h>>>"," ",">"]
  elif b="h>>>" then
    if a<>" " then [b,a,">"] else ["h",a,"<"] fi;
  elif b="i>" then
    if a<>" " then [b," ",">"] else ["i>>","I",">"] fi;
  elif b="i>>" then
    if a<>" " then [b,a,">"] else ["rs",a,">"] fi;
  elif b="rs" then
    if a=" " then [b,"I",">"] else ["s<<",a,"<"] fi;
  elif b="s<<" then
    if a<>" " then [b,a,"<"] else ["d",a,"<"] fi;
  else ["h",a,"="] fi; end;
```

$TO7 := \mathbf{proc}(b, a)$ (10.1.23.7)

```
if b = "s" then
    if a = " " then
        ["h", a, "="]
    else
        ["s<", a, "<"]
    end if
elif b = "s<" then
    if a <> " " then
        [b, a,
       "<"]
    else
        ["ss", " ", "<"]
    end if
elif b = "ss" then
    ["d", "I",
   "="]
elif b = "d" then
    ["d<", " ", "<"]
elif b = "d<" then
    if a <> " " then
        [b, a, "<"]
```

```
        else
            ["d<<", a, "<"]
        end if
    elif b = "d<<" then
        if a <> " " then
            [b, a, "<"]
        else
            ["d>",
            "I", ">"]
        end if
    elif b = "d>" then
        if a <> " " then
            [b, a,
            ">"]
        else
            ["d?", a, ">"]
        end if
    elif b = "d?" then
        if a <> " " then
            ["d>>", a, ">"]
        else
            ["r", "I", ">"]
        end if
    elif b = "d>>" then
        if a <> " " then
            [b, a, ">"]
        else
            ["d", a,
            "<"]
        end if
    elif b = "r" then
        if a = " " then
            [b, "I", ">"]
        else
            ["mm", a, "<"]
        end if
    elif b = "mm" then
        ["m<", " ", "<"]
```

```
elif b = "m<" then
    if a <> " " then
        [b, a, "<"]
    else
        ["a", a,
       "<"]
    end if
elif b = "a" then
    ["a<", " ", "<"]
elif b = "a<" then
    if a <> " " then
        [b, a, "<"]
    else
        ["a<<", a,
       "<"]
    end if
elif b = "a<<" then
    if a <> " " then
        [b, a, "<"]
    else
        ["a>", "I", ">"]
    end if
elif b = "a>" then
    if a <> " " then
        [b, a, ">"]
    else
        ["a?", a, ">"]
    end if
elif b = "a?" then
    if a <> " " then
        ["a>>", a, ">"]
    else
        ["ra",
       "I", ">"]
    end if
elif b = "a>>" then
    if a <> " " then
        [b, a,
```

```
            ">"]
        else
            ["a", a, "<"]
        end if
    elif b = "ra" then
        if a = " " then
            [b, "I", ">"]
        else
            ["rr", a, "<"]
        end if
    elif b = "rr" then
        ["m>", " ", ">"]
    elif b = "m>" then
        if a <> " " then
            [b, a, ">"]
        else
            ["md", a, "<"]
        end if
    elif b = "md" then
        ["m?", " ", "<"]
    elif b = "m?" then
        if a <> " " then
            ["m<", a, "<"]
        else
            ["rm", " ", ">"]
        end if
    elif b = "rm" then
        if a = " " then
            [b, "I", ">"]
        else
            ["rrm", a,
            "<"]
        end if
    elif b = "rrm" then
        ["c<<", " ", "<"]
    elif b = "c<<" then
        if a <> " " then
            [b, a, "<"]
```

```
        else
            ["c<<<<", a, "<"]
        end if
    elif b = "c<<<<" then
        if a <> " " then
            [b, a, "<"]
        else
            ["c<<<<<", a, "<"]
        end if
    elif b = "c<<<<<" then
        if a <> " " then
            [b, a, "<"]
        else
            ["cd",
           a, ">"]
        end if
    elif b = "cd" then
        ["c?", " ", ">"]
    elif b = "c?" then
        if a <> " " then
            ["c>", a, ">"]
        else
            ["i>", a,
          ">"]
        end if
    elif b = "c>" then
        if a <> " " then
            [b, a, ">"]
        else
            ["c>>", a, ">"]
        end if
    elif b = "c>>" then
        if a <> " " then
            [b, a, ">"]
        else
            ["c>>>", a, ">"]
        end if
    elif b = "c>>>" then
```

```
        if a <> " " then
            [b, a, ">"]
        else
            ["c>>>>", " ", ">"]
        end if
    elif b = "c>>>>" then
        if a = " " then
            [b, a, ">"]
        else
            ["c??", " ", ">"]
        end if
    elif b = "c??" then
        if a <> " " then
            ["c<", a, "<"]
        else
            ["h<",
            a, "<"]
        end if
    elif b = "c<" then
        if a = " " then
            [b, a, "<"]
        else
            ["c<<", a, "<"]
        end if
    elif b = "h<" then
        if a = " " then
            [b, a, "<"]
        else
            ["h<<", a, "<"]
        end if
    elif b = "h<<" then
        if a <> " " then
            [b, a, "<"]
        else
            ["h<<<", a, "<"]
        end if
    elif b = "h<<<" then
        if a <> " " then
```

```
            [b, a, "<"]
        else
            ["h<<<<", a, "<"]
        end if
    elif b = "h<<<<" then
        if a <> " " then
            [b, a, "<"]
        else
            ["h>", a, ">"]
        end if
    elif b = "h>" then
        if a <> " " then
            [b,
           " ", ">"]
        else
            ["h>>", a, ">"]
        end if
    elif b = "h>>" then
        if a <> " " then
            [b, " ", ">"]
        else
            ["hd", a, ">"]
        end if
    elif b = "hd" then
        ["h>>>", " ", ">"]
    elif b = "h>>>" then
        if a <> " " then
            [b, a, ">"]
        else
            ["h", a, "<"]
        end if
    elif b = "i>" then
        if a <> " " then
            [b, " ", ">"]
        else
            ["i>>",
           "I", ">"]
        end if
```

```
    elif b = "i>>" then
        if a <> " " then
            [b, a,
            ">"]
        else
            ["rs", a, ">"]
        end if
    elif b = "rs" then
        if a = " " then
            [b, "I", ">"]
        else
            ["s<<", a, "<"]
        end if
    elif b = "s<<" then
        if a <> " " then
            [b, a, "<"]
        else
            ["d", a,
            "<"]
        end if
    else
        ["h", a, "="]
    end if
end proc
```

