Berechenbarkeit und Komplexität Sommersemester 01

Aufgaben zur Größenordnungen und Erfüllbarkeit

ORD1) Finden Sie alle Relationen $f \in O(g)$ zwischen den Funktionen

$$n^2, 2^n, (\log n)^2, n!, \sqrt{n}^{\sqrt{n}}, n^n, n \log n, n^{2+\sin n}, (\log n)^{\log n}, \log(n!)$$

Festlegung: $\log n$ bedeutet $\lceil \log_2 n \rceil$, d. h. log zur Basis Zwei, aufgerundet.

ORD2) Sind die Funktionen $(\log n)!$ bzw. $(\log \log n)!$ durch ein Polynom beschränkt?

ORD3) Das folgende Programm soll die Feld–Elemente $A[i \dots j]$ sortieren:

```
procedure sort (i, j) =
    if i + 1 < j then
       d := ( j - i + 1 ) / 3;  -- bei Division abrunden
       sort ( i, j - d );
       sort ( i + d, j );
       sort ( i, j - d ):
    else
       if A[i] > A[j] then vertausche A[i] mit A[j]; end if
    end if;
```

(Überzeugen Sie sich davon, daß das Programm korrekt ist.)

Bestimmen Sie die Anzahl $c(n)$ der Elementvergleiche `A[i] > A[j]`, die dieses Programm beim Aufruf `sort (1, n)` ausführt.

Die Funktion $c(n)$ ist polynomial beschränkt. Finden Sie die kleinste reelle Zahl e, für die $c(n) \in O(n^e)$.

(Vergleichen Sie mit den Laufzeiten anderer Sortierverfahren.)

Zu den Aufgaben SAT*: Sie können eine erfüllende Belegung in dieser Form vom autotool prüfen lassen: `student = [ 1, 2, 3 ]`. Das bedeutet $x_1 = x_2 = x_3 =$ True, und für alle anderen vorkommenden $x_i =$ False.

SAT1) Ist diese aussagenlogische Formel erfüllbar?

$(x_1 \vee x_2 \vee x_3) \wedge (\overline{x_1} \vee \overline{x_2} \vee \overline{x_3}) \wedge (x_2 \vee x_3 \vee x_4) \wedge (\overline{x_2} \vee \overline{x_3} \vee \overline{x_4}) \wedge (x_3 \vee x_4 \vee x_5) \wedge (\overline{x_3} \vee \overline{x_4} \vee \overline{x_5}) \wedge$
$(x_4 \vee x_5 \vee x_6) \wedge (\overline{x_4} \vee \overline{x_5} \vee \overline{x_6}) \wedge (x_5 \vee x_6 \vee x_7) \wedge (\overline{x_5} \vee \overline{x_6} \vee \overline{x_7}) \wedge (x_6 \vee x_7 \vee x_8) \wedge (\overline{x_6} \vee \overline{x_7} \vee \overline{x_8}) \wedge$
$(x_1 \vee x_3 \vee x_5) \wedge (\overline{x_1} \vee \overline{x_3} \vee \overline{x_5}) \wedge (x_2 \vee x_4 \vee x_6) \wedge (\overline{x_2} \vee \overline{x_4} \vee \overline{x_6}) \wedge (x_3 \vee x_5 \vee x_7) \wedge (\overline{x_3} \vee \overline{x_5} \vee \overline{x_7}) \wedge$
$(x_4 \vee x_6 \vee x_8) \wedge (\overline{x_4} \vee \overline{x_6} \vee \overline{x_8}) \wedge (x_1 \vee x_4 \vee x_7) \wedge (\overline{x_1} \vee \overline{x_4} \vee \overline{x_7}) \wedge (x_2 \vee x_5 \vee x_8) \wedge (\overline{x_2} \vee \overline{x_5} \vee \overline{x_8})$

SAT2) Ist diese aussagenlogische Formel erfüllbar?

