UNIVERSITY OF INFORMATION TECHNOLOGY
FACULTY OF COMPUTER SCIENCE

SOLVING KNAPSACK PROBLEMS USING GOOGLE OR TOOLS

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Class: CS106.O21

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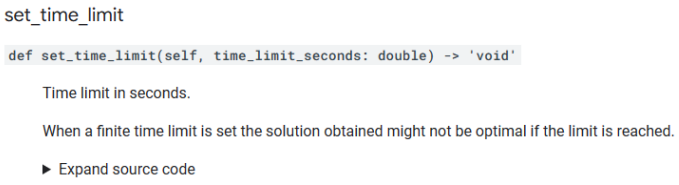
1. Experiment set-up

To set up the experiments, I first install the or-tools module and clone the directory containing the test-case set for the experiments. I follow the instructions from the homepage to implement a solver for Knapsack problems. Additionally, I need to retrieve all files from the repository and read and convert data from them. However, there are too many files in the repository, so for each group, I will take all different sizes and for each size, I will take 10 files (in both the R01000 and R10000 directories). In total, I have 13x8x10 files as test cases for this problem. I will set the time limit to 180 seconds (equivalent to 3 minutes). If the algorithm's solution time touches or exceeds 180 seconds, it will be considered non-optimal according to the reference included in Google OR-Tools.


set_time_limit

```
def set_time_limit(self, time_limit_seconds: double) -> 'void'
```

Time limit in seconds.

When a finite time limit is set the solution obtained might not be optimal if the limit is reached.

▶ Expand source code

In this experiment, I will have 3 files:

- **solver.py**: used to clone data and run random test cases.
- **random_file_result.py**: used to select 8 random result files in each group for easy statistics (1040 testcases will create almost 20 pages table).
- **check_optimal_of_test_group.py**: used to evaluate the optimality rate of the result files for each test case group.

2. Statistics and Evaluation

2.1. Statistics

I have randomly selected 8 files from each test group to make the statistical analysis lighter.

- **Test case**: the path of file test case.
- **Time**: duration of the algorithm's execution in seconds.
- **Value**: total value of optimal packed items.
- **Weight**: total weight of optimal packed items.
- **Optimal**: True, if it is an optimal solution. False, if is a non-optimal solution.

Test case	Time	Value	Weight	Optimal
00Uncorrelated \n00100 \R01000 \s025.kp	0.000	37308	24402	True
00Uncorrelated \n00100 \R10000 \s056.kp	0.000	358851	243958	True
00Uncorrelated \n00050 \R01000 \s083.kp	0.000	19444	10766	True
00Uncorrelated \n00050 \R10000 \s091.kp	0.000	213998	135467	True
00Uncorrelated \n05000 \R01000 \s060.kp	0.000	2006371	1250925	True
00Uncorrelated \n05000 \R10000 \s090.kp	0.000	20368880	12412821	True
00Uncorrelated \n02000 \R01000 \s020.kp	0.000	804706	498206	True
00Uncorrelated \n02000 \R10000 \s098.kp	0.000	8056247	5048898	True