```
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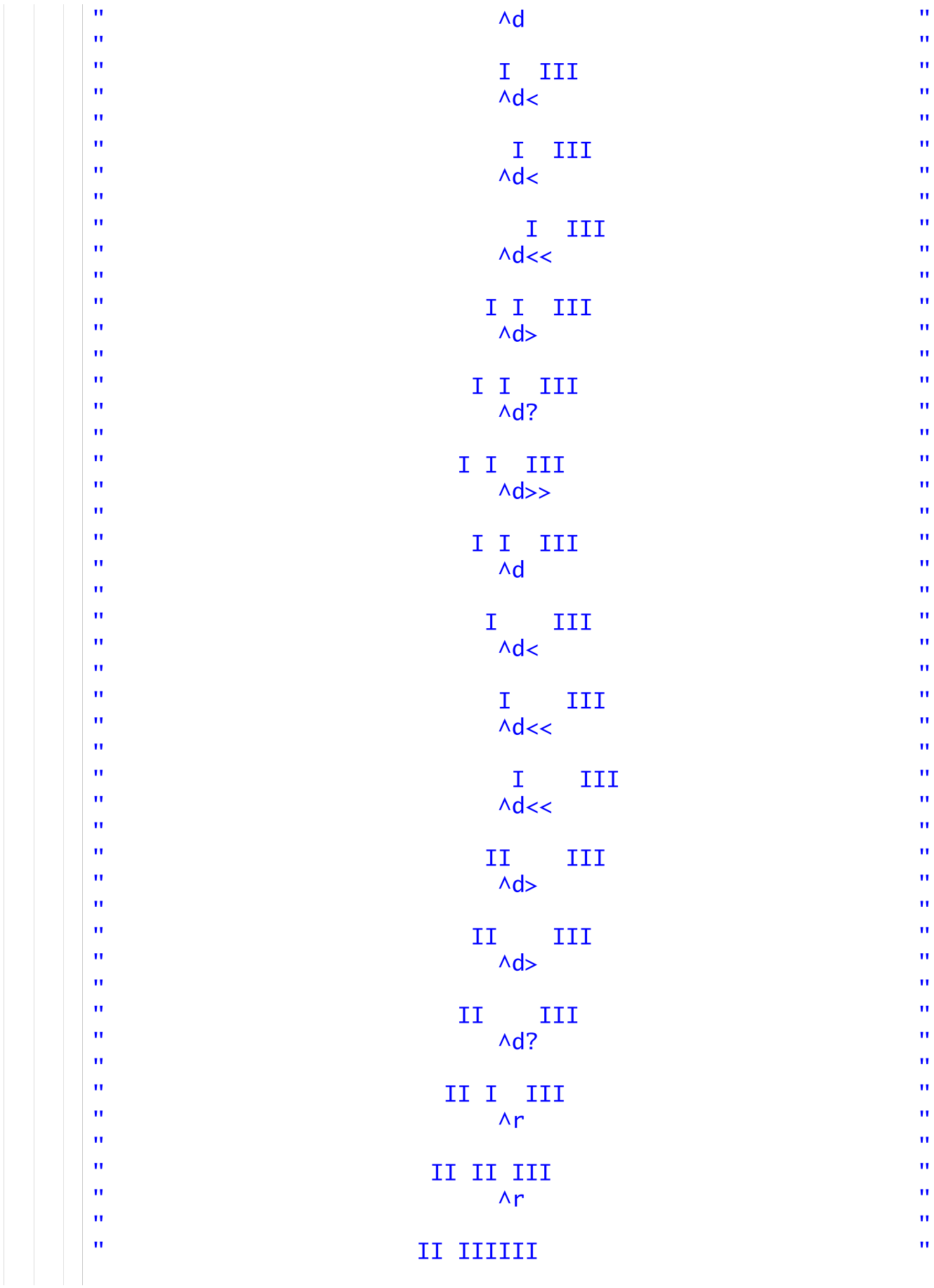
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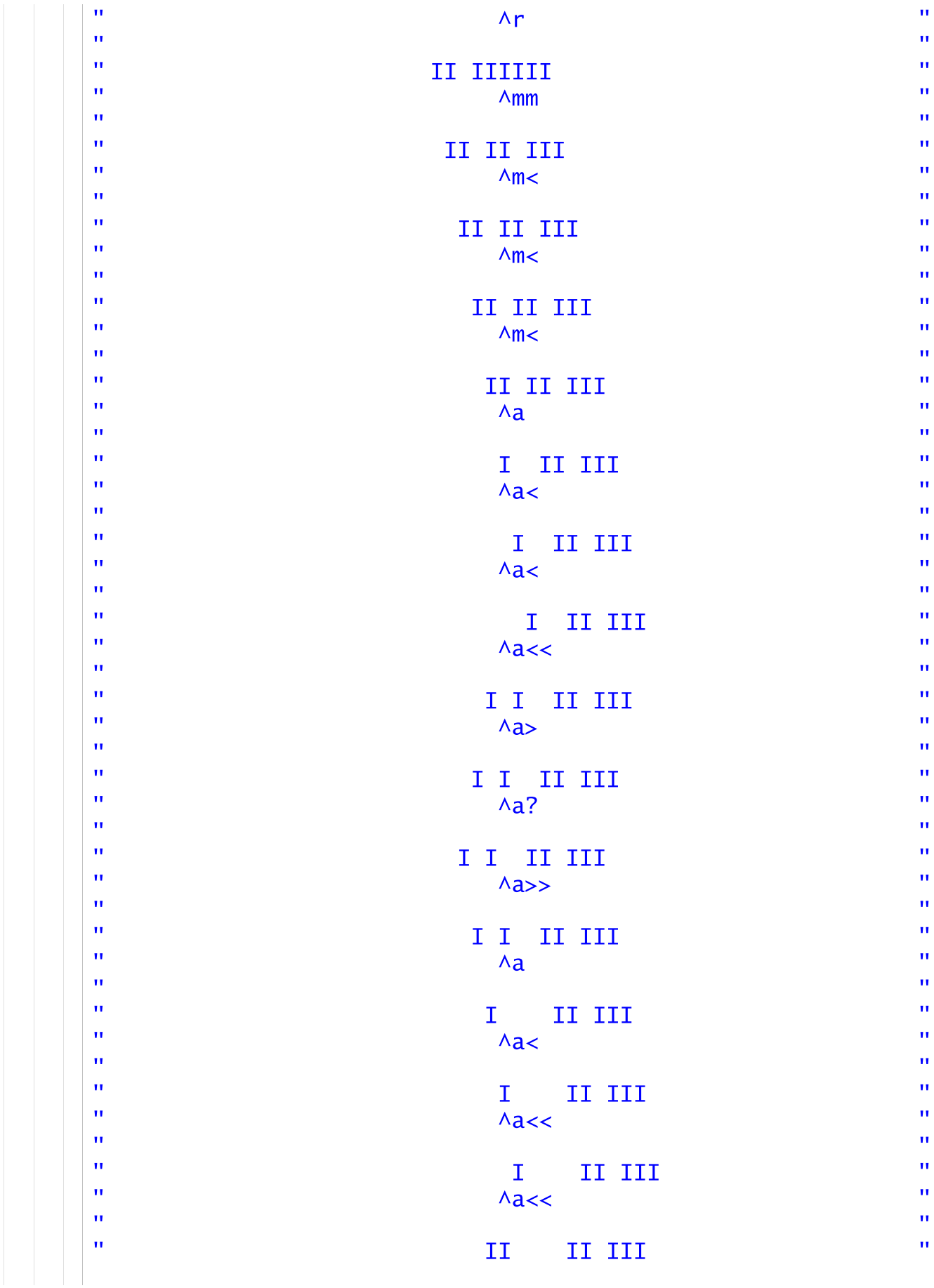
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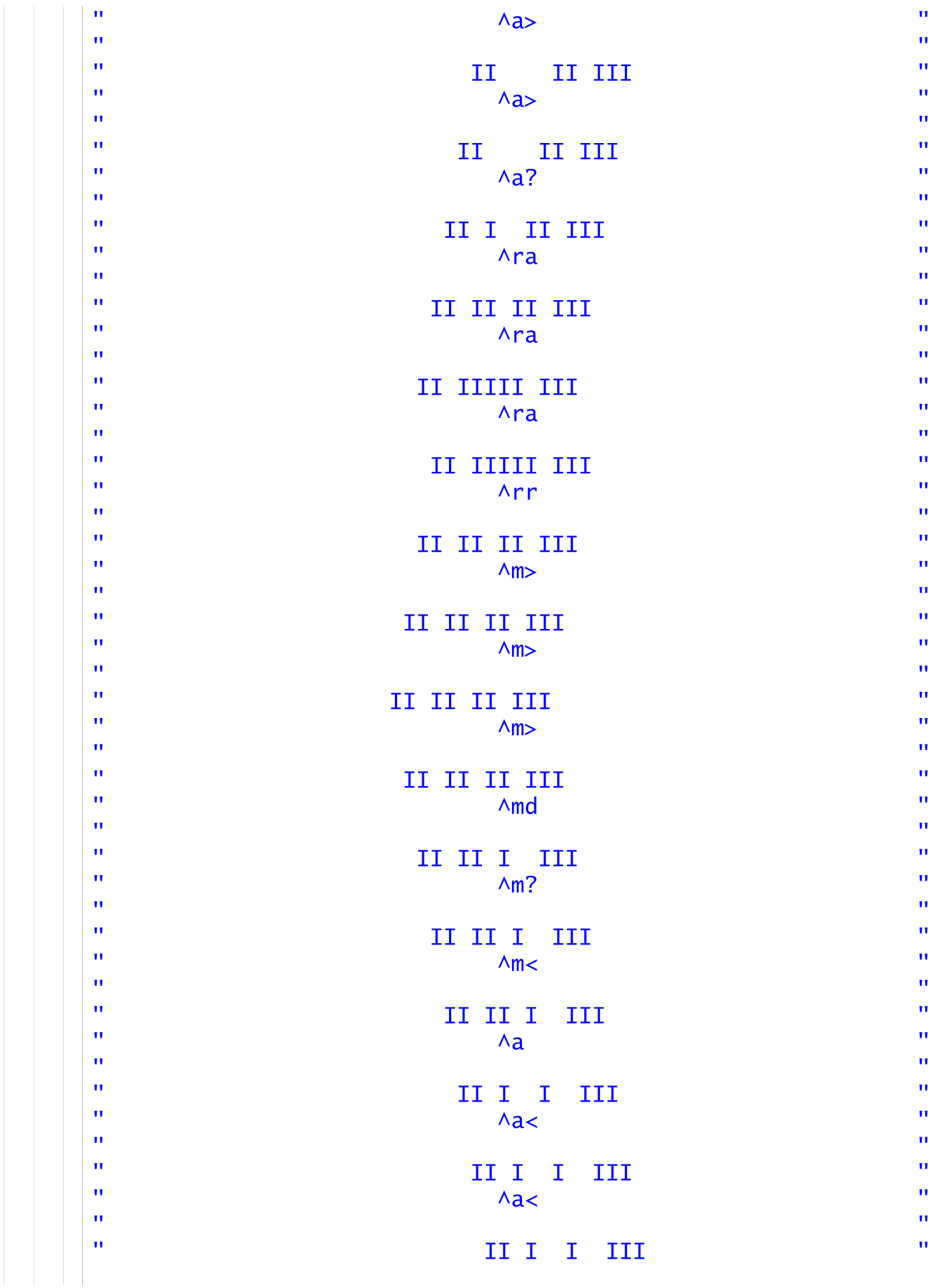
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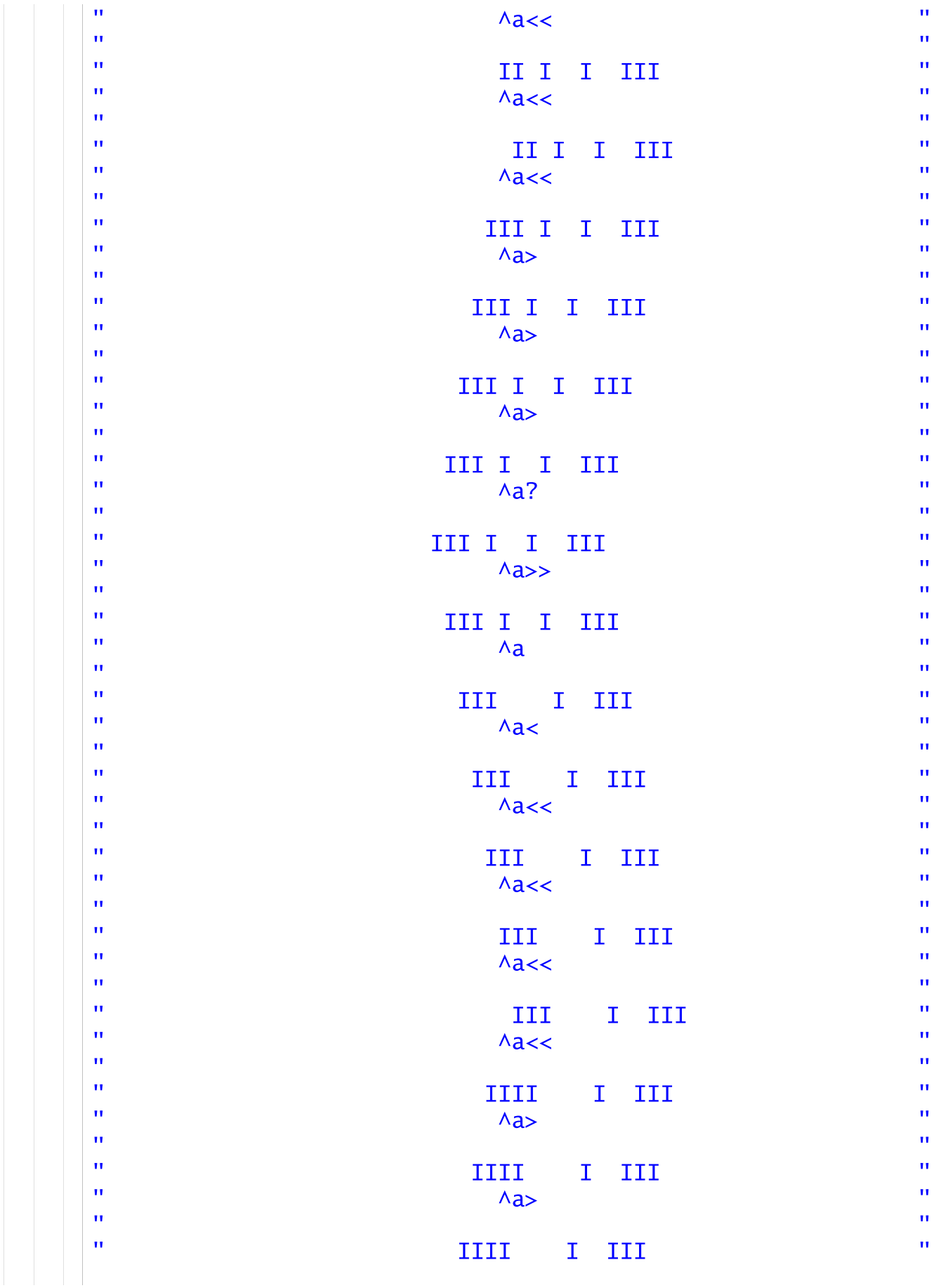
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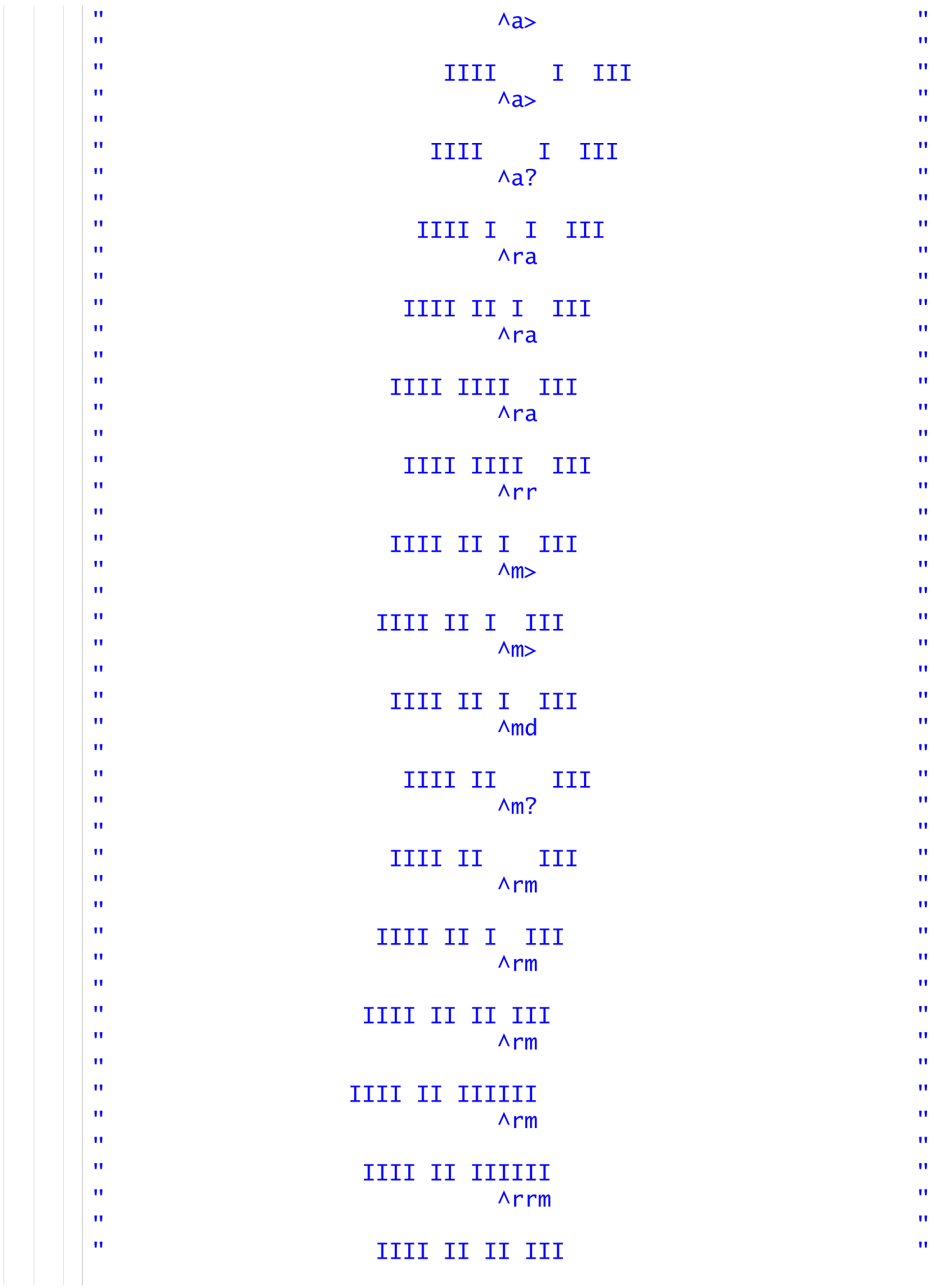
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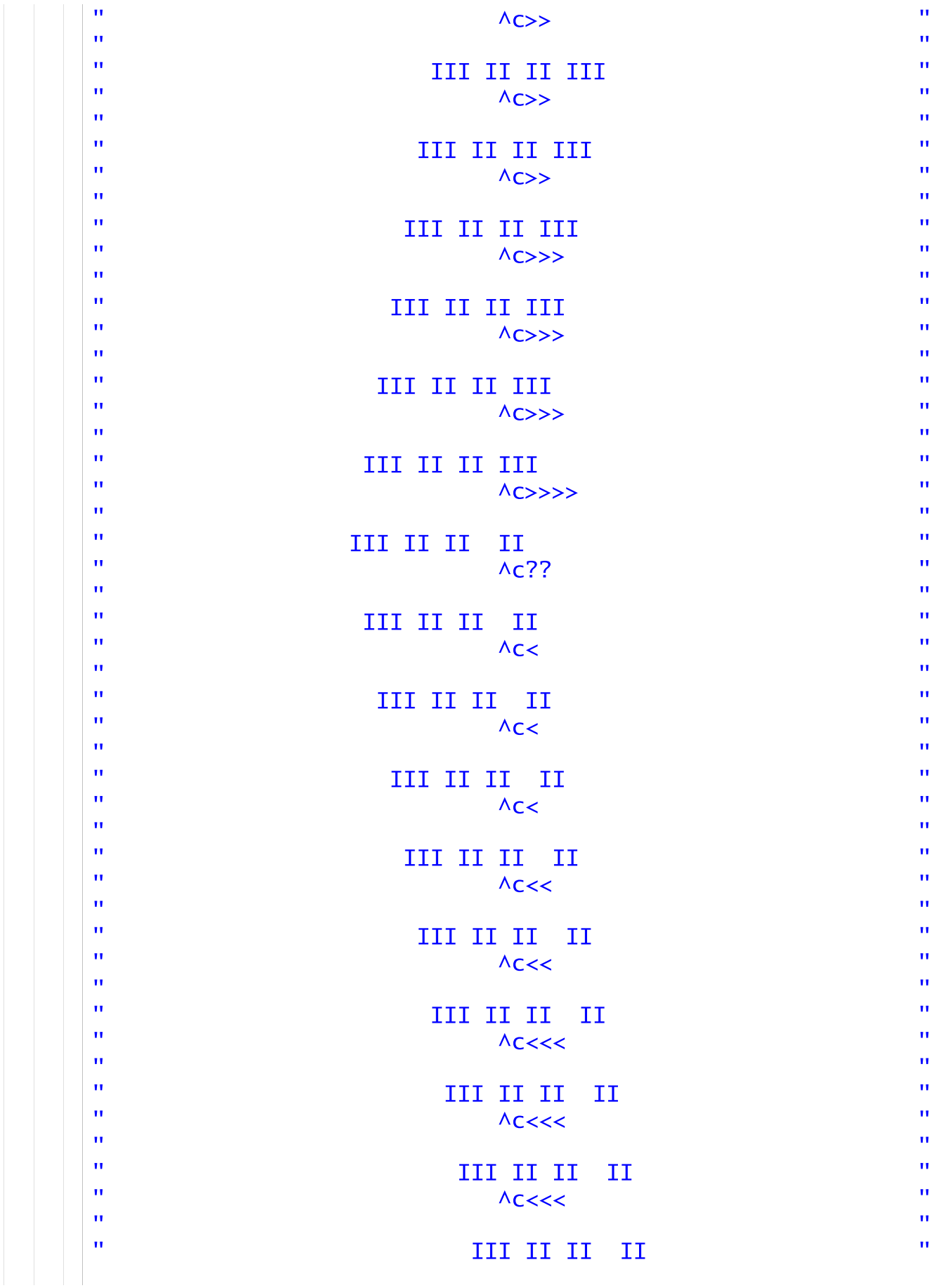
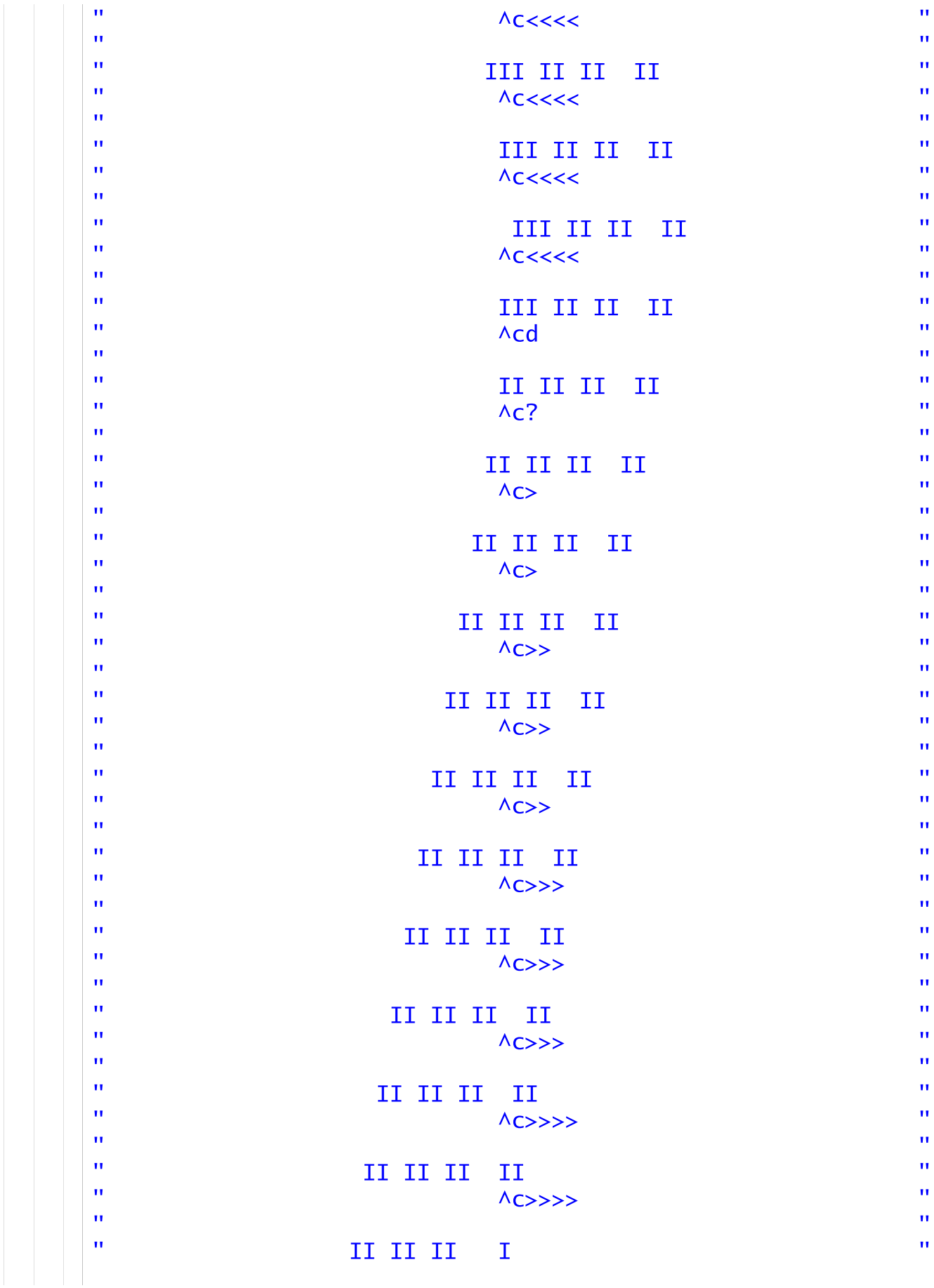
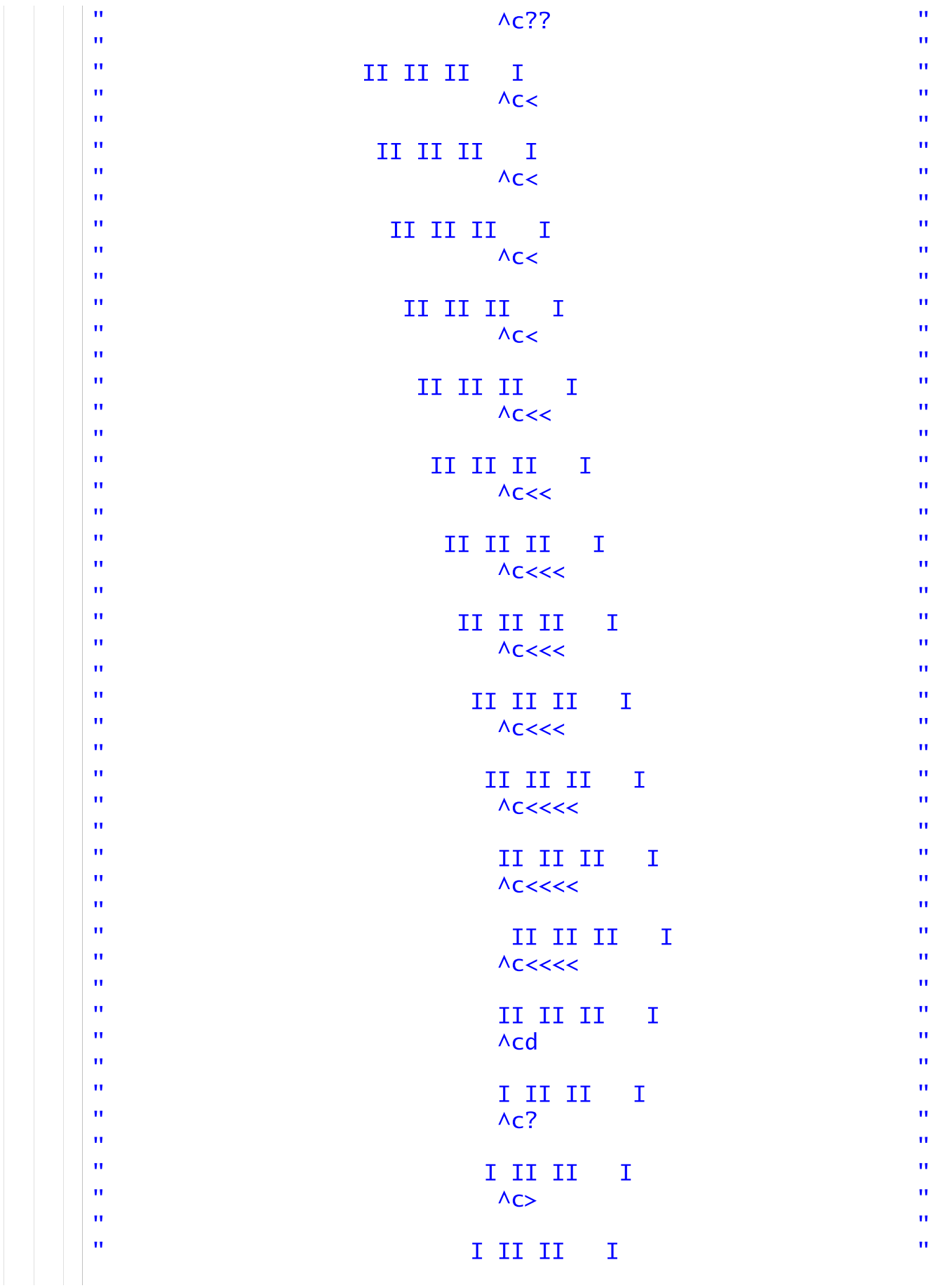
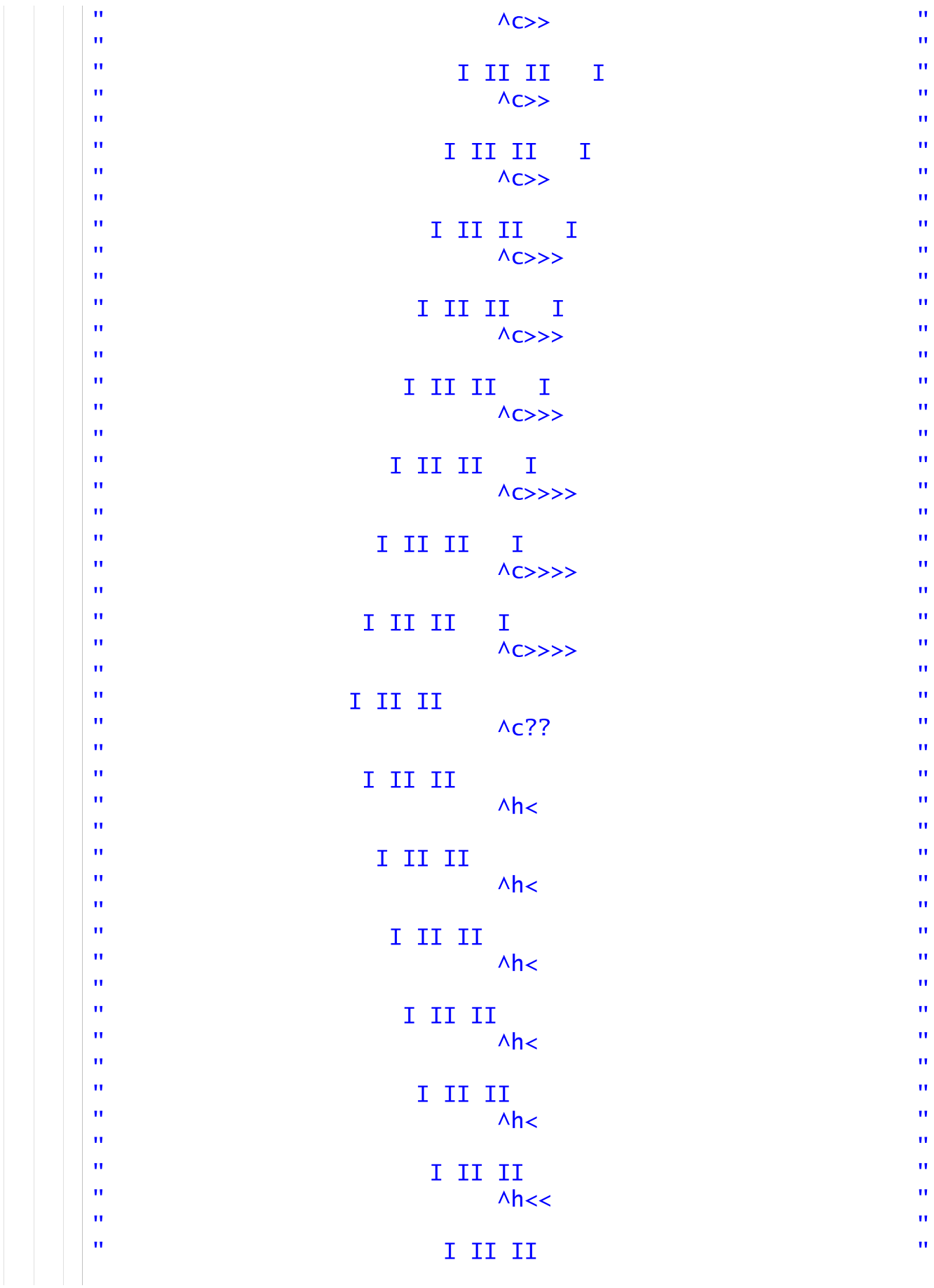
"                                                            "
"                        IIII II II III                      "
"                    ^c<<<<                                  "
"                                                            "
"                         IIII II II III                     "
"                    ^c<<<<                                  "
"                                                            "
"                         IIII II II III                     "
"                    ^cd                                     "
"                                                            "
"                         III II II III                      "
"                    ^c?                                     "
"                                                            "
"                        III II II III                       "
"                    ^c>                                     "
"                                                            "
"                      III II II III                         "
"                    ^c>                                     "
"                                                            "
"                     III II II III                          "
"                    ^c>                                     "
"                                                            "
"                    III II II III                           "
```


^c>>
III II II III
^c>>
III II II III
^c>>
III II II III
^c>>>
III II II III
^c>>>
III II II III
^c>>>
III II II III
^c>>>>
III II II II
^c??
III II II II
^c<
III II II II
^c<
III II II II
^c<
III II II II
^c<<
III II II II
^c<<
III II II II
^c<<<
III II II II
^c<<<
III II II II
^c<<<
III II II II


^c<<<<
III II II II
^c<<<<
III II II II
^c<<<<
III II II II
^c<<<<
III II II II
^cd
II II II II
^c?
II II II II
^c>
II II II II
^c>
II II II II
^c>>
II II II II
^c>>
II II II II
^c>>
II II II II
^c>>>
II II II II
^c>>>
II II II II
^c>>>
II II II II
^c>>>>
II II II II
^c>>>>
II II II I


^c??
II II II I
^c<
II II II I
^c<
II II II I
^c<
II II II I
^c<
II II II I
^c<<
II II II I
^c<<
II II II I
^c<<<
II II II I
^c<<<
II II II I
^c<<<
II II II I
^c<<<<
II II II I
^c<<<<
II II II I
^c<<<<
II II II I
^cd
I II II I
^c?
I II II I
^c>
I II II I


^c>>
I II II I
^c>>
I II II I
^c>>
I II II I
^c>>>
I II II I
^c>>>
I II II I
^c>>>
I II II I
^c>>>>
I II II I
^c>>>>
I II II I
^c>>>>
I II II
^c??
I II II
^h<
I II II
^h<
I II II
^h<
I II II
^h<
I II II
^h<
I II II
^h<<
I II II