$(x_1 \vee x_2 \vee x_3) \wedge (\overline{x_1} \vee \overline{x_2} \vee \overline{x_3}) \wedge (x_2 \vee x_3 \vee x_4) \wedge (\overline{x_2} \vee \overline{x_3} \vee \overline{x_4}) \wedge (x_3 \vee x_4 \vee x_5) \wedge (\overline{x_3} \vee \overline{x_4} \vee \overline{x_5}) \wedge$
$(x_4 \vee x_5 \vee x_6) \wedge (\overline{x_4} \vee \overline{x_5} \vee \overline{x_6}) \wedge (x_5 \vee x_6 \vee x_7) \wedge (\overline{x_5} \vee \overline{x_6} \vee \overline{x_7}) \wedge (x_6 \vee x_7 \vee x_8) \wedge (\overline{x_6} \vee \overline{x_7} \vee \overline{x_8}) \wedge$
$(x_7 \vee x_8 \vee x_9) \wedge (\overline{x_7} \vee \overline{x_8} \vee \overline{x_9}) \wedge (x_1 \vee x_3 \vee x_5) \wedge (\overline{x_1} \vee \overline{x_3} \vee \overline{x_5}) \wedge (x_2 \vee x_4 \vee x_6) \wedge (\overline{x_2} \vee \overline{x_4} \vee \overline{x_6}) \wedge$
$(x_3 \vee x_5 \vee x_7) \wedge (\overline{x_3} \vee \overline{x_5} \vee \overline{x_7}) \wedge (x_4 \vee x_6 \vee x_8) \wedge (\overline{x_4} \vee \overline{x_6} \vee \overline{x_8}) \wedge (x_5 \vee x_7 \vee x_9) \wedge (\overline{x_5} \vee \overline{x_7} \vee \overline{x_9}) \wedge$
$(x_1 \vee x_4 \vee x_7) \wedge (\overline{x_1} \vee \overline{x_4} \vee \overline{x_7}) \wedge (x_2 \vee x_5 \vee x_8) \wedge (\overline{x_2} \vee \overline{x_5} \vee \overline{x_8}) \wedge (x_3 \vee x_6 \vee x_9) \wedge (\overline{x_3} \vee \overline{x_6} \vee \overline{x_9})$
$\wedge (x_1 \vee x_5 \vee x_9) \wedge (\overline{x_1} \vee \overline{x_5} \vee \overline{x_9})$