Table 2.1. Result statistics

Test case	Time	Value	Weight	Optimal
01WeaklyCorrelated \n00200 \R01000 \s008.kp	0.000	54285	48557	True
01WeaklyCorrelated \n00200 \R10000 \s040.kp	0.000	517543	475328	True
01WeaklyCorrelated \n00500 \R01000 \s005.kp	0.000	135595	123199	True
01WeaklyCorrelated \n00500 \R10000 \s063.kp	0.000	1328056	1201302	True
01WeaklyCorrelated \n10000 \R01000 \s049.kp	0.000	2733312	2476684	True
01WeaklyCorrelated \n10000 \R10000 \s089.kp	0.033	27313400	24729920	True
01WeaklyCorrelated \n05000 \R01000 \s007.kp	0.033	1356859	1225891	True
01WeaklyCorrelated \n05000 \R10000 \s007.kp	0.101	13551437	12247961	True
02StronglyCorrelated \n00100 \R01000 \s083.kp	180.009	30043	23043	False
02StronglyCorrelated \n00100 \R10000 \s041.kp	0.000	320567	251567	True
02StronglyCorrelated \n00050 \R01000 \s050.kp	0.050	17552	14252	True
02StronglyCorrelated \n00050 \R10000 \s093.kp	0.116	159406	124406	True
02StronglyCorrelated \n00200 \R01000 \s010.kp	180.064	63975	50175	False
02StronglyCorrelated \n00200 \R10000 \s053.kp	0.015	624354	486354	True
02StronglyCorrelated \n01000 \R01000 \s004.kp	180.0247	321670	251170	False
02StronglyCorrelated \n01000 \R10000 \s067.kp	180.063	3225196	2525196	False
03InverseStronglyCorrelated\n01000\R01000\s042.kp	180.077	271495	303495	False
03InverseStronglyCorrelated\n01000\R10000\s009.kp	180.062	2575844	2882844	False
03InverseStronglyCorrelated\n00200\R01000\s098.kp	180.003	53627	59927	False
03InverseStronglyCorrelated\n00200\R10000\s077.kp	180.044	539681	602681	False
03InverseStronglyCorrelated\n10000\R01000\s038.kp	179.771	2655160	2969260	True
03InverseStronglyCorrelated\n10000\R10000\s052.kp	179.812	26423578	29572578	True
03InverseStronglyCorrelated\n00100\R01000\s028.kp	0.000	24327	27327	True
03InverseStronglyCorrelated\n00100\R10000\s050.kp	180.017	263771	295771	False
04AlmostStronglyCorrelated\n00500\R01000\s000.kp	180.008	162154	127278	False
04AlmostStronglyCorrelated\n00500\R10000\s024.kp	102.476	162443	127434	True
04AlmostStronglyCorrelated\n01000\R01000\s012.kp	180.030	319793	249677	False
04AlmostStronglyCorrelated\n01000\R10000\s004.kp	180.023	3215320	2509834	False
04AlmostStronglyCorrelated\n02000\R01000\s047.kp	179.984	636576	496211	True
04AlmostStronglyCorrelated\n02000\R10000\s050.kp	180.000	6406444	5006851	False
04AlmostStronglyCorrelated\n10000\R01000\s045.kp	179.815	3186652	2483759	True
04AlmostStronglyCorrelated\n10000\R10000\s055.kp	179.558	31805534	24769463	True
05SubsetSum\n00050\R01000\s038.kp	0.000	11243	11243	True
05SubsetSum\n00050\R10000\s080.kp	0.000	116230	116230	True
05SubsetSum\n00200\R01000\s044.kp	0.000	47076	47076	True
05SubsetSum\n00200\R10000\s082.kp	0.016	511700	511700	True
05SubsetSum\n01000\R01000\s046.kp	0.000	245262	245262	True
05SubsetSum\n01000\R10000\s086.kp	0.000	2480357	2480357	True
05SubsetSum\n00500\R01000\s067.kp	0.000	123918	123918	True
05SubsetSum\n00500\R10000\s004.kp	0.000	1281236	1281236	True
06UncorrelatedWithSimilarWeights\n10000\R01000\s065.kp	179.555	3754377	495246320	True
06UncorrelatedWithSimilarWeights\n10000\R10000\s020.kp	179.629	3738452	495245745	True
06UncorrelatedWithSimilarWeights\n05000\R01000\s065.kp	187.674	1883210	247625944	False
06UncorrelatedWithSimilarWeights\n05000\R10000\s038.kp	179.982	1871304	247624255	True
06UncorrelatedWithSimilarWeights\n00050\R01000\s051.kp	0.039	20230	2401529	True
06UncorrelatedWithSimilarWeights\n00050\R10000\s026.kp	0.031	19538	2401027	True
06UncorrelatedWithSimilarWeights\n01000\R01000\s073.kp	0.057	363676	49523817	True
06UncorrelatedWithSimilarWeights\n01000\R10000\s048.kp	0.032	377396	49526356	True