```
"                    ^h<<                                    "
"                                                            "
"                  I II II                                   "
"                    ^h<<<                                   "
"                                                            "
"                   I II II                                  "
"                    ^h<<<                                   "
"                                                            "
"                    I II II                                 "
"                    ^h<<<                                   "
"                                                            "
"                    I II II                                 "
"                    ^h<<<<                                  "
"                                                            "
"                     I II II                                "
"                    ^h<<<<                                  "
"                                                            "
"                    I II II                                 "
"                    ^h>                                     "
"                                                            "
"                     II II                                  "
"                    ^h>                                     "
"                                                            "
"                    II II                                   "
"                    ^h>>                                    "
"                                                            "
"                    I II                                    "
"                    ^h>>                                    "
"                                                            "
"                     II                                     "
"                    ^h>>                                    "
"                                                            "
"                    II                                      "
"                    ^hd                                     "
"                                                            "
"                    I                                       "
"                    ^h>>>                                   "
"                                                            "
"                   I                                        "
"                    ^h>>>                                   "
"                                                            "
"                    I                                       "
"                    ^h                                      "
"                                                            "
"                    I                                       "
"                    ^h                                      "
```

10.1.24. Szavak kódolása számmá és vissza.

```
> Digits36:="0123456789abcdefghijklmnopqrstuvwxyz"; length(%)
  ;
  digit2number:=proc(d::string) searchtext(d,Digits36)-1 end;
  digit2number("a");
```

$$Digits36 := \text{"0123456789abcdefghijklmnopqrstuvwxyz"}$$

$$36$$

$$digit2number := \mathbf{proc}(d::string)\ searchtext(d, Digits36) - 1\ \mathbf{end\ proc}$$

$$10 \qquad (10.1.24.1)$$

```
> string2number:=proc(s::string,r::posint) local i,n; n:=0;
  for i to length(s) do n:=n*r+digit2number(s[i]) od; n; end;
  string2number("f0",16); string2number("eg",16);
```

$$string2number := \mathbf{proc}(s::string, r::posint)\ \mathbf{local}\ i, n;\ n := 0;\ \mathbf{for}\ i\ \mathbf{to}\ length(s)\ \mathbf{do}\ n := n * r + digit2number(s[i])\ \mathbf{end\ do};\ n\ \mathbf{end\ proc}$$

$$240$$

$$240 \qquad (10.1.24.2)$$

```
> number2string:=proc(n::nonnegint,r::posint) local nn,nnn,s;
  s:=""; nn:=n;
  while nn>0 do
    nnn:=irem(nn,r); nn:=iquo(nn,r); s:=cat("",Digits36
  [nnn+1],s);
  od; s; end;
  number2string(240,16);
```

$$number2string := \mathbf{proc}(n::nonnegint, r::posint)\ \mathbf{local}\ nn, nnn, s;\ s := \text{""};\ nn := n;\ \mathbf{while}\ 0 < nn\ \mathbf{do}\ nnn := irem(nn, r);\ nn := iquo(nn, r);\ s := cat(\text{""}, Digits36[nnn + 1], s)\ \mathbf{end\ do};\ s$$

```
end proc
```

"f0" (10.1.24.3)

```
> number2stringnon0:=proc(n::nonnegint,r::posint) local nn,
  nnn,s;
  s:=""; nn:=n;
  while nn>0 do
    nnn:=irem(nn-1,r)+1; nn:=iquo(nn-nnn,r); s:=cat("",
  Digits36[nnn+1],s);
  od; s; end;
  number2stringnon0(240,16);
```

```
number2stringnon0 := proc(n::nonnegint, r::posint)
  local nn, nnn,
  s;
  s := "";
  nn := n;
  while 0 < nn do
    nnn := irem(nn - 1, r) + 1;
    nn := iquo(nn - nnn, r);
    s := cat("", Digits36[nnn + 1], s)
  end do;
  s
end proc
```

"eg" (10.1.24.4)

10.1.25. Turing-gép szimulálása egy szalaggal.

```
> # In the general Turing One-tape simulator:
  # T is the Turing-machine to simulate;
  # k is the number of the tapes of T;
  # x a character, not <,>,= and not in the tape ABC of T.

  TOsimul:=proc(b,a) local i,j,ii,xx,bb,bbb,L;
  global k,T,x; xx:=cat(x$j=1..k);
  if b=start then [cat("<h1"," "$j=1..k,start," "$j=1..2*k),
  a,"="]
  elif b=halt then [halt,a,"="]
  elif b[1..2]="<h" then i:=digit2number(b[3]); ii:=Digits36
  [i+2];
    if i<k then
      if a<>" " then
        [cat("<h",ii,b[4..2+i],a,b[4+i..-1])," ","<"]
      elif b[3+i]<>" " and b[3+i]<>x then
        [cat("<h",ii,b[4..2+i],x,b[4+i..-1]),b[3+i],"<"]
```

```
    else
      [cat("<h",ii,b[4..-1]),a,"<"] fi;
  else
    if a<>" " then
      [cat("<a1",b[4..2+i],a,b[4+i..-1])," ","<"]
    elif b[3+i]<>" " and b[3+i]<>x then
      [cat("<a1",b[4..2+i],x,b[4+i..-1]),b[3+i],"<"]
    else
      [cat("<a1",b[4..-1]),a,"<"] fi;
  fi;
elif b[1..2]="<a" then i:=digit2number(b[3]); ii:=Digits36
[i+2];
  if i<k then
    if b[3+i]<>" " and b[3+i]<>x then
      [cat("<a",ii,b[4..-2*k+i-2],a,b[-2*k+i..-1]),a,"<"]
    else [cat("<a",ii,b[4..-1]),a,"<"] fi;
  else
    if b[3+i]<>" " and b[3+i]<>x then
      bb:=cat("<h1",b[4..-2*k+i-2],a,b[-2*k+i..-1])
    else bb:=cat("<h1",b[4..-1]) fi;
    if bb[4..3+k]=xx then ii:=Digits36[k+1];
      L:=T(bb[4+k..-2*k-1],bb[j]$j=-2*k..-k-1);
      [cat(">a",ii," "$j=1..k,op(L)),a,"="]
    else
      [bb,a,"<"]
    fi;
  fi;
elif b[1..2]=">a" then i:=digit2number(b[3]); ii:=Digits36
[i];
  if i>1 then
    if b[3+i]<>" " and b[3+i]<>x and b[-2*k+i-1]<>x then
      [cat(">a",ii,b[4..-2*k+i-2],x,b[-2*k+i..-1]),b[-2*k+i
-1],">"]
    else [cat(">a",ii,b[4..-1]),a,">"] fi;
  else ii:=Digits36[k+1];
    if b[3+i]<>" " and b[3+i]<>x and b[-2*k+i-1]<>x then
      [cat(">h",ii,b[4..-2*k+i-2],x,b[-2*k+i..-1]),b[-2*k+i
-1],">"]
    else [cat(">h",ii,b[4..-1]),a,">"] fi;
  fi;
elif b[1..2]=">h" then i:=digit2number(b[3]); ii:=Digits36
[i];
  if i>1 then if i=k then bbb:="" else bbb:=bb[-k+i..-1]
fi;
    if b[3+i]=space and a<>space then
      bb:=cat(">h",ii,b[4..2+i],a,b[4+i..-1]);
      if bb[-k+i-1]="<" then
        [bb,a,">"]
```

