Mini-task report: SDC with simulated annealing

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1 Introduction

The task was to implement a simulated annealing approach (SA) for SDC (system of difference constraints). LPsolve is used to get a schedule for a given set of constraints. The SA-algorithm mutates the order of the constraints to reduce the number of clock cycles of the schedule.

2 Resources and Constraints

The constraints consist of data flow - and resource constraints. The data flow constraints determine, that no operation must start, before all predecessors have obtained a result. The resource constraints prevent, that the same resource is used twice at the same time.

2.1 Resources

Each hardware has a certain amount of resources and resource types. There is a fixed list of operations given in the framework:

Operation name (ar)	delay	weight
MEM	2	9.0
ADD	1	1.0
SUB	1	1.4
MUL	4	2.3
DIV	18	4.3
SH	1	2.0
AND	1	2.0
OR	1	2.0
CMP	1	2.1
OTHER	1	1.0
SLACK	1	0.0

Each resource type can support multiple operations. For this project, the resource(types) are assumed to be overlap-free:

$$\neg\exists R_1, R_2 \in Resources; Op_1, Op_2 \in Operations : Op_1 \in R_1 \wedge Op_1 \in R_2 \wedge Op_2 \in R_1 \wedge Op_2 \notin R_2$$

Each resource can handle one operation within a certain time (delay). Multiple resources of the same type may exist.

2.2 Data Flow Constraints

The data flow constraints are fixed and only need to be computed once.

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3 Simulated Annealing

The principal structure of any simulated annealing looks like this:

```
S = RandomConfiguration();
T = InitialTemperature();
while (ExitCriterion()==false) {
  while (InnerLoopCriterion() == false) {
    S_new = Generate(S);
    Δ C = Cost(S_new)-Cost(S);
    r = random(0,1);
    if (r < e^(-ΔC/T)) S = S_new
  }
  T = updateTemperature();
}
```

The implementation is located in scheduler/SASDC.java:schedule. The parameters are:

- *Random Configuration* ...
- *Initial Temperature* is determined by applying n(nodes) random changes and saving the costs of each change. T is then $20 * standardDeviation(costs)$.
- *Exit Criterion* is the condition, when the simulated annealing should stop. For each temperature, the number of applied changes and the number of accepted changes is counted. When less then 12% of the changes are accepted, the algorithm stops.
- *Update Temperature* decreases T by a factor tu, which depends on the acceptance ratio as well:

acceptance ratio (ar)	temperature factor (tu)
> 96%	0.5
96 .. 80%	0.9
80 .. 15%	0.95
< 15%	0.8

- *Inner Loop Criterion* determines, how many changes are tested for the same temperature. Each change usually moves one node in the ordering of constraint-equations. The larger the number of nodes becomes, the more often each node should be moved, so the number of iterations should depend on the node count. Further more, there is a quality factor $\in [1..10]$ for the algorithm, which can be passed via the third program argument. The formula $n_{inner} = \left\lceil quality * n_{nodes}^{4/3} \right\rceil$ is known to yield a result, thats quality belongs to the given quality.

File	Number of Nodes	cost fkt of ASAP	cost fkt of ALAP	cost fkt of SA/SDC	Quality factor of SA	Number of Iterations	Runtime / s
ADPCMn-decode-271-381	27	64.8	56.0	31.9	1	20494	29.39
				30.5	5	82216	113.38
				30.5	10	144181	185.55
ADPCMn-decode-425-472	12	23.8	23.8	34.2	1	85	0.11
				21.8	5	7591	6.37
				21.8	10	11001	9.13
ADPCMn-decode-524-553	7	25.4	26.4	25.4	1	15	0.02
				25.4	5	68	0.07
				25.4	10	135	0.13
ADPCMn-decode-559-599	9	26.1	27.2	28.2	1	20	0.03
				25.1	5	4137	3.26
				28.2	10	377	0.35
ADPCMn-decode-631-729	23	44.8	40.0	33.3	1	5017	5.81
				24.3	5	13121	14.65
				22.9	10	108076	120.56
ADPCMn-decode-771-791	5	13.5	13.5	22.5	1	10	0.01
				22.5	5	44	0.04
				22.5	10	87	0.08
ADPCMn-decode-803-832	8	18.8	18.8	20.2	1	17	0.02
				20.2	5	81	0.08
				20.2	10	161	0.16
AESrkgcyclic	24	24.4	23.4	37.4	1	421	0.61
				32.4	5	13881	18.84
				30.4	10	28414	38.14
BLAKE256Digest-processBlock-160-230	21	57.4	58.4	32.4	1	10905	12.11
				22.4	5	58291	64.11
				31.4	10	175161	194.06
BLAKE256Digest-processBlock-189-1577	308	414.9	128.7	110.9	1	6244	241.63
				97.9	5	31204	1236.87
ContrastFilter-filter-13-252	47	72.0	67.7	50.8	1	4251	9.49
				37.7	5	24622	54.00
				33.2	10	101821	218.61
ECOH256Digest-AES2RoundsAll-2-666	179	262.3	174.4	58.1	1	175567	2733.60

The table above compares the results of simple ASAP / ALAP-Schedules with the results of the implemented simulated annealing algorithm.

5 Conclusion