Table 2.1. Result statistics

Test case	Time	Value	Weight	Optimal
07SpannerUncorrelated\n00050\R01000\s009.kp	0.172	7606	4290	True
07SpannerUncorrelated\n00050\R10000\s042.kp	0.000	70970	31312	True
07SpannerUncorrelated\n01000\R01000\s024.kp	180.026	251228	148930	False
07SpannerUncorrelated\n01000\R10000\s040.kp	180.067	2103711	383497	False
07SpannerUncorrelated\n00200\R01000\s056.kp	180.074	45310	23977	False
07SpannerUncorrelated\n00200\R10000\s036.kp	180.093	485209	475118	False
07SpannerUncorrelated\n00500\R01000\s069.kp	180.070	90678	45605	False
07SpannerUncorrelated\n00500\R10000\s001.kp	181.920	1193638	636829	False
08SpannerWeaklyCorrelated\n00500\R01000\s093.kp	180.058	113776	90802	False
08SpannerWeaklyCorrelated\n00500\R10000\s043.kp	180.061	686490	465474	False
08SpannerWeaklyCorrelated\n00050\R01000\s080.kp	0.068	16907	4821	True
08SpannerWeaklyCorrelated\n00050\R10000\s012.kp	0.975	93198	55937	True
08SpannerWeaklyCorrelated\n01000\R01000\s084.kp	180.044	19009	202182	False
08SpannerWeaklyCorrelated\n01000\R10000\s004.kp	180.015	934102	415588	False
08SpannerWeaklyCorrelated\n00100\R01000\s054.kp	180.080	26114	13716	False
08SpannerWeaklyCorrelated\n00100\R10000\s008.kp	180.066	214155	141794	False
09SpannerStronglyCorrelated\n00200\R01000\s043.kp	180.106	95134	17334	False
09SpannerStronglyCorrelated\n00200\R10000\s021.kp	182.663	967577	209577	False
09SpannerStronglyCorrelated\n00050\R01000\s093.kp	3.433	26049	8949	True
09SpannerStronglyCorrelated\n00050\R10000\s021.kp	0.451	255000	54000	True
09SpannerStronglyCorrelated\n05000\R01000\s060.kp	178.903	2227440	546840	True
09SpannerStronglyCorrelated\n05000\R10000\s053.kp	179.941	25165314	9371314	True
09SpannerStronglyCorrelated\n01000\R01000\s025.kp	179.456	518768	161068	True
09SpannerStronglyCorrelated\n01000\R10000\s019.kp	180.046	4633302	1771302	False
10MultipleStronglyCorrelated\n00500\R01000\s011.kp	180.065	204150	126750	False
10MultipleStronglyCorrelated\n00500\R10000\s046.kp	180.042	2026892	1256892	False
10MultipleStronglyCorrelated\n00200\R01000\s003.kp	0.000	81150	50850	True
10MultipleStronglyCorrelated\n00200\R10000\s049.kp	0.016	789936	480936	True
10MultipleStronglyCorrelated\n10000\R01000\s090.kp	179.496	4038963	2490563	True
10MultipleStronglyCorrelated\n10000\R10000\s015.kp	179.529	40213072	24774072	True
10MultipleStronglyCorrelated\n05000\R01000\s018.kp	179.885	2007242	1234742	True
10MultipleStronglyCorrelated\n05000\R10000\s034.kp	179.907	20062188	12311188	True
11ProfitCeiling\n10000\R01000\s043.kp	179.740	2479953	2480848	True
11ProfitCeiling\n10000\R10000\s017.kp	179.688	24677049	24678021	True
11ProfitCeiling\n05000\R01000\s071.kp	179.948	1241166	1241643	True
11ProfitCeiling\n05000\R10000\s043.kp	179.961	12400401	12400879	True
11ProfitCeiling\n00500\R01000\s090.kp	95.156	123042	123094	True
11ProfitCeiling\n00500\R10000\s052.kp	180.070	1239027	1239065	False
11ProfitCeiling\n02000\R01000\s063.kp	180.034	494628	494827	False
11ProfitCeiling\n02000\R10000\s076.kp	180.005	4987770	4987974	False
12Circle\n05000\R01000\s099.kp	179.957	25914062	1229848	True
12Circle\n05000\R10000\s050.kp	179.948	824068203	12361648	True
12Circle\n00200\R01000\s023.kp	182.364	1041346	49421	False
12Circle\n00200\R10000\s018.kp	187.784	33432774	501517	False
12Circle\n02000\R01000\s088.kp	180.040	10643367	505121	False
12Circle\n00050\R01000\s019.kp	0.000	242526	11510	True
12Circle\n00050\R10000\s047.kp	9.228	8294913	124430	True

Table 2.1. Result statistics

2.2 Evaluation

Test Group	Files	Optimal Files	Rate
00Uncorrelated	80	80	1.0
01WeaklyCorrelated	80	80	1.0
02StronglyCorrelated	80	42	0.525
03InverseStronglyCorrelated	80	45	0.5625
04AlmostStronglyCorrelated	80	53	0.6625
05SubsetSum	80	80	1.0
06UncorrelatedWithSimilarWeights	80	62	0.775
07SpannerUncorrelated	80	36	0.45
08SpannerWeaklyCorrelated	80	35	0.4375
09SpannerStronglyCorrelated	80	38	0.475
10MultipleStronglyCorrelated	80	54	0.675
11ProfitCeiling	80	50	0.625
12Circle	80	44	0.55

Table 2.2. Ratio of result files optimal

- **00Uncorrelated, 01WeaklyCorrelated, and 05SubsetSum** have an optimality ratio of **1.0**, indicating that all result files were optimal. This suggests that these test groups were the **easiest** to solve optimally.

- **04AlmostStronglyCorrelated**, **06UncorrelatedWithSimilarWeights**, **10MultipleStronglyCorrelated** and **11ProfitCeiling** have relatively high optimality ratios of **0.6625**, **0.775**, **0.675** and **0.625**, respectively, which implies that a significant majority of the test cases were solved optimally, making them **moderately difficult**.

- **02StronglyCorrelated**, **03InverseStronglyCorrelated** and **12Circle** show lower optimality ratios of **0.525**, **0.5625**, and **0.55** respectively. These groups present a **greater challenge** compared to the others, with fewer optimal results.

- **07SpannerUncorrelated**, **08SpannerWeaklyCorrelated**, and **09SpannerStronglyCorrelated** have the lowest optimality ratios of **0.45**, **0.4375**, and **0.475**, respectively. These groups were **the most difficult**, with less than half of the result files being optimal.