```
        else [bb,space,">"] fi;
      elif b[3+i]<>space and b[3+i]<>x then
        if b[-k+i-1]="<" then
          bb:=cat(">h",ii,b[4..2+i],x,b[4+i..-1]);
          [cat(bb[1..-k+i-2],space,bbb),space,">"]
        elif b[-k+i-1]="=" then
          bb:=cat(">h",ii,b[4..2+i],x,b[4+i..-1]);
          [cat(bb[1..-k+i-2],space,bbb),b[3+i],">"]
        elif b[-k+i-1]=">" then
          bb:=cat(">h",ii,b[4..-1]);
          [cat(bb[1..-k+i-2],x,bbb),space,">"]
        else
          bb:=cat(">h",ii,b[4..2+i],x,b[4+i..-1]);
          [cat(bb[1..-k+i-2],space,bbb),b[3+i],">"] fi;
      else
        [cat(">h",ii,b[4..-1]),space,">"] fi;
    else ii:=Digits36[k+1]; if i=k then bbb:="" else bbb:=b[-
  k+i..-1] fi;
      if b[3+i]=space and a<>space then
        bb:=cat(">a",ii,b[4..2+i],a,b[4+i..-1]);
        if bb[-k+i-1]="<" then
          L:=[bb,a,">"]
        else L:=[bb,space,">"] fi;
      elif b[3+i]<>space and b[3+i]<>x then
        if b[-k+i-1]="<" then
          bb:=cat(">a",ii,b[4..2+i],x,b[4+i..-1]);
          L:=[cat(bb[1..-k+i-2],space,bbb),space,">"]
        elif b[-k+i-1]="=" then
          bb:=cat(">a",ii,b[4..2+i],x,b[4+i..-1]);
          L:=[cat(bb[1..-k+i-2],space,bbb),b[3+i],">"]
        elif b[-k+i-1]=">" then
          bb:=cat(">a",ii,b[4..-1]);
          L:=[cat(bb[1..-k+i-2],x,bbb),space,">"]
        else
          bb:=cat(">a",ii,b[4..2+i],x,b[4+i..-1]);
          L:=[cat(bb[1..-k+i-2],space,bbb),b[3+i],">"] fi;
      else
        L:=[cat(">a",ii,b[4..-1]),space,">"] fi;
      bb:=L[1];
      if bb[4..3+k]=xx then
        if bb[4+k]=halt then [halt,a,"<"] else
          [cat("<h1"," "$j=1..k,bb[4+k..-2*k-1]," "$j=1..2*k)
  ,a,"="] fi;
      else L fi;
    fi;
  fi; end;
```

TOsimul := **proc**(*b*, *a*) (10.1.25.1)

local *i*, *j*, *ii*, *xx*, *bb*, *bbb*, *L*;

```
global k, T, x;
xx := cat( `$`(x, j = 1 ..k) );
if b = start then
    [cat("<h1",
    `$`(" ", j = 1 ..k), start, `$`(" ", j = 1 ..2 * k)), a, "="]
elif b = halt then
    [halt, a, "="]
elif b[1 ..2] = "<h" then
    i := digit2number(b[3]);
    ii := Digits36[i + 2];
    if i < k then
        if a <> " " then
            [cat("<h", ii, b[4 ..i + 2], a, b[4 + i..-1]), " ",
            "<"]
        elif b[3 + i] <> " " and b[3 + i] <> x then
            [cat("<h", ii, b[4 ..i + 2], x, b[4 + i..-1]), b[3 + i],
            "<"]
        else
            [cat("<h", ii, b[4 ..-1]), a, "<"]
        end if
    else
        if a <> " " then
            [cat("<a1", b[4 ..i + 2], a, b[4 + i..-1]), " ",
            "<"]
        elif b[3 + i] <> " " and b[3 + i] <> x then
            [cat("<a1", b[4 ..i + 2], x, b[4 + i..-1]), b[3 + i], "<"]
        else
            [cat("<a1", b[4 ..-1]), a, "<"]
        end if
    end if
elif b[1 ..2] = "<a" then
    i := digit2number(b[3]);
    ii := Digits36[i + 2];
    if i < k then
        if b[3 + i] <> " " and b[3 + i] <> x then
            [cat("<a", ii,
            b[4 ..-2 * k + i - 2], a, b[-2 * k + i..-1]), a, "<"]
        else
```

```
                [cat("<a", ii, b[4..-1]), a, "<"]
            end if
        else
            if b[3+i]<>" " and b[3+i]<>x then
                bb:= cat("<h1",
                b[4..-2*k+i-2], a, b[-2*k+i..-1])
            else
                bb:= cat("<h1", b[4..-1])
            end if;
            if bb[4..3+k]=xx then
                ii:= Digits36[k+1];
                L:= T(bb[4+k..-2*k-1], `$`(bb[j],
                j=-2*k..-k-1));
                [cat(">a", ii, `$`(" ", j=1..k),
                op(L)), a, "="]
            else
                [bb, a, "<"]
            end if
        end if
    elif b[1..2]=">a" then
        i:= digit2number(b[3]);
        ii:= Digits36[i];
        if 1<i then
            if b[3+i]<>" " and b[3+i]<>x
             and b[-2*k+i-1]<>x then
                [cat(">a", ii,
                b[4..-2*k+i-2], x, b[-2*k+i..-1]),
                b[-2*k+i-1], ">"]
            else
                [cat(">a", ii, b[4..-1]),
                a, ">"]
            end if
        else
            ii:= Digits36[k+1];
            if b[3+i]<>" " and b[3+i]<>x
             and b[-2*k+i-1]<>x then
                [cat(">h", ii,
                b[4..-2*k+i-2], x, b[-2*k+i..-1]),
```

```
                b[-2*k+i-1], ">"]
            else
                [cat(">h", ii, b[4..-1]),
                a, ">"]
            end if
        end if
    elif b[1..2] = ">h" then
        i := digit2number(b[3]);
        ii := Digits36[i];
        if 1 < i then
            if i = k then
                bbb := ""
            else
                bbb := bb[-k+i..-1]
            end if;
            if b[3+i] = space and a <> space then
                bb := cat(">h",
                ii, b[4..i+2], a, b[4+i..-1]);
                if bb[-k+i-1] = "<" then
                    [bb, a, ">"]
                else
                    [bb,
                    space, ">"]
                end if
            elif b[3+i] <> space and b[3+i] <> x then
                if b[-k+i-1] = "<" then
                    bb := cat(">h", ii, b[4..i+2],
                    x, b[4+i..-1]);
                    [cat(bb[1..-k+i-2], space,
                    bbb), space, ">"]
                elif b[-k+i-1] = "=" then
                    bb := cat(">h", ii, b[4..i+2], x, b[4+i..-1]);
                    [cat(bb[1..-k+i-2], space, bbb), b[3+i], ">"]
                elif b[-k+i-1] = ">" then
                    bb := cat(">h", ii,
                    b[4..-1]);
                    [cat(bb[1..-k+i-2], x, bbb),
                    space, ">"]
```

```
                else
                    bb := cat(">h", ii, b[4..i+2], x,
                    b[4+i..-1]);
                    [cat(bb[1..-k+i-2], space,
                    bbb), b[3+i], ">"]
                end if
            else
                [cat(">h", ii,
                b[4..-1]), space, ">"]
            end if
        else
            ii := Digits36[k+1];
            if i = k then
                bbb := ""
            else
                bbb := b[-k+i..-1]
            end if;
            if b[3+i] = space and a <> space then
                bb := cat(">a",
                ii, b[4..i+2], a, b[4+i..-1]);
                if bb[-k+i-1] = "<" then
                    L := [bb, a, ">"]
                else
                    L := [bb, space, ">"]
                end if
            elif b[3+i] <> space and b[3+i] <> x then
                if b[-k+i-1] = "<" then
                    bb := cat(">a", ii, b[4..i+2],
                    x, b[4+i..-1]);
                    L := [cat(bb[1..-k+i-2],
                    space, bbb), space, ">"]
                elif b[-k+i-1] = "=" then
                    bb := cat(">a", ii,
                    b[4..i+2], x, b[4+i..-1]);
                    L := [cat(bb[1..-k+i-2], space, bbb), b[3+i],
                    ">"]
                elif b[-k+i-1] = ">" then
                    bb := cat(">a",
```

```
                ii, b[4..-1]);
                 L:=[cat(bb[1..-k+i-2], x, bbb),
                space, ">"]
            else
                 bb:=cat(">a", ii, b[4..i+2], x,
                b[4+i..-1]);
                 L:=[cat(bb[1..-k+i-2], space,
                bbb), b[3+i], ">"]
            end if
        else
            L:=[cat(">a", ii,
            b[4..-1]), space, ">"]
        end if;
        bb:=L[1];
        if bb[4..3+k]=xx then
            if bb[4+k]=halt then
                [halt, a,
                "<"]
            else
                [cat("<h1", `$`(" ", j=1..k),
                bb[4+k..-2*k-1], `$`(" ", j=1..2*k)), a, "="]
            end if
        else
            L
        end if
    end if
  end if
end proc
```

```
> T:=T62;    # Turing mashine to simulate
  k:=2;      # Number of tapes
  x:=".";    # A character not <,>,=, and not in the tape ABC

  TOsimul,"s","11  11ff","":Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts
  (%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%)
  :Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts
  (%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%)
  :Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts
  (%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%)
  :Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts
  (%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%)
```

```
:Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts
(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%)
:Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts
(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%)
:Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts
(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%)
:Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts
(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%)
:Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts
(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):
```

$T := T62$

$k := 2$

$x := "."$

```
"                                                              "
"                        11  11ff                              "
"                              ^s                              "
"                                                              "
"                        11  11ff                              "
"                              ^<h1  s                         "
"                                                              "
"                         11  11f                              "
"                              ^<h2f s                         "
"                                                              "
"                          11  11                              "
"                              ^<a1ffs                         "
"                                                              "
"                           11  11                             "
"                               ^<a2ffs1                       "
"                                                              "
"                            11  11                            "
"                               ^<h1ffs11                      "
"                                                              "
"                             11 f11                           "
"                               ^<h2.fs11                      "
"                                                              "
"                              11ff11                          "
"                               ^<a1..s11                      "
"                                                              "
"                               11ff11                         "
"                               ^<a2..s11                      "
"                                                              "
"                               11ff11                         "
"                               ^>a2  c10<<                    "
"                                                              "
"                              11ff11                          "
"                               ^>a1  c10<<                    "
"                                                              "
```

```
"                          11ff11                                "
"                            ^>h2  c10<<                         "
"                                                                "
"                           11ff11                               "
"                             ^>h1 fc10<<                        "
"                                                                "
"                          11ff11                                "
"                              ^>a2ffc10<<                       "
"                                                                "
"                         11ff01                                 "
"                              ^>a1ffc1.<<                       "
"                                                                "
"                        11ff01                                  "
"                              ^>h2ffc..<<                       "
"                                                                "
"                       11ff01                                   "
"                              ^>h1f.c..<                        "
"                                                                "
"                       11ff01                                   "
"                              ^<h1  c                           "
"                                                                "
"                        11ff01                                  "
"                              ^<h2  c                           "
"                                                                "
"                         11ff01                                 "
"                              ^<a1  c                           "
"                                                                "
"                          11ff01                                "
"                              ^<a2  c                           "
"                                                                "
"                           11ff01                               "
"                             ^<h1  c                            "
"                                                                "
"                            11f 01                              "
"                              ^<h2f c                           "
"                                                                "
"                             11  01                             "
"                              ^<a1ffc                           "
"                                                                "
"                              11  01                            "
"                              ^<a2ffc1                          "
"                                                                "
"                               11  01                           "
"                              ^<h1ffc11                         "
"                                                                "
"                               f11  01                          "
"                              ^<h2.fc11                         "
"                                                                "
```

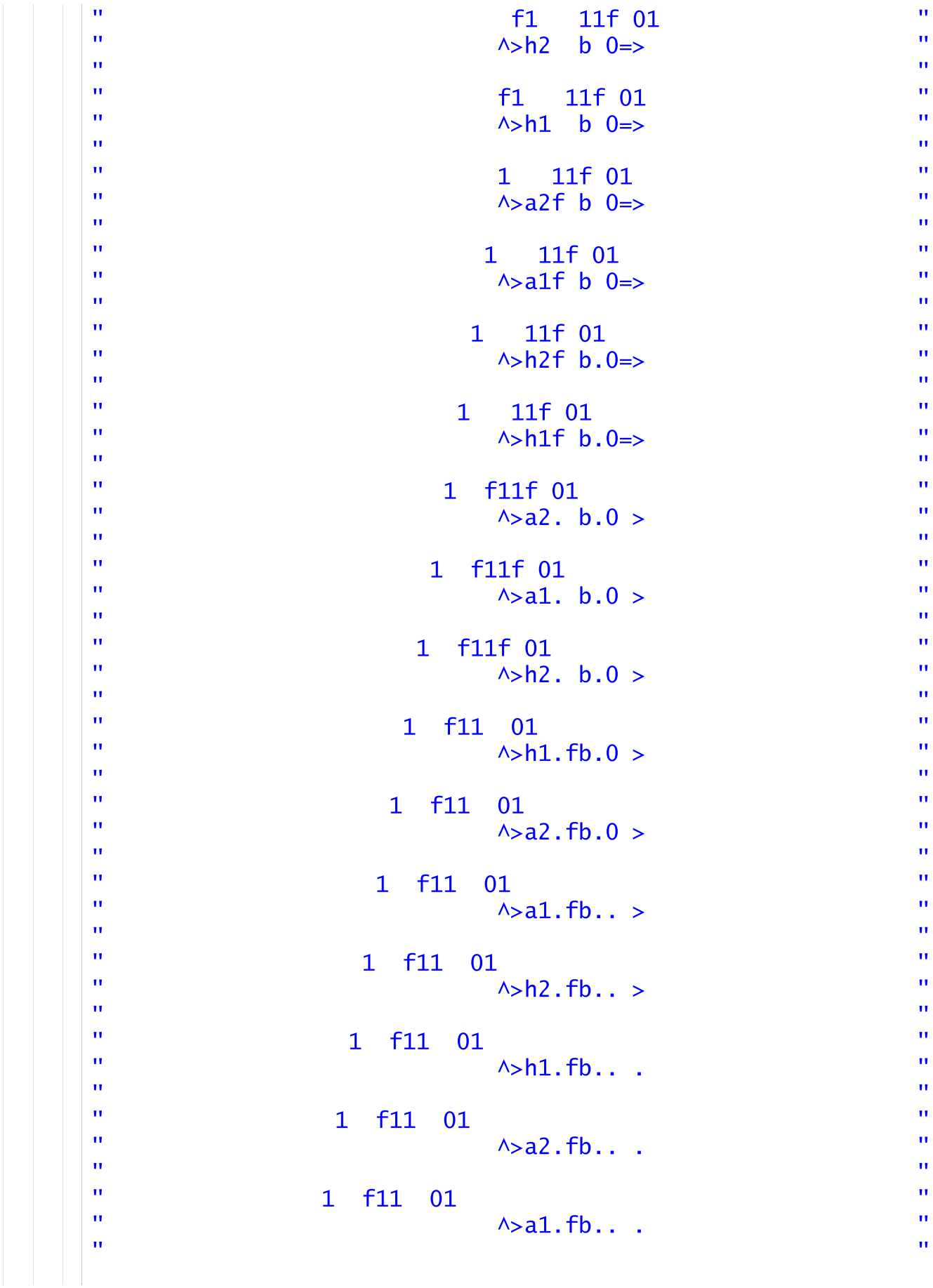
```
"                                ff11  01                                  "
"                               ^<a1..c11                                  "
"                                                                          "
"                                 ff11  01                                 "
"                               ^<a2..c11                                  "
"                                                                          "
"                                 ff11  01                                 "
"                               ^>a2  c11<<                                "
"                                                                          "
"                                ff11  01                                  "
"                               ^>a1  c11<<                                "
"                                                                          "
"                               ff11  01                                   "
"                               ^>h2  c11<<                                "
"                                                                          "
"                              ff11  01                                    "
"                               ^>h1 fc11<<                                "
"                                                                          "
"                             ff11  01                                     "
"                               ^>a2ffc11<<                                "
"                                                                          "
"                            ff11  01                                      "
"                               ^>a1ffc1.<<                                "
"                                                                          "
"                           ff11  01                                       "
"                               ^>h2ffc..<<                                "
"                                                                          "
"                          ff11  01                                        "
"                               ^>h1f.c..<                                 "
"                                                                          "
"                          ff11  01                                        "
"                               ^<h1  c                                    "
"                                                                          "
"                           ff11  01                                       "
"                               ^<h2  c                                    "
"                                                                          "
"                            ff11  01                                      "
"                               ^<a1  c                                    "
"                                                                          "
"                             ff11  01                                     "
"                               ^<a2  c                                    "
"                                                                          "
"                              ff11  01                                    "
"                               ^<h1  c                                    "
"                                                                          "
"                               f 11  01                                   "
"                               ^<h2f c                                    "
"                                                                          "
```