SAT3) Finden Sie eine erfüllende Belegung für

$(x_{1} \lor x_{2} \lor x_{3} \lor x_{4}) \land (\overline{x_{1}} \lor \overline{x_{2}} \lor \overline{x_{3}} \lor \overline{x_{4}}) \land (x_{2} \lor x_{3} \lor x_{4} \lor x_{5}) \land (\overline{x_{2}} \lor \overline{x_{3}} \lor \overline{x_{4}} \lor \overline{x_{5}}) \land (x_{3} \lor x_{4} \lor x_{5} \lor x_{6}) \land (\overline{x_{3}} \lor \overline{x_{4}} \lor \overline{x_{5}} \lor \overline{x_{6}}) \land (x_{4} \lor x_{5} \lor x_{6} \lor x_{7}) \land (\overline{x_{4}} \lor \overline{x_{5}} \lor \overline{x_{6}} \lor \overline{x_{7}}) \land (x_{5} \lor x_{6} \lor x_{7} \lor x_{8}) \land (\overline{x_{5}} \lor \overline{x_{6}} \lor \overline{x_{7}} \lor \overline{x_{8}}) \land (x_{6} \lor x_{7} \lor x_{8} \lor x_{9}) \land (\overline{x_{6}} \lor \overline{x_{7}} \lor \overline{x_{8}} \lor \overline{x_{9}}) \land (x_{7} \lor x_{8} \lor x_{9} \lor x_{10}) \land (\overline{x_{7}} \lor \overline{x_{8}} \lor \overline{x_{9}} \lor \overline{x_{10}}) \land (x_{8} \lor x_{9} \lor x_{10} \lor x_{11}) \land (\overline{x_{8}} \lor \overline{x_{9}} \lor \overline{x_{10}} \lor \overline{x_{11}}) \land (x_{9} \lor x_{10} \lor x_{11} \lor x_{12}) \land (\overline{x_{9}} \lor \overline{x_{10}} \lor \overline{x_{11}} \lor \overline{x_{12}}) \land (x_{10} \lor x_{11} \lor x_{12} \lor x_{13}) \land (\overline{x_{10}} \lor \overline{x_{11}} \lor \overline{x_{12}} \lor \overline{x_{13}}) \land (x_{11} \lor x_{12} \lor x_{13} \lor x_{14}) \land (\overline{x_{11}} \lor \overline{x_{12}} \lor \overline{x_{13}} \lor \overline{x_{14}}) \land (x_{12} \lor x_{13} \lor x_{14} \lor x_{15}) \land (\overline{x_{12}} \lor \overline{x_{13}} \lor \overline{x_{14}} \lor \overline{x_{15}}) \land (x_{13} \lor x_{14} \lor x_{15} \lor x_{16}) \land (\overline{x_{13}} \lor \overline{x_{14}} \lor \overline{x_{15}} \lor \overline{x_{16}}) \land (x_{14} \lor x_{15} \lor x_{16} \lor x_{17}) \land (\overline{x_{14}} \lor \overline{x_{15}} \lor \overline{x_{16}} \lor \overline{x_{17}}) \land (x_{15} \lor x_{16} \lor x_{17} \lor x_{18}) \land (\overline{x_{15}} \lor \overline{x_{16}} \lor \overline{x_{17}} \lor \overline{x_{18}}) \land (x_{16} \lor x_{17} \lor x_{18} \lor x_{19}) \land (\overline{x_{16}} \lor \overline{x_{17}} \lor \overline{x_{18}} \lor \overline{x_{19}}) \land (x_{17} \lor x_{18} \lor x_{19} \lor x_{20}) \land (\overline{x_{17}} \lor \overline{x_{18}} \lor \overline{x_{19}} \lor \overline{x_{20}}) \land (x_{18} \lor x_{19} \lor x_{20} \lor x_{21}) \land (\overline{x_{18}} \lor \overline{x_{19}} \lor \overline{x_{20}} \lor \overline{x_{21}}) \land (x_{19} \lor x_{20} \lor x_{21} \lor x_{22}) \land (\overline{x_{19}} \lor \overline{x_{20}} \lor \overline{x_{21}} \lor \overline{x_{22}}) \land (x_{20} \lor x_{21} \lor x_{22} \lor x_{23}) \land (\overline{x_{20}} \lor \overline{x_{21}} \lor \overline{x_{22}} \lor \overline{x_{23}}) \land (x_{21} \lor x_{22} \lor x_{23} \lor x_{24}) \land (\overline{x_{21}} \lor \overline{x_{22}} \lor \overline{x_{23}} \lor \overline{x_{24}}) \land (x_{22} \lor x_{23} \lor x_{24} \lor x_{25}) \land (\overline{x_{22}} \lor \overline{x_{23}} \lor \overline{x_{24}} \lor \overline{x_{25}}) \land (x_{23} \lor x_{24} \lor x_{25} \lor x_{26}) \land (\overline{x_{23}} \lor \overline{x_{24}} \lor \overline{x_{25}} \lor \overline{x_{26}}) \land (x_{24} \lor x_{25} \lor x_{26} \lor x_{27}) \land (\overline{x_{24}} \lor \overline{x_{25}} \lor \overline{x_{26}} \lor \overline{x_{27}}) \land (x_{25} \lor x_{26} \lor x_{27} \lor x_{28}) \land (\overline{x_{25}} \lor \overline{x_{26}} \lor \overline{x_{27}} \lor \overline{x_{28}}) \land (x_{26} \lor x_{27} \lor x_{28} \lor x_{29}) \land (\overline{x_{26}} \lor \overline{x_{27}} \lor \overline{x_{28}} \lor \overline{x_{29}}) \land (x_{27} \lor x_{28} \lor x_{29} \lor x_{30}) \land (\overline{x_{27}} \lor \overline{x_{28}} \lor \overline{x_{29}} \lor \overline{x_{30}}) \land (x_{28} \lor x_{29} \lor x_{30} \lor x_{31}) \land (\overline{x_{28}} \lor \overline{x_{29}} \lor \overline{x_{30}} \lor \overline{x_{31}}) \land (x_{29} \lor x_{30} \lor x_{31} \lor x_{32}) \land (\overline{x_{29}} \lor \overline{x_{30}} \lor \overline{x_{31}} \lor \overline{x_{32}}) \land (x_{30} \lor x_{31} \lor x_{32} \lor x_{33}) \land (\overline{x_{30}} \lor \overline{x_{31}} \lor \overline{x_{32}} \lor \overline{x_{33}}) \land (x_{31} \lor x_{32} \lor x_{33} \lor x_{34}) \land (\overline{x_{31}} \lor \overline{x_{32}} \lor \overline{x_{33}} \lor \overline{x_{34}}) \land$
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$(x_{1} \lor x_{10} \lor x_{19} \lor x_{28}) \land (\overline{x_{1}} \lor \overline{x_{10}} \lor \overline{x_{19}} \lor \overline{x_{28}}) \land (x_{2} \lor x_{11} \lor x_{20} \lor x_{29}) \land (\overline{x_{2}} \lor \overline{x_{11}} \lor \overline{x_{20}} \lor \overline{x_{29}}) \land (x_{3} \lor x_{12} \lor x_{21} \lor x_{30}) \land (\overline{x_{3}} \lor \overline{x_{12}} \lor \overline{x_{21}} \lor \overline{x_{30}}) \land (x_{4} \lor x_{13} \lor x_{22} \lor x_{31}) \land (\overline{x_{4}} \lor \overline{x_{13}} \lor \overline{x_{22}} \lor \overline{x_{31}}) \land (x_{5} \lor x_{14} \lor x_{23} \lor x_{32}) \land (\overline{x_{5}} \lor \overline{x_{14}} \lor \overline{x_{23}} \lor \overline{x_{32}}) \land (x_{6} \lor x_{15} \lor x_{24} \lor x_{33}) \land (\overline{x_{6}} \lor \overline{x_{15}} \lor \overline{x_{24}} \lor \overline{x_{33}}) \land (x_{7} \lor x_{16} \lor x_{25} \lor x_{34}) \land (\overline{x_{7}} \lor \overline{x_{16}} \lor \overline{x_{25}} \lor \overline{x_{34}}) \land$
$(x_{1} \lor x_{11} \lor x_{21} \lor x_{31}) \land (\overline{x_{1}} \lor \overline{x_{11}} \lor \overline{x_{21}} \lor \overline{x_{31}}) \land (x_{2} \lor x_{12} \lor x_{22} \lor x_{32}) \land (\overline{x_{2}} \lor \overline{x_{12}} \lor \overline{x_{22}} \lor \overline{x_{32}}) \land (x_{3} \lor x_{13} \lor x_{23} \lor x_{33}) \land (\overline{x_{3}} \lor \overline{x_{13}} \lor \overline{x_{23}} \lor \overline{x_{33}}) \land (x_{4} \lor x_{14} \lor x_{24} \lor x_{34}) \land (\overline{x_{4}} \lor \overline{x_{14}} \lor \overline{x_{24}} \lor \overline{x_{34}}) \land (x_{1} \lor x_{12} \lor x_{23} \lor x_{34}) \land (\overline{x_{1}} \lor \overline{x_{12}} \lor \overline{x_{23}} \lor \overline{x_{34}})$