```
"                                  11  01                    "
"                              ^<a1ffc                       "
"                                                            "
"                                  11  01                    "
"                              ^<a2ffc                       "
"                                                            "
"                                   11  01                   "
"                              ^<h1ffc                       "
"                                                            "
"                               f    11  01                  "
"                              ^<h2.fc                       "
"                                                            "
"                               ff    11  01                 "
"                              ^<a1..c                       "
"                                                            "
"                                ff    11  01                "
"                              ^<a2..c                       "
"                                                            "
"                                ff    11  01                "
"                              ^>a2  b 1=>                   "
"                                                            "
"                               ff    11  01                 "
"                              ^>a1  b 1=>                   "
"                                                            "
"                              ff    11  01                  "
"                              ^>h2  b 1=>                   "
"                                                            "
"                              f    11  01                   "
"                              ^>h1 fb 1=>                   "
"                                                            "
"                                  11  01                    "
"                              ^>a2ffb 1=>                   "
"                                                            "
"                             1   11  01                     "
"                              ^>a1ffb .=>                   "
"                                                            "
"                            1   11  01                      "
"                              ^>h2ffb..=>                   "
"                                                            "
"                           1   11  01                       "
"                              ^>h1ffb..=.                   "
"                                                            "
"                          1  f11  01                        "
"                              ^>a2.fb.. .                   "
"                                                            "
"                         1  f11  01                         "
"                              ^>a1.fb.. .                   "
"                                                            "
```

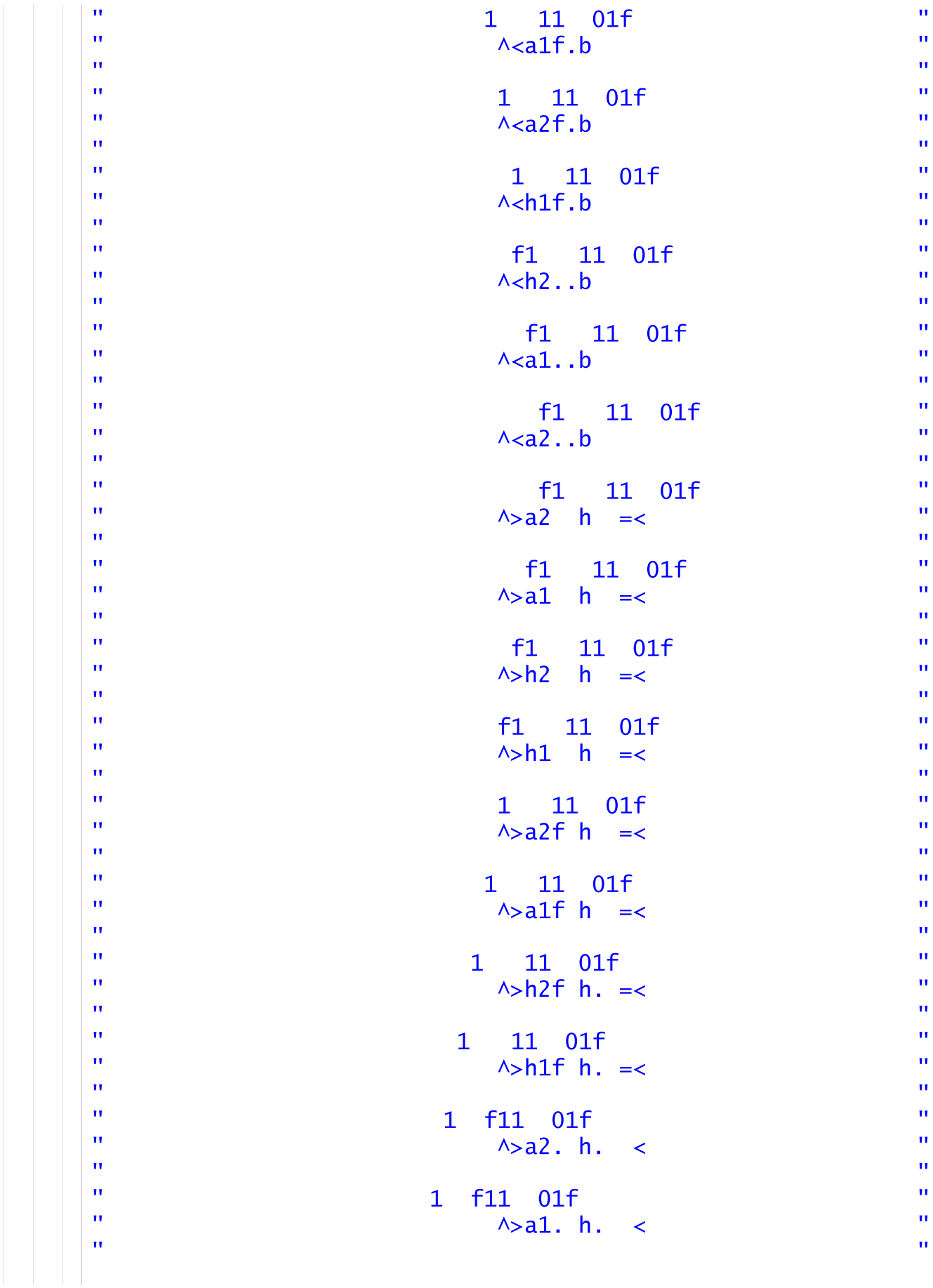
```
"                          1  f11  01                          "
"                             ^>h2.fb.. .                      "
"                                                              "
"                         1  f11f 01                           "
"                             ^>h1..b..                        "
"                                                              "
"                         1  f11f 01                           "
"                             ^<h1  b                          "
"                                                              "
"                          1  f11f 01                          "
"                             ^<h2  b                          "
"                                                              "
"                           1  f11  01                         "
"                             ^<a1 fb                          "
"                                                              "
"                            1  f11  01                        "
"                             ^<a2 fb                          "
"                                                              "
"                             1  f11  01                       "
"                             ^<h1 fb 1                        "
"                                                              "
"                              1   11  01                      "
"                             ^<h2ffb 1                        "
"                                                              "
"                               1 f 11  01                     "
"                             ^<a1f.b 1                        "
"                                                              "
"                             1 f 11  01                       "
"                             ^<a2f.b 1                        "
"                                                              "
"                              1 f 11  01                      "
"                             ^<h1f.b 1                        "
"                                                              "
"                              f1 f 11  01                     "
"                             ^<h2..b 1                        "
"                                                              "
"                               f1 f 11  01                    "
"                             ^<a1..b 1                        "
"                                                              "
"                                f1 f 11  01                   "
"                             ^<a2..b 1                        "
"                                                              "
"                                f1 f 11  01                   "
"                             ^>a2  b 1=>                      "
"                                                              "
"                               f1 f 11  01                    "
"                             ^>a1  b 1=>                      "
"                                                              "
```

```
"                          f1 f 11  01                    "
"                         ^>h2  b 1=>                     "
"                                                         "
"                         f1 f 11  01                     "
"                         ^>h1  b 1=>                     "
"                                                         "
"                         1 f 11  01                      "
"                         ^>a2f b 1=>                     "
"                                                         "
"                        1 f 11  01                       "
"                         ^>a1f b 1=>                     "
"                                                         "
"                       1 f 11  01                        "
"                         ^>h2f b.1=>                     "
"                                                         "
"                      1   11  01                         "
"                         ^>h1ffb.1=>                     "
"                                                         "
"                     1  f11  01                          "
"                         ^>a2.fb.1 >                     "
"                                                         "
"                    1  f11  01                           "
"                         ^>a1.fb.. >                     "
"                                                         "
"                   1  f11  01                            "
"                         ^>h2.fb.. >                     "
"                                                         "
"                  1  f11  01                             "
"                         ^>h1.fb.. .                     "
"                                                         "
"                 1  f11  01                              "
"                         ^>a2.fb.. .                     "
"                                                         "
"                1  f11  01                               "
"                         ^>a1.fb.. .                     "
"                                                         "
"               1  f11  01                                "
"                         ^>h2.fb.. .                     "
"                                                         "
"              1  f11  01f                                "
"                         ^>h1..b..                       "
"                                                         "
"              1  f11  01f                                "
"                         ^<h1  b                         "
"                                                         "
"               1  f11  01f                               "
"                         ^<h2  b                         "
"                                                         "
```

```
"                    1  f11  01                                    "
"                            ^<a1 fb                               "
"                                                                  "
"                     1  f11  01                                   "
"                            ^<a2 fb                               "
"                                                                  "
"                      1  f11  01                                  "
"                            ^<h1 fb 0                             "
"                                                                  "
"                       1  f11  01                                 "
"                            ^<h2 fb 0                             "
"                                                                  "
"                        1  f11f 01                                "
"                            ^<a1 .b 0                             "
"                                                                  "
"                         1  f11f 01                               "
"                            ^<a2 .b 0                             "
"                                                                  "
"                          1  f11f 01                              "
"                            ^<h1 .b 0                             "
"                                                                  "
"                           1   11f 01                             "
"                            ^<h2f.b 0                             "
"                                                                  "
"                            1   11f 01                            "
"                            ^<a1f.b 0                             "
"                                                                  "
"                            1   11f 01                            "
"                            ^<a2f.b 0                             "
"                                                                  "
"                             1   11f 01                           "
"                            ^<h1f.b 0                             "
"                                                                  "
"                             f1   11f 01                          "
"                            ^<h2..b 0                             "
"                                                                  "
"                              f1   11f 01                         "
"                            ^<a1..b 0                             "
"                                                                  "
"                               f1   11f 01                        "
"                            ^<a2..b 0                             "
"                                                                  "
"                               f1   11f 01                        "
"                            ^>a2  b 0=>                           "
"                                                                  "
"                              f1   11f 01                         "
"                            ^>a1  b 0=>                           "
"                                                                  "
```


f1 11f 01
^>h2 b 0=>
f1 11f 01
^>h1 b 0=>
1 11f 01
^>a2f b 0=>
1 11f 01
^>a1f b 0=>
1 11f 01
^>h2f b.0=>
1 11f 01
^>h1f b.0=>
1 f11f 01
^>a2. b.0 >
1 f11f 01
^>a1. b.0 >
1 f11f 01
^>h2. b.0 >
1 f11 01
^>h1.fb.0 >
1 f11 01
^>a2.fb.0 >
1 f11 01
^>a1.fb.. >
1 f11 01
^>h2.fb.. >
1 f11 01
^>h1.fb.. .
1 f11 01
^>a2.fb.. .
1 f11 01
^>a1.fb.. .

```
"                1  f11  01                                    "
"                              ^>h2.fb.. .                     "
"                                                              "
"               1  f11  01    f                                "
"                              ^>h1..b..                       "
"                                                              "
"               1  f11  01    f                                "
"                              ^<h1  b                         "
"                                                              "
"                1  f11  01    f                                "
"                              ^<h2  b                         "
"                                                              "
"                 1  f11  01                                   "
"                              ^<a1 fb                         "
"                                                              "
"                  1  f11  01                                  "
"                              ^<a2 fb                         "
"                                                              "
"                   1  f11  01                                 "
"                              ^<h1 fb                         "
"                                                              "
"                    1  f11  01                                "
"                              ^<h2 fb                         "
"                                                              "
"                     1  f11  01f                              "
"                              ^<a1 .b                         "
"                                                              "
"                      1  f11  01f                             "
"                              ^<a2 .b                         "
"                                                              "
"                       1  f11  01f                            "
"                              ^<h1 .b                         "
"                                                              "
"                        1  f11  01f                           "
"                              ^<h2 .b                         "
"                                                              "
"                         1  f11  01f                          "
"                              ^<a1 .b                         "
"                                                              "
"                          1  f11  01f                         "
"                              ^<a2 .b                         "
"                                                              "
"                           1  f11  01f                        "
"                              ^<h1 .b                         "
"                                                              "
"                            1   11  01f                       "
"                              ^<h2f.b                         "
"                                                              "
```


1 11 01f
^<a1f.b
1 11 01f
^<a2f.b
1 11 01f
^<h1f.b
f1 11 01f
^<h2..b
f1 11 01f
^<a1..b
f1 11 01f
^<a2..b
f1 11 01f
^>a2 h =<
f1 11 01f
^>a1 h =<
f1 11 01f
^>h2 h =<
f1 11 01f
^>h1 h =<
1 11 01f
^>a2f h =<
1 11 01f
^>a1f h =<
1 11 01f
^>h2f h. =<
1 11 01f
^>h1f h. =<
1 f11 01f
^>a2. h. <
1 f11 01f
^>a1. h. <

```
"                          1  f11  01f                          "
"                               ^>h2. h.  <                     "
"                                                               "
"                         1  f11  01f                           "
"                               ^>h1. h.  <                     "
"                                                               "
"                        1  f11  01f                            "
"                               ^>a2. h.  <                     "
"                                                               "
"                       1  f11  01f                             "
"                               ^>a1. h.  <                     "
"                                                               "
"                      1  f11  01f                              "
"                               ^>h2. h.  <                     "
"                                                               "
"                     1  f11  01f                               "
"                               ^>h1.fh.  <                     "
"                                                               "
"                    1  f11  01f                                "
"                               ^>a2.fh.  <                     "
"                                                               "
"                   1  f11  01f                                 "
"                               ^>a1.fh.. <                     "
"                                                               "
"                  1  f11  01f                                  "
"                               ^>h2.fh.. <                     "
"                                                               "
"                 1  f11  01f                                   "
"                               ^>h1..h..                       "
"                                                               "
"                  1  f11  01f                                  "
"                               ^h                              "
"                                                               "
"                  1  f11  01f                                  "
"                               ^h                              "
```

▶ *10.1.26. Megjegyzés.*

▼ *10.1.27. Feladat.*

▼ *10.1.28. Szemétgyüjtés.*

```
> # In the general garbage collection:
  # T is the original Turing-machine;
  # k is the number of the tapes of T;
  # x a character, not <,>,=,space and start and not in the
  tape ABC of T.

  Tgarbage:=proc() local i,ii,j,k,b,a,L,LL; global T,x;
```

```
k:=nargs-1; b:=args[1]; a:=args[2..k+1];
if b=start then [cat(start,start),a,"="$j=1..k]
elif b=halt then [halt,a,"="$j=1..k]
elif b[1]=start and b[2..-1]<>halt then
  L:=[a]; LL:=[];
  for i to k do
    if L[i]=x then LL:=[op(LL),space] else LL:=[op(LL),L[i]
] fi;
  od;
  L:=T(b[2..-1],op(LL));
  LL:=[cat(start,L[1])];
  for i to k do
    if L[i+1]=space then LL:=[op(LL),x] else LL:=[op(LL),L
[i+1]] fi;
  od;
  [op(LL),op(L[k+2..-1])]
elif b=cat(start,halt) then [cat(x,"1",x),a,">","="$j=2..k]
elif b[1]=x and b[3..-1]=x then
  i:=digit2number(b[2]);
  [cat(b,">"),a[1..i-1],x,a[i+1..-1],"="$j=1..i-1,">","=
"$j=i+1..k]
elif b[1]=x and b[3..-1]=cat(x,">") then
  i:=digit2number(b[2]);
  if a[i]<>space then
    [b,a[1..i-1],space,a[i+1..-1],"="$j=1..i-1,">","="$j=
i+1..k]
  else
    [cat(b[1..3],"="),a[1..i-1],space
      ,a[i+1..-1],"="$j=1..i-1,"<","="$j=i+1..k] fi;
elif b[1]=x and b[3..-1]=cat(x,"=") then
  i:=digit2number(b[2]);
  if a[i]<>x then
    [b,a[1..i-1],space,a[i+1..-1],"="$j=1..i-1,"<","="$j=
i+1..k]
  else
    [cat(b[1..3],"<"),a[1..i-1],space,
      a[i+1..-1],"="$j=1..i-1,"<","="$j=i+1..k] fi;
elif b[1]=x and b[3..-1]=cat(x,"<") then
  i:=digit2number(b[2]);
  if a[i]=space then
    [cat(b[1..2],space,"<"),a[1..i-1],x,
      a[i+1..-1],"="$j=1..i-1,"<","="$j=i+1..k]
  elif a[i]=x then
    [cat(b[1..2],space,"<"),a[1..i-1],x,
      a[i+1..-1],"="$j=1..i-1,"<","="$j=i+1..k]
  else
    [b,a,"="$j=1..i-1,"<","="$j=i+1..k] fi;
elif b[1]=x and b[3..-1]=cat(space,"<") then
```

```
    i:=digit2number(b[2]);
    if a[i]=space then
      [cat(b[1..2],">",x),a[1..i-1],space,
        a[i+1..-1],"="$j=1..i-1,"<","="$j=i+1..k]
    else
      [b,a[1..i-1],space,a[i+1..-1],"="$j=1..i-1,"<","="$j=
  i+1..k] fi;
  elif b[1]=x and b[3..-1]=cat(">",x) then
    i:=digit2number(b[2]);
    if a[i]=x then
      [b[1..3],a[1..i-1],space,a[i+1..-1],"="$j=1..i-1,">","=
  "$j=i+1..k]
    else
      [b,a[1..i-1],space,a[i+1..-1],"="$j=1..i-1,">","="$j=
  i+1..k] fi;
  else
    i:=digit2number(b[2]); ii:=Digits36[i+2];
    if a[i]=space then
      if i=k then
        [halt,a[1..i-1],space,a[i+1..-1],"="$j=1..i-1,"<","=
  "$j=i+1..k]
      else
        [cat(x,ii,x),a[1..i-1],space,
          a[i+1..-1],"="$j=1..i-1,"<",">","="$j=i+2..k] fi;
    else
      [b,a,"="$j=1..i-1,">","="$j=i+1..k] fi;
  fi; end;
```

$Tgarbage := \mathbf{proc}()$ (10.1.28.1)

local *i*, *ii*, *j*, *k*, *b*, *a*, *L*, *LL*;

global *T*, *x*;

$k := nargs - 1;$

$b := args[1];$

$a := args[2..k+1];$

if $b = start$ **then**

$[cat(start, start), a, `\$`("=", j = 1..k)]$

elif $b = halt$ **then**

$[halt, a, `\$`("=", j = 1..k)]$

elif $b[1] = start$ **and** $b[2..-1] <> halt$ **then**

$L := [a];$

$LL := [];$

for *i* **to** *k* **do**

if $L[i] = x$ **then**

$LL := [op(LL), space]$

```
            else
                LL := [op(LL), L[i]]
            end if
        end do;
        L := T(b[2..-1], op(LL));
        LL := [cat(start, L[1])];
        for i to k do
            if L[i+1] = space then
                LL := [op(LL), x]
            else
                LL := [op(LL), L[i+1]]
            end if
        end do;
        [op(LL),
       op(L[k+2..-1])]
    elif b = cat(start, halt) then
        [cat(x, "1",
       x), a, ">", `$`("=", j = 2..k)]
    elif b[1] = x and b[3..-1] = x then
        i := digit2number(b[2]);
        [cat(b, ">"), a[1..i-1], x,
       a[i+1..-1], `$`("=", j = 1..i-1), ">", `$`("=",
       j = i+1..k)]
    elif b[1] = x and b[3..-1] = cat(x, ">") then
        i := digit2number(b[2]);
        if a[i] <> space then
            [b, a[1..i-1],
           space, a[i+1..-1], `$`("=", j = 1..i-1), ">", `$`("=",
           j = i+1..k)]
        else
            [cat(b[1..3], "="), a[1..i-1], space,
           a[i+1..-1], `$`("=", j = 1..i-1), "<", `$`("=",
           j = i+1..k)]
        end if
    elif b[1] = x and b[3..-1] = cat(x,
    "=") then
        i := digit2number(b[2]);
        if a[i] <> x then
```

```
            [b,
            a[1..i-1], space, a[i+1..-1], `$`("=", j=1..i-1),
            "<", `$`("=", j=i+1..k)]
        else
            [cat(b[1..3], "<"),
            a[1..i-1], space, a[i+1..-1], `$`("=", j=1..i-1),
            "<", `$`("=", j=i+1..k)]
        end if
    elif b[1]=x and b[3..-1]=cat(x, "<") then
        i:=digit2number(b[2]);
        if a[i]=space then
            [cat(b[1..2],
            space, "<"), a[1..i-1], x, a[i+1..-1], `$`("=",
            j=1..i-1), "<", `$`("=", j=i+1..k)]
        elif a[i]=x then
            [cat(b[1..2], space, "<"), a[1..i-1], x, a[i+1..-1],
            `$`("=", j=1..i-1), "<", `$`("=", j=i+1..k)]
        else
            [b,
            a, `$`("=", j=1..i-1), "<", `$`("=", j=i+1..k)]
        end if
    elif b[1]=x and b[3..-1]=cat(space, "<") then
        i:=digit2number(b[2]);
        if a[i]=space then
            [cat(b[1..2], ">",
            x), a[1..i-1], space, a[i+1..-1], `$`("=",
            j=1..i-1), "<", `$`("=", j=i+1..k)]
        else
            [b,
            a[1..i-1], space, a[i+1..-1], `$`("=", j=1..i-1),
            "<", `$`("=", j=i+1..k)]
        end if
    elif b[1]=x and b[3..-1]=cat(">", x) then
        i:=digit2number(b[2]);
        if a[i]=x then
            [b[1..3], a[1..i-1],
            space, a[i+1..-1], `$`("=", j=1..i-1), ">", `$`("=",
            j=i+1..k)]
```

```
        else
            [b, a[1..i-1], space, a[i+1..-1],
            `$`("=", j=1..i-1), ">", `$`("=", j=i+1..k)]
        end if
    else
        i:= digit2number(b[2]);
        ii:= Digits36[i+2];
        if a[i] = space then
            if i = k then
                [halt, a[1..i-1], space,
                a[i+1..-1], `$`("=", j=1..i-1), "<", `$`("=",
                j=i+1..k)]
            else
                [cat(x, ii, x), a[1..i-1], space,
                a[i+1..-1], `$`("=", j=1..i-1), "<", ">",
                `$`("=", j=i+2..k)]
            end if
        else
            [b, a, `$`("=",
            j=1..i-1), ">", `$`("=", j=i+1..k)]
        end if
    end if
end proc
```

```
> T:=T62;    # Turing mashine to add garbage collection
  k:=2;      # Number of tapes
  x:="*";    # A character not <,>,=,start and space and not
  in the tape ABC

  Tgarbage,"s","11","","11","":Ts(%):Ts(%):Ts(%):Ts(%):Ts(%)
  :Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts
  (%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%)
  :Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts
  (%):Ts(%):Ts(%):
```

$$T := T62$$

$$k := 2$$

$$x := "*"$$

```
"                                                          "
"                          11                              "
"                          11                              "
"                           ^s                             "
"                                                          "
```

```
"                    11                  "
"                    11                  "
"                     ^ss                "
"                                         "
"                     11                  "
"                     10                  "
"                     ^sc                "
"                                         "
"                      11                 "
"                      10                 "
"                     ^sc                "
"                                         "
"                     *11                 "
"                    110                  "
"                     ^sb                "
"                                         "
"                     *11                 "
"                   110                   "
"                     ^sb                "
"                                         "
"                     *11                 "
"                 110                     "
"                     ^sb                "
"                                         "
"                     *11                 "
"                  110*                   "
"                     ^sh                "
"                                         "
"                    *11                  "
"                   110*                  "
"                     ^*1*               "
"                                         "
"                   **1                   "
"                   110*                  "
"                     ^*1*>              "
"                                         "
"                  **                     "
"                   110*                  "
"                     ^*1*>              "
"                                         "
"                   **                    "
"                   110*                  "
"                     ^*1*=              "
"                                         "
"                    **                   "
"                   110*                  "
"                     ^*1*=              "
"                                         "
```

```
"                    *                    "
"                  110*                   "
"                    ^*1*<                "
"                                         "
"                     *                   "
"                  110*                   "
"                    ^*1 <                "
"                                         "
"                      *                  "
"                  110*                   "
"                    ^*1>*                "
"                                         "
"                     *                   "
"                  110*                   "
"                    ^*1>*                "
"                                         "
"                    *                    "
"                  110*                   "
"                    ^*1>*                "
"                                         "
"                                         "
"                  110*                   "
"                    ^*1>                 "
"                                         "
"                                         "
"                 110*                    "
"                    ^*2*                 "
"                                         "
"                                         "
"                110*                     "
"                    ^*2*>                "
"                                         "
"                                         "
"                 110*                    "
"                    ^*2*=                "
"                                         "
"                                         "
"                  110                    "
"                    ^*2*<                "
"                                         "
"                                         "
"                   110                   "
"                    ^*2*<                "
"                                         "
"                                         "
"                    110                  "
"                    ^*2*<                "
"                                         "
```

```
"                                                                    "
"                          110                                       "
"                         ^*2*<                                      "
"                                                                    "
"                                                                    "
"                          *110                                      "
"                         ^*2 <                                      "
"                                                                    "
"                                                                    "
"                           *110                                     "
"                         ^*2>*                                      "
"                                                                    "
"                                                                    "
"                          *110                                      "
"                         ^*2>*                                      "
"                                                                    "
"                                                                    "
"                         *110                                       "
"                         ^*2>*                                      "
"                                                                    "
"                                                                    "
"                         110                                        "
"                         ^*2>                                       "
"                                                                    "
"                                                                    "
"                        110                                         "
"                         ^*2>                                       "
"                                                                    "
"                                                                    "
"                       110                                          "
"                         ^*2>                                       "
"                                                                    "
"                                                                    "
"                      110                                           "
"                         ^*2>                                       "
"                                                                    "
"                                                                    "
"                      110                                           "
"                         ^h                                         "
"                                                                    "
"                                                                    "
"                      110                                           "
"                         ^h                                         "
```

10.1.29. Univerzális Turing-gépek.

```
> UT:=proc(b,a1,a2,a3)
  if b="s" then
```

```
    if a3<>" " then
      if a2=" " then ["h",a1,a2,a3,"=","=","="]
      elif a2=a3 then ["s",a1,a2,a3,"=","<","<"]
      else ["t0",a1,a2,a3,"=","<","<"] fi;
    else ["s1",a1,a2,a3,"=","=","="] fi;
  elif b="s1" then
    if a1=a2 then ["v0",a1,a2,a3,"=","<",">"]
    else ["t1",a1,a2,a3,"=","<",">"] fi;
  elif b="t0" then
    if a3<>" " then ["t0",a1,a2,a3,"=","<","<"]
    else ["t1",a1,a2,a3,"=","<",">"] fi;
  elif b="t1" then
    if a3<>" " then ["t1",a1,a2,a3,"=","<",">"]
    else ["t2",a1,a2,a3,"=","<","<"] fi;
  elif b="t2" then ["s",a1,a2,a3,"=","<","="]
  elif b="v0" then
    if a3<>" " then ["v0",a1,a2,a3,"=","=",">"]
    else ["e0",a1,a2,a3,"=","=","<"] fi;
  elif b="e0" then
    if a3<>" " then ["e0",a1,a2,a2,"=","<","<"]
    else ["e1",a1,a2,a3,"=","=","="] fi;
  elif b="e1" then ["e2",a2,a2,a3,"=","<","="]
  elif b="e2" then
    if a2=" " then ["v1",a1,a2,a3,"=",">",">"]
    elif a2="0" then ["v1",a1,a2,a3,"<",">",">"]
    else ["v1",a1,a2,a3,">",">",">"] fi;
  elif b="v1" then ["v2",a1,a2,a3,"=",">","="]
  elif b="v2" then
    if a2=" " and a3<>" " then ["v4",a1,a2,a3,"=","<","="]
    elif a3<>" " then ["v2",a1,a2,a3,"=",">",">"]
    else ["v3",a1,a2,a3,"=",">","<"] fi;
  elif b="v3" then
    if a3<>" " then ["v3",a1,a2,a3,"=",">","<"]
    else ["v1",a1,a2,a3,"=",">",">"] fi;
  elif b="v4" then
    if a2=" " then ["v4",a1,a2,a3,"=","<","="]
    else ["v5",a1,a2,a3,"=","=","="] fi;
  elif b="v5" then
    if a3<>" " then ["v5",a1,a2,a3,"=","=",">"]
    else ["s",a1,a2,a3,"=","=","<"] fi;
  else ["h",a1,a2,a3,"=","=","="] fi; end;
```

$UT := \mathbf{proc}(b, a1, a2, a3)$ (10.1.29.1)

$\mathbf{if}\ b = \text{"s"}\ \mathbf{then}$

$\mathbf{if}\ a3 <> \text{" "}\ \mathbf{then}$

$\mathbf{if}\ a2 = \text{" "}\ \mathbf{then}$

```
                ["h", a1, a2, a3, "=", "=", "="]
            elif a2 = a3 then
                ["s", a1, a2, a3, "=", "<", "<"]
            else
                ["t0", a1, a2, a3, "=", "<", "<"]
            end if
        else
            ["s1", a1, a2,
            a3, "=", "=", "="]
        end if
    elif b = "s1" then
        if a1 = a2 then
            ["v0", a1, a2, a3, "=", "<", ">"]
        else
            ["t1", a1, a2, a3, "=",
            "<", ">"]
        end if
    elif b = "t0" then
        if a3 <> " " then
            ["t0",
            a1, a2, a3, "=", "<", "<"]
        else
            ["t1", a1, a2, a3, "=", "<",
            ">"]
        end if
    elif b = "t1" then
        if a3 <> " " then
            ["t1", a1,
            a2, a3, "=", "<", ">"]
        else
            ["t2", a1, a2, a3, "=", "<", "<"]
        end if
    elif b = "t2" then
        ["s", a1, a2, a3, "=", "<", "="]
    elif b = "v0" then
        if a3 <> " " then
            ["v0", a1, a2, a3, "=", "=",
            ">"]
```

```
        else
            ["e0", a1, a2, a3, "=", "=", "<"]
        end if
    elif b = "e0" then
        if a3 <> " " then
            ["e0", a1, a2, a2, "=", "<",
           "<"]
        else
            ["e1", a1, a2, a3, "=", "=", "="]
        end if
    elif b = "e1" then
        ["e2", a2, a2, a3, "=", "<", "="]
    elif b = "e2" then
        if a2 = " " then
            ["v1", a1, a2, a3, "=", ">",
           ">"]
        elif a2 = "0" then
            ["v1", a1, a2, a3, "<", ">", ">"]
        else
            ["v1", a1, a2, a3, ">", ">", ">"]
        end if
    elif b = "v1" then
        ["v2", a1, a2, a3, "=", ">", "="]
    elif b = "v2" then
        if a2 = " " and a3 <> " " then
            ["v4", a1, a2, a3, "=", "<", "="]
        elif a3 <> " " then
            ["v2", a1, a2, a3, "=", ">", ">"]
        else
            ["v3", a1, a2, a3, "=", ">", "<"]
        end if
    elif b = "v3" then
        if a3 <> " " then
            ["v3", a1, a2, a3, "=", ">", "<"]
        else
            ["v1", a1,
           a2, a3, "=", ">", ">"]
        end if
```

```
    elif b = "v4" then
        if a2 = " " then
            ["v4", a1, a2, a3, "=", "<", "="]
        else
            ["v5", a1,
            a2, a3, "=", "=", "="]
        end if
    elif b = "v5" then
        if a3 <> " " then
            ["v5", a1, a2, a3, "=", "=", ">"]
        else
            ["s", a1,
            a2, a3, "=", "=", "<"]
        end if
    else
        ["h", a1, a2, a3, "=", "=",
        "="]
    end if
end proc
```

```
> # A one-tape Turing machine: delete one letter from left
  hand side
  T:=proc(b,a)
  if b="s" then
    if a=" " then ["d"," ",">"] else ["s",a,"<"] fi;
  elif b="d" then ["b"," ",">"]
  elif b="b" then
    if a<>" " then ["b",a,">"] else ["h",a,"<"] fi;
  else ["h",a,"="] fi end;
```

$$T := \mathbf{proc}(b, a) \tag{10.1.29.2}$$

```
    if b = "s" then
        if a = " " then
            ["d", " ", ">"]
        else
            ["s",
            a, "<"]
        end if
    elif b = "d" then
        ["b", " ", ">"]
    elif b = "b" then
        if a <> " " then
```

```
            ["b", a, ">"]
        else
            ["h", a, "<"]
        end if
    else
        ["h", a, "="]
    end if
end proc
```

```
> T,"s","01",":Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):
"                                                                "
"                                01                              "
"                                 ^s                             "
"                                                                "
"                                 01                             "
"                                 ^s                             "
"                                                                "
"                                  01                            "
"                                 ^s                             "
"                                                                "
"                                 01                             "
"                                 ^d                             "
"                                                                "
"                                 1                              "
"                                 ^b                             "
"                                                                "
"                                1                               "
"                                 ^b                             "
"                                                                "
"                                 1                              "
"                                 ^h                             "
"                                                                "
"                                 1                              "
"                                 ^h                             "
```

```
> UT,"s","01","",cat("1 01 00","0000000","0100100","1 10 01",
  "1 10001","1 10101","0 11 10","1010010","1110110"),"","00",
  "":Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts
  (%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%)
  :Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts
  (%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%)
  :Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts
  (%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%)
  :Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts
  (%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%)
  :Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts
  (%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%)
```

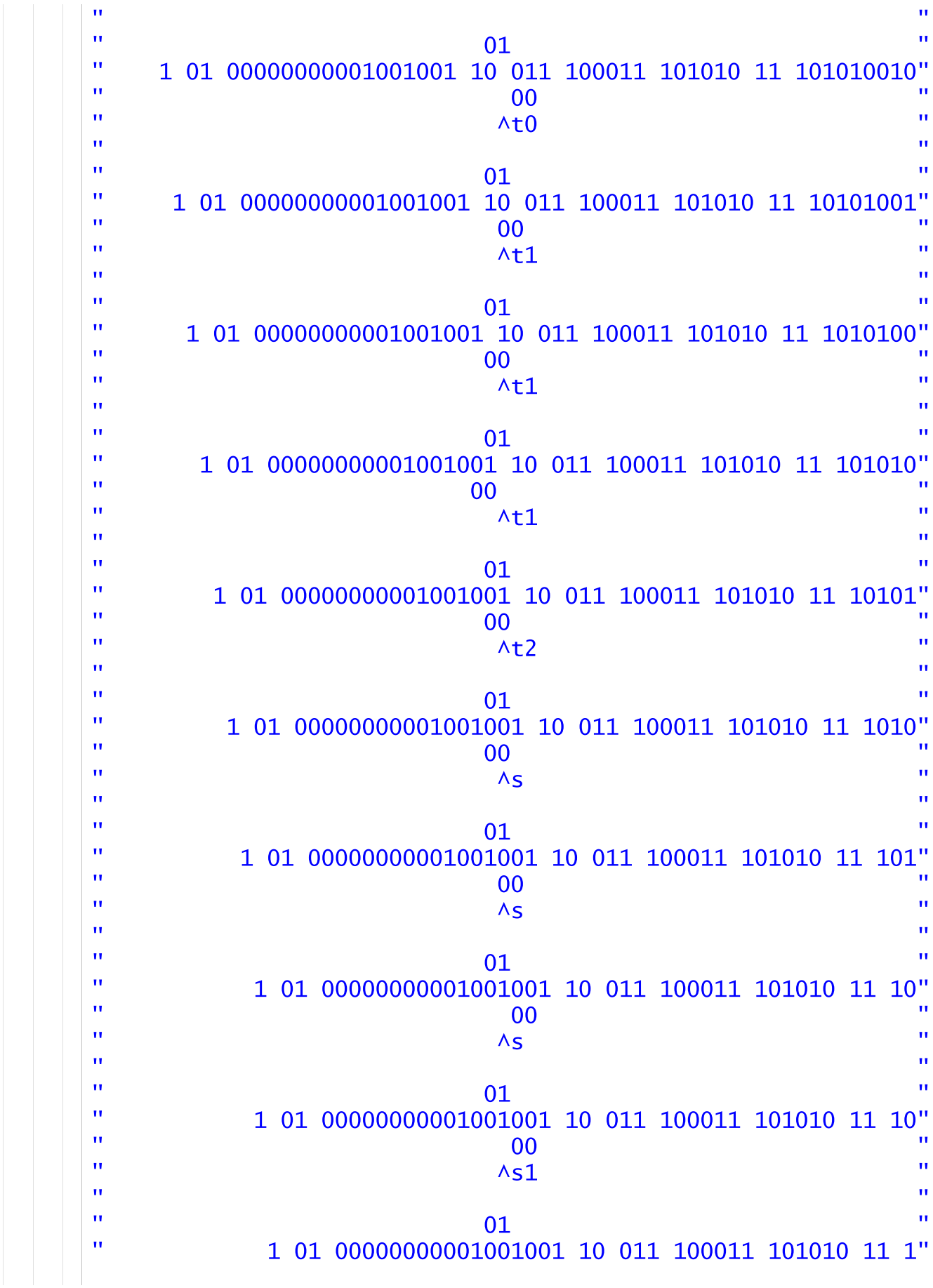
:Ts(%):Ts(%):Ts(%):

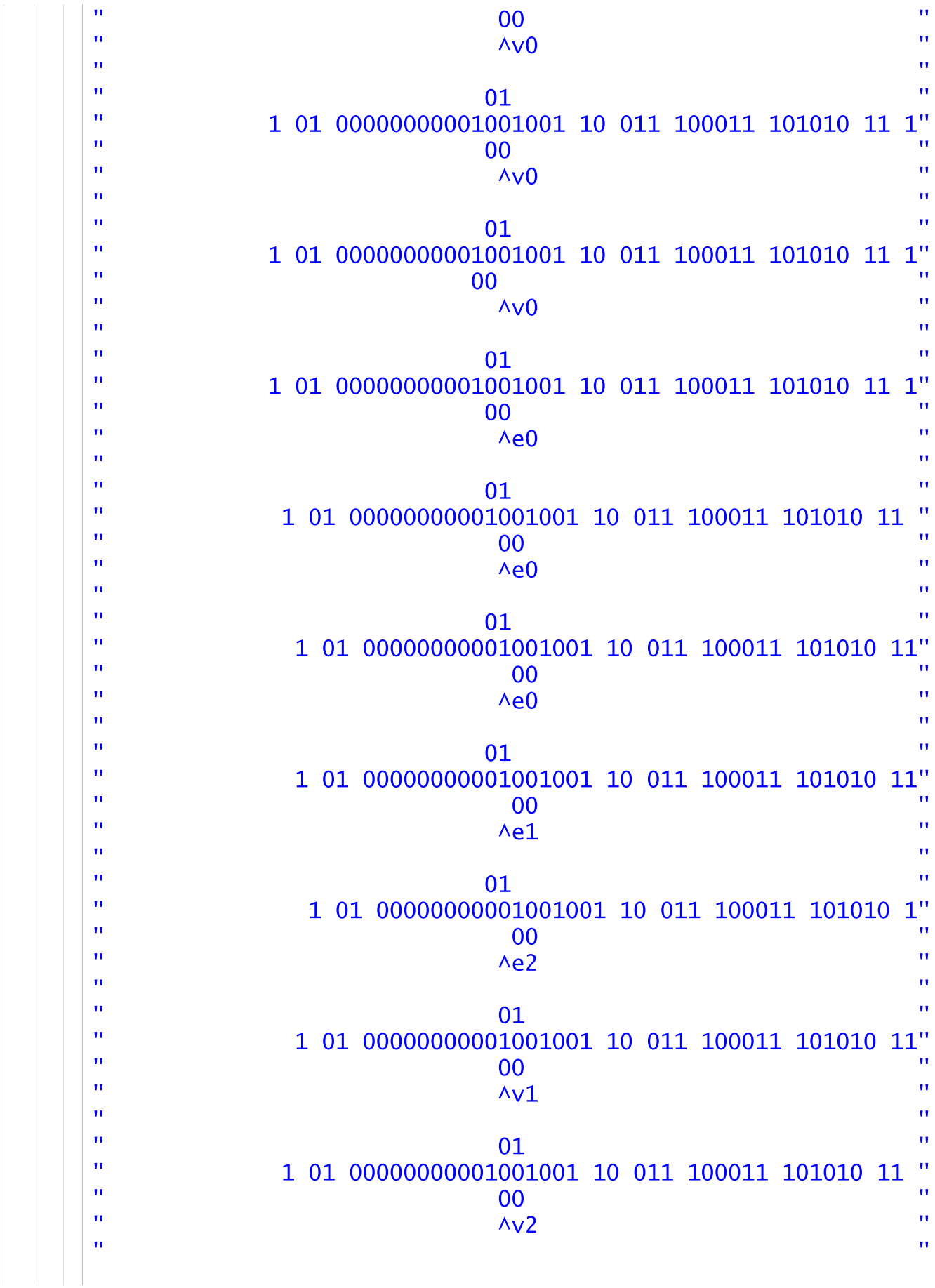
```
   :Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts
   (%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%)
   :Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts
   (%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%)
   :Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts
   (%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%):Ts(%)
   :Ts(%):Ts(%):Ts(%):Ts(%):
"                                                              "
"                                01                            "
"011 101010 11 10101001011101l0                                "
"                                00                            "
"                                 ^s                           "
"                                                              "
"                                01                            "
"0011 101010 11 10101001011101l0                               "
"                                 00                           "
"                                 ^s                           "
"                                                              "
"                                01                            "
"00011 101010 11 10101001011101l0                              "
"                                  00                          "
"                                 ^t0                          "
"                                                              "
"                                01                            "
"100011 101010 11 10101001011101l0                             "
"                                 00                           "
"                                 ^t1                          "
"                                                              "
"                                01                            "
" 100011 101010 11 10101001011101l0                            "
"                                 00                           "
"                                  ^t1                         "
"                                                              "
"                                01                            "
"1 100011 101010 11 10101001011101l0                           "
"                               00                             "
"                                  ^t1                         "
"                                                              "
"                                01                            "
"11 100011 101010 11 10101001011101l0                          "
"                                 00                           "
"                                  ^t2                         "
"                                                              "
"                                01                            "
"011 100011 101010 11 10101001011101l0                         "
"                                 00                           "
"                                  ^s                          "
"                                                              "
```

```
"                              01                                  "
" 011 100011 101010 11 1010100101110110                            "
"                               00                                 "
"                               ^s                                 "
"                                                                  "
"                              01                                  "
"0 011 100011 101010 11 1010100101110110                           "
"                                00                                "
"                               ^t0                                "
"                                                                  "
"                              01                                  "
"10 011 100011 101010 11 1010100101110110                          "
"                               00                                 "
"                               ^t1                                "
"                                                                  "
"                              01                                  "
" 10 011 100011 101010 11 1010100101110110                         "
"                              00                                  "
"                               ^t1                                "
"                                                                  "
"                              01                                  "
"1 10 011 100011 101010 11 1010100101110110                        "
"                             00                                   "
"                               ^t1                                "
"                                                                  "
"                              01                                  "
"01 10 011 100011 101010 11 1010100101110110                       "
"                              00                                  "
"                               ^t2                                "
"                                                                  "
"                              01                                  "
"001 10 011 100011 101010 11 1010100101110110                      "
"                              00                                  "
"                               ^s                                 "
"                                                                  "
"                              01                                  "
"1001 10 011 100011 101010 11 1010100101110110                     "
"                               00                                 "
"                               ^s                                 "
"                                                                  "
"                              01                                  "
"01001 10 011 100011 101010 11 1010100101110110                    "
"                                00                                "
"                               ^t0                                "
"                                                                  "
"                              01                                  "
"001001 10 011 100011 101010 11 1010100101110110                   "
"                               00                                 "
```

```
"                                ^t1                                "
"                                                                   "
"                               01                                  "
"1001001 10 011 100011 101010 11 10101001011110110                 "
"                               00                                  "
"                                ^t1                                "
"                                                                   "
"                               01                                  "
"01001001 10 011 100011 101010 11 10101001011110110                "
"                              00                                   "
"                                ^t1                                "
"                                                                   "
"                               01                                  "
"001001001 10 011 100011 101010 11 10101001011110110               "
"                               00                                  "
"                                ^t2                                "
"                                                                   "
"                               01                                  "
"0001001001 10 011 100011 101010 11 10101001011110110              "
"                               00                                  "
"                                ^s                                 "
"                                                                   "
"                               01                                  "
"00001001001 10 011 100011 101010 11 10101001011110110             "
"                                00                                 "
"                                ^t0                                "
"                                                                   "
"                               01                                  "
"000001001001 10 011 100011 101010 11 10101001011110110            "
"                                 00                                "
"                                ^t0                                "
"                                                                   "
"                               01                                  "
"0000001001001 10 011 100011 101010 11 10101001011110110           "
"                                00                                 "
"                                ^t1                                "
"                                                                   "
"                               01                                  "
"00000001001001 10 011 100011 101010 11 10101001011110110          "
"                               00                                  "
"                                ^t1                                "
"                                                                   "
"                               01                                  "
"000000001001001 10 011 100011 101010 11 10101001011110110         "
"                              00                                   "
"                                ^t1                                "
"                                                                   "
"                               01                                  "
```

```
"0000000001001001 10 011 100011 101010 11 1010100101110110   "
"                              00                             "
"                               ^t2                           "
"                                                             "
"                              01                             "
"00000000001001001 10 011 100011 101010 11 1010100101110110  "
"                              00                             "
"                               ^s                            "
"                                                             "
"                              01                             "
" 00000000001001001 10 011 100011 101010 11 1010100101110110 "
"                               00                            "
"                               ^t0                           "
"                                                             "
"                              01                             "
"1 00000000001001001 10 011 100011 101010 11 1010100101110110"
"                                00                           "
"                               ^t0                           "
"                                                             "
"                              01                             "
"01 00000000001001001 10 011 100011 101010 11 101010010111011"
"                               00                            "
"                               ^t1                           "
"                                                             "
"                              01                             "
" 01 00000000001001001 10 011 100011 101010 11 10101001011101"
"                              00                             "
"                               ^t1                           "
"                                                             "
"                              01                             "
"1 01 00000000001001001 10 011 100011 101010 11 1010100101110"
"                             00                              "
"                               ^t1                           "
"                                                             "
"                              01                             "
" 1 01 00000000001001001 10 011 100011 101010 11 101010010111"
"                              00                             "
"                               ^t2                           "
"                                                             "
"                              01                             "
"  1 01 00000000001001001 10 011 100011 101010 11 10101001011"
"                              00                             "
"                               ^s                            "
"                                                             "
"                              01                             "
"   1 01 00000000001001001 10 011 100011 101010 11 1010100101"
"                               00                            "
"                               ^t0                           "
```


01
1 01 00000000001001001 10 011 100011 101010 11 101010010
00
^t0
01
1 01 00000000001001001 10 011 100011 101010 11 10101001
00
^t1
01
1 01 00000000001001001 10 011 100011 101010 11 1010100
00
^t1
01
1 01 00000000001001001 10 011 100011 101010 11 101010
00
^t1
01
1 01 00000000001001001 10 011 100011 101010 11 10101
00
^t2
01
1 01 00000000001001001 10 011 100011 101010 11 1010
00
^s
01
1 01 00000000001001001 10 011 100011 101010 11 101
00
^s
01
1 01 00000000001001001 10 011 100011 101010 11 10
00
^s
01
1 01 00000000001001001 10 011 100011 101010 11 10
00
^s1
01
1 01 00000000001001001 10 011 100011 101010 11 1


00
^v0
01
1 01 0000000001001001 10 011 100011 101010 11 1
00
^v0
01
1 01 0000000001001001 10 011 100011 101010 11 1
00
^v0
01
1 01 0000000001001001 10 011 100011 101010 11 1
00
^e0
01
1 01 0000000001001001 10 011 100011 101010 11
00
^e0
01
1 01 0000000001001001 10 011 100011 101010 11
00
^e0
01
1 01 0000000001001001 10 011 100011 101010 11
00
^e1
01
1 01 0000000001001001 10 011 100011 101010 1
00
^e2
01
1 01 0000000001001001 10 011 100011 101010 11
00
^v1
01
1 01 0000000001001001 10 011 100011 101010 11
00
^v2

```
"                                01                                  "
"              1 01 00000000001001001 10 011 100011 101010 11 1"
"                               00                                   "
"                                ^v2                                 "
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"                            ^s                                 "
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"                                ^t1                               "
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"                                 ^v3                                  "
"                                                                      "
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"                                 ^v1                                  "
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"                                 00                                   "
"                                 ^v2                                  "
"                                                                      "
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"0000001001001 10 011 100011 101010 11 10101001011110110              "
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"                                 ^v2                                  "
"                                                                      "
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"                                 00                                   "
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"1 10 011 100011 101010 11 10101001011110110                            "
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" 10 011 100011 101010 11 10101001011110110                             "
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"                                   ^v2                                 "
"                                                                       "
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"10 011 100011 101010 11 10101001011110110                              "
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"                                   ^v2                                 "
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"                                   ^v2                                 "
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"                                ^t1                                "
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"                                ^t1                                "
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"                                ^t1                                "
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"                                ^t2                                "
"                                                                   "
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"                                ^s                                 "
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"                                ^t0                                "
"                                                                   "
"                                 01                                "
```

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"                                 ^t1                         "
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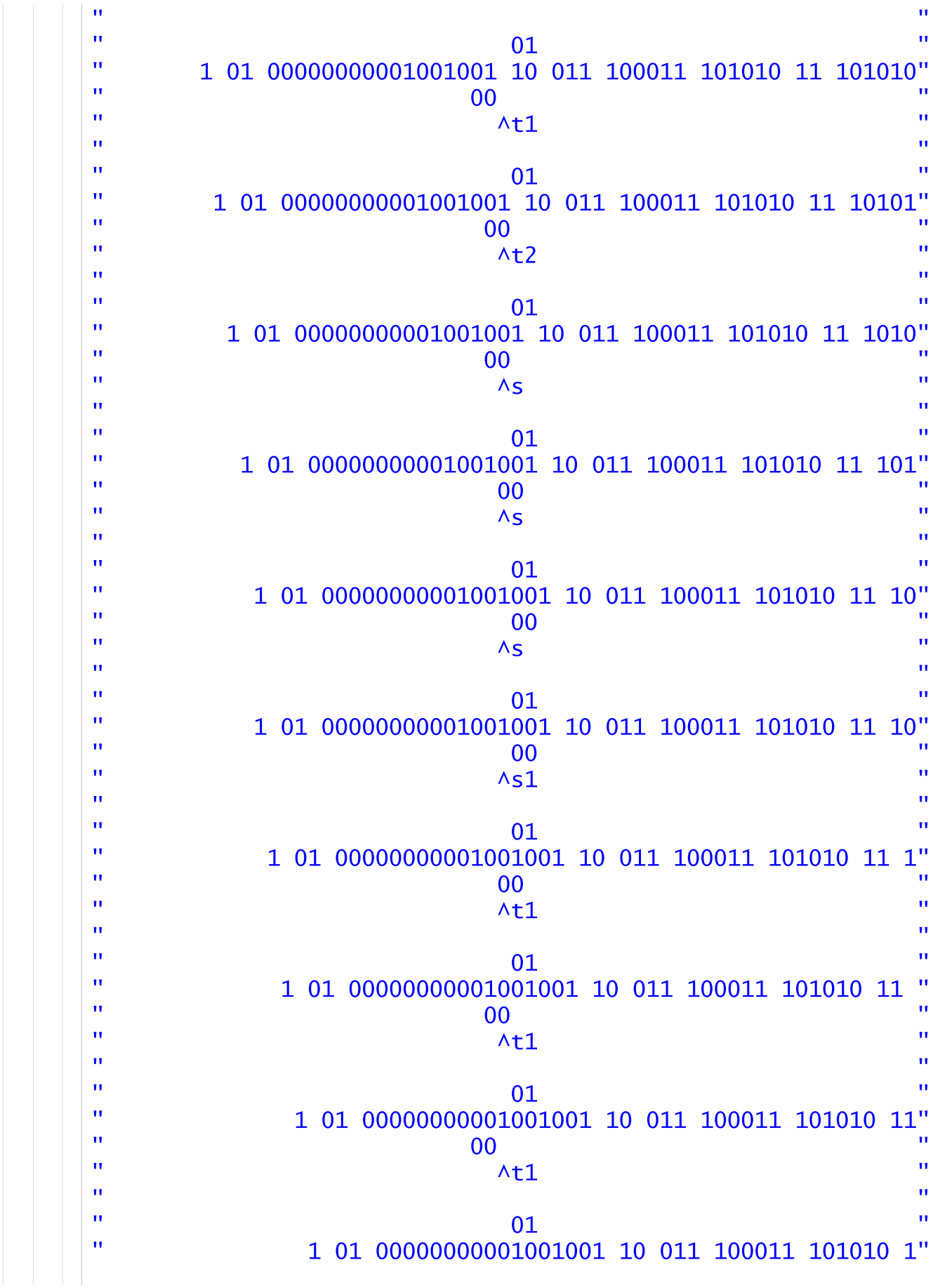
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^t1
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^t2
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^s
01
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^s
01
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01
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00
^t1
01
1 01 00000000001001001 10 011 100011 101010 11
00
^t1
01
1 01 00000000001001001 10 011 100011 101010 1

```
"                              00                                  "
"                               ^t2                                "
"                                                                  "
"                                01                                "
"                  1 01 0000000001001001 10 011 100011 101010      "
"                              00                                  "
"                               ^s                                 "
"                                                                  "
"                                01                                "
"                   1 01 0000000001001001 10 011 100011 101010"    "
"                              00                                  "
"                               ^s                                 "
"                                                                  "
"                                01                                "
"                    1 01 0000000001001001 10 011 100011 10101"    "
"                              00                                  "
"                               ^s                                 "
"                                                                  "
"                                01                                "
"                    1 01 0000000001001001 10 011 100011 10101"    "
"                              00                                  "
"                               ^s1                                "
"                                                                  "
"                                01                                "
"                     1 01 0000000001001001 10 011 100011 1010"    "
"                              00                                  "
"                               ^t1                                "
"                                                                  "
"                                01                                "
"                      1 01 0000000001001001 10 011 100011 101"    "
"                             00                                   "
"                              ^t1                                 "
"                                                                  "
"                                01                                "
"                       1 01 0000000001001001 10 011 100011 10"    "
"                            00                                    "
"                              ^t1                                 "
"                                                                  "
"                                01                                "
"                        1 01 0000000001001001 10 011 100011 1"    "
"                             00                                   "
"                              ^t2                                 "
"                                                                  "
"                                01                                "
"                         1 01 0000000001001001 10 011 100011 "    "
"                             00                                   "
"                              ^s                                  "
"                                                                  "
```

```
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"                               ^s                                "
"                                                                 "
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"                               ^s                                "
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"                               ^s1                               "
"                                                                 "
"                                01                               "
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"                               00                                "
"                               ^v0                               "
"                                                                 "
"                                01                               "
"                            1 01 00000000001001001 10 011 1000"
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"                               ^v0                               "
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"                               ^v0                               "
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"                                01                               "
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"                              00                                 "
"                               ^e0                               "
"                                                                 "
"                                01                               "
"                             1 01 00000000001001001 10 011 100"
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"                               ^e0                               "
"                                                                 "
"                                01                               "
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"                                01                               "
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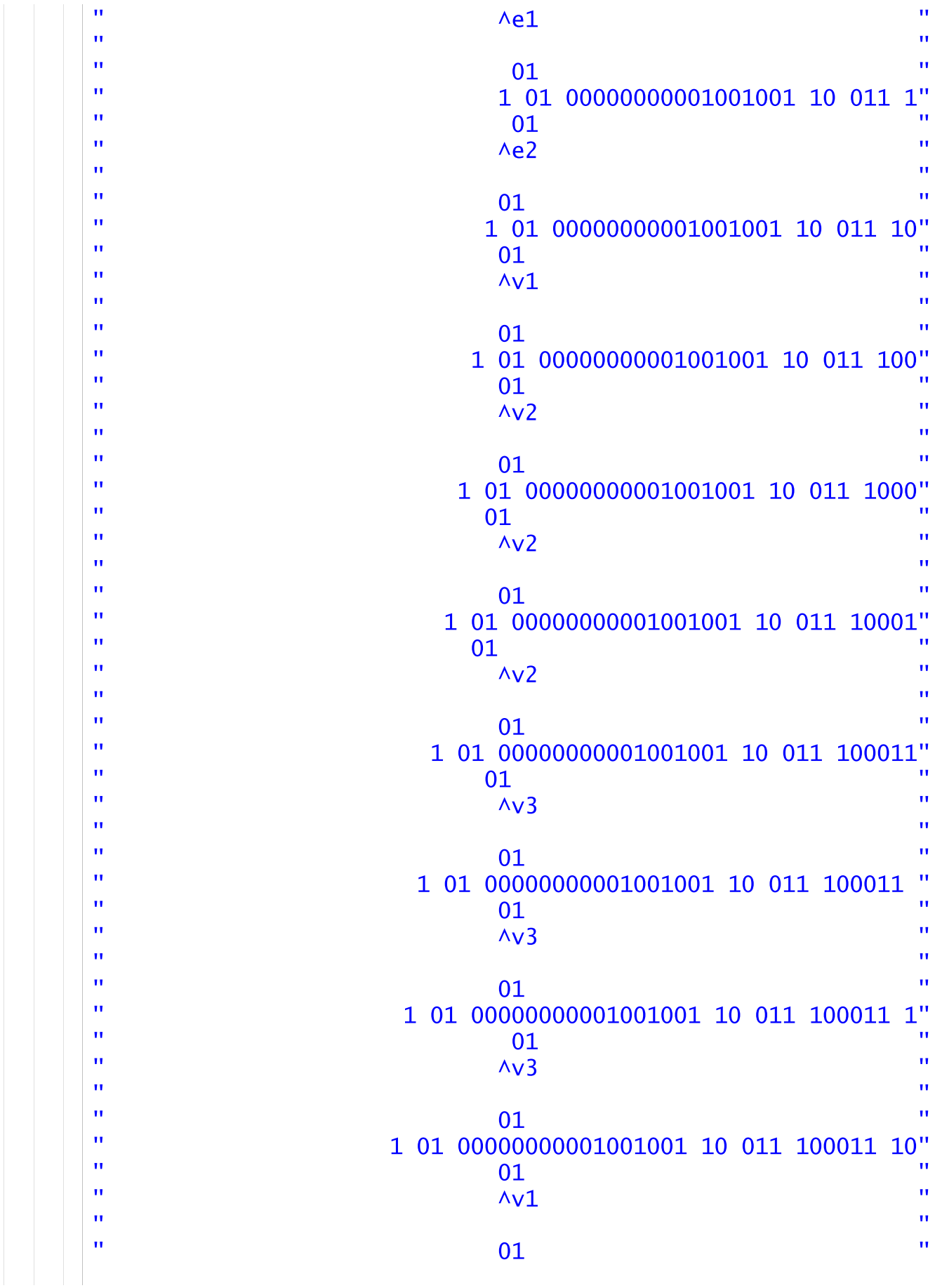
^e1
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01
^e2
01
1 01 00000000001001001 10 011 10
01
^v1
01
1 01 00000000001001001 10 011 100
01
^v2
01
1 01 00000000001001001 10 011 1000
01
^v2
01
1 01 00000000001001001 10 011 10001
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01
^v3
01
1 01 00000000001001001 10 011 100011 1
01
^v3
01
1 01 00000000001001001 10 011 100011 10
01
^v1
01

```
"                    1 01 00000000001001001 10 011 100011 101"
"                              01                              "
"                              ^v2                             "
"                                                              "
"                              01                              "
"                   1 01 00000000001001001 10 011 100011 1010"
"                             01                               "
"                              ^v2                             "
"                                                              "
"                              01                              "
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"                              01                              "
"                 1 01 00000000001001001 10 011 100011 101010"
"                             01                               "
"                              ^v3                             "
"                                                              "
"                              01                              "
"                1 01 00000000001001001 10 011 100011 101010 "
"                              01                              "
"                              ^v3                             "
"                                                              "
"                              01                              "
"               1 01 00000000001001001 10 011 100011 101010 1"
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"                              ^v3                             "
"                                                              "
"                              01                              "
"              1 01 00000000001001001 10 011 100011 101010 11"
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"                              ^v1                             "
"                                                              "
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"             1 01 00000000001001001 10 011 100011 101010 11 "
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"                              ^v2                             "
"                                                              "
"                              01                              "
"            1 01 00000000001001001 10 011 100011 101010 11 1"
"                             01                               "
"                              ^v2                             "
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"                              ^v2                             "
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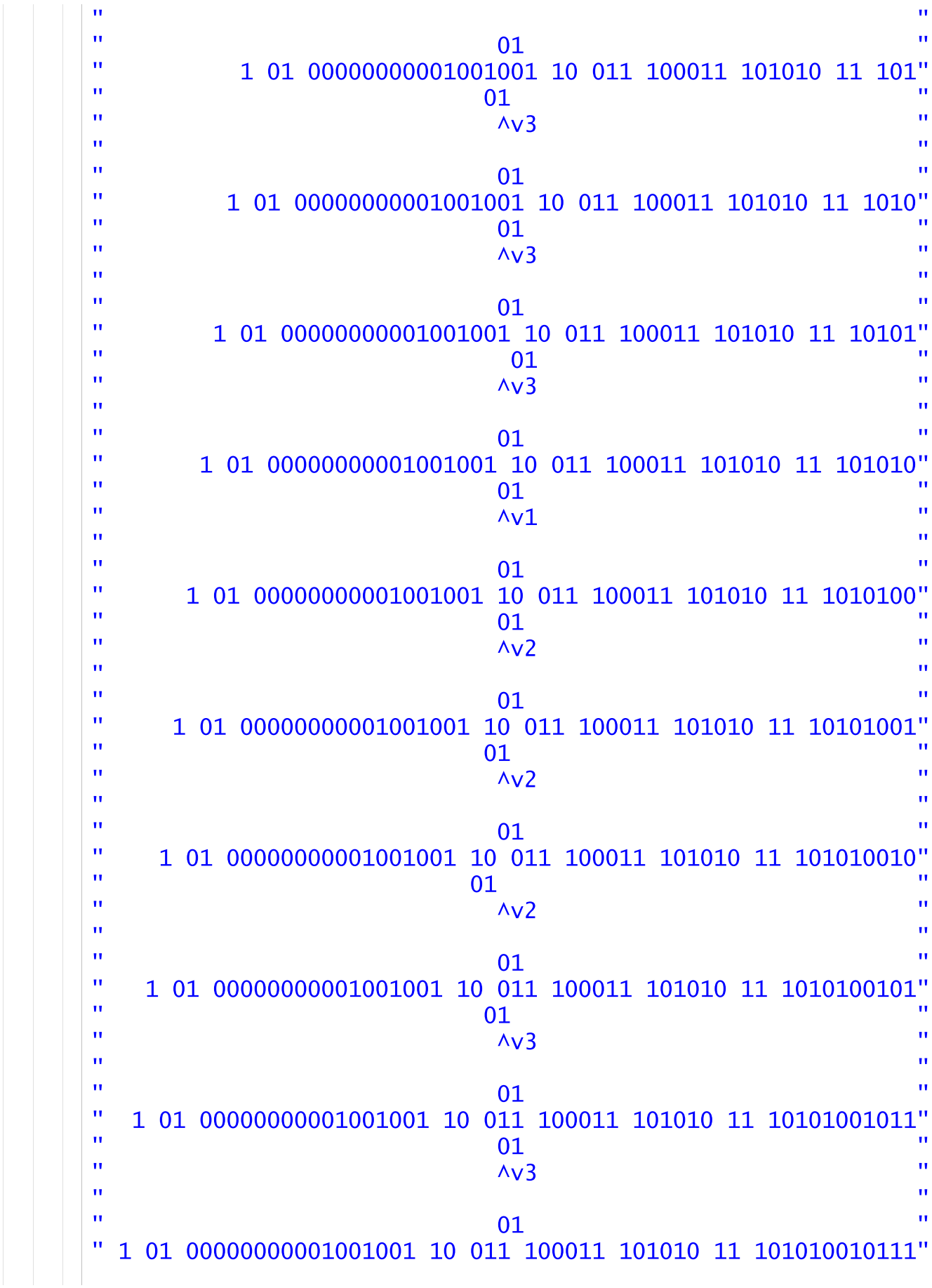
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^v3
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^v3
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^v3
01
1 01 00000000001001001 10 011 100011 101010 11 101010
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1 01 00000000001001001 10 011 100011 101010 11 10101001011
01
^v3
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1 01 00000000001001001 10 011 100011 101010 11 101010010111

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"                                 01                                 "
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"                                ^v2                                 "
"                                                                    "
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"                                ^v3                                 "
"                                                                    "
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"                               ^h                             "
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▼ *10.1.30. Egyszalagos univerzális Turing-gép.*

▶ *10.1.31. Feladat.*

▼ *10.1.32. Félszalagos Turing-gépek.*
▼ *10.1.33. Félszalagos Turing-gép szimulálása Turing-gépen.*
▼ *10.1.34. Turing-gép szimulálása félszalagos gépen.*
▼ *10.1.35. Post-gép szimulálása félszalagos gépen.*
▼ *10.1.36. Tétel: Post-gép szimulálása Turing-gépen.*
▼ *10.1.37. Tétel: Turing-gép szimulálása Post-gépen.*
▼ *10.1.38. Korlótozott gépmodellek.*
▼ *10.1.39. Tétel.*
▼ *10.1.40. RAM-gép.*
▼ *10.1.41. RAM-gép végrehajtási ideje.*
▼ *10.1.42. Példák.*
▼ *10.1.43. Feladat.*
▼ *10.1.44. Turing-gép szimulálása RAM-gépen.*
▼ *10.1.45. Megjegyzés.*
▼ *10.1.46. RAM-gép szimulálása Turing-gépen.*
▶ *10.1.47. Megjegyzés.*
▼ *10.1.48. Tárolt programú gép.*
▼ **10.1.49. Markov-automaták.*
▼ **10.1.50. Turing-gép szimulálása Markov-automatán.*
▼ **10.1.51. Markov-automata szimulálása Turing-gépen.*
▼ **10.1.52. Sejtautomaták.*
▼ **10.1.53. Példák.*
▼ **10.1.54. Sejtautomata szimulálása Turing-gépen.*
▼ **10.1.55. Turing-gép szimulálása sejtautomatán.*
▼ **10.1.56. Church-féle lambda-kalkulus.*
▼ *->10.1.57. Feladat.*
▶ *10.1.58. További feladatok.*

▼ 10.2. Kiszámíthatóság

▶ *10.2.1. Kiszámítható függvények.*
▶ *10.2.2. Nyelvek.*
▶ *10.2.3. Eldönthető nyelvek.*
▶ *10.2.4. Felsorolható nyelvek.*

- *10.2.5. Kiszámítható parciális függvények.*
- *–>10.2.6. Feladat.*
- *–>10.2.7. Feladat.*
- *10.2.8. Feladat.*
- *–>10.2.9. Feladat.*
- *10.2.10. Tétel.*
- *10.2.11. Megjegyzés.*
- *10.2.12. A Church–tézis.*
- *10.2.13. Tétel.*
- *10.2.14. Lemma.*
- *10.2.15. Tétel.*
- *–>10.2.16. Feladat.*
- *10.2.17. A megállási feladat.*
- *10.2.18. Tétel.*
- *10.2.19. Tétel.*
- *10.2.20. Tétel.*
- *10.2.21. Tétel.*
- *10.2.22. Matematikai problémák algoritmikus megoldhatatlansága.*
- *10.2.23. Diophantoszi egyenletek algoritmikus megoldhatatlansága.*
- *10.2.24. Dominó–probléma.*
- *10.2.25. Parciális rekurzív és primitív rekurzív függvények.*
- *10.2.26. Példák primitív rekurzív függvényekre.*
- **10.2.27. Tétel.*
- **10.2.28. Tétel.*
- **10.2.29. Rekurzív függvények.*
- *–>10.2.30. Feladat.*
- *–>10.2.31. Feladat.*
- *–>10.2.32. Feladat.*
- *–>10.2.33. Feladat.*
- *–>10.2.34. Feladat.*
- *–>10.2.35. Feladat.*
- *–>10.2.36. Feladat.*

▶ *10.2.37. További feladatok.*

▼ 10.3. Idő és tár

▼ *10.3.1. Algoritmusok idő- és tárigénye.*
▼ *10.3.2. Példák.*
▼ *10.3.3. Nemdeterminisztikus Turing-gépek.*
▶ *10.3.4. Tétel.*
▼ *10.3.5. Tanú.*
▼ *10.3.6. Példák.*
▶ *10.3.7. Tanú-tétel.*
▶ *10.3.8. Következmény.*
▶ *10.3.9. Megjegyzés.*
▶ *->10.3.10. Feladat.*
▶ *->10.3.11. Feladat.*
▼ *->10.3.12. Feladat.*
▼ *->10.3.13. Feladat.*
▶ *10.3.14. További feladatok.*