Threads Analysis

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Section 1: Methodology

In a program where numerous threads are used to process information, certain quantities of threads are more optimal than others. In this specific project, threads are used to concurrently compute the number of support points of various plane equations. The goal is to determine the optimal number of threads that should be simultaneously calculating the number of support points of the randomly generated planes.

To do so, I created a function called *TestTime*. An outer loop runs i times, with each iteration testing i threads. For each thread, the main pipeline is run 200 times, with the difference in the system time calculated before and after the 200 executions. The elapsed time is divided by 200 to determine the average running time for each quantity of thread over 200 executions.

To facilitate the graphing process, the results of the runtime tests are written to a .XYZ file. The first column represents the number of threads, and the second column represents the average runtime for that number of threads. This file can be imported into Excel to create a graphic that represents the runtime versus the number of threads for different configurations. The code used to execute the tests is shown in *Figure 1*.

The program was run twice, once running up to 35 threads and once up to 250 threads. This allows for more precise graphic visualization of the first 35 threads, whilst also illustrating the general trend as the number of threads reach significantly larger numbers.

```
func TestTime(points []Point3D, bestSupport *Plane3DwSupport, confidence float64,
percentageOfPointsOnPlane float64, eps float64, numIterations int) {
    file, err := os.Create("ComputationTimesLargerSample.XYZ")
    ErrorCheck(err)
    defer file.Close()
    file.WriteString("Threads\tTime\n")

    for i := 1 ; i <= 250; i++ {
        start := time.Now()
        for j := 0 ; j < 200 ; j++ {
            Pipeline(i, points, bestSupport, confidence, percentageOfPointsOnPlane,
eps, numIterations)
        }
        end := time.Now()
        elapsed := end.Sub(start)
        _, err := file.WriteString(fmt.Sprintf("%d\t%f\n", i,
float64(elapsed.Milliseconds())/200.0))
        ErrorCheck(err)
```

```
        fmt.Printf("Average elapsed time with %d threads: %v\n", i, elapsed/200)
    }
    err = file.Sync()
    ErrorCheck(err)
}
```

Figure 1: The Code Used to Effectuate the Tests

Section 2: Results

The most insightful of the two executions is the runtime versus the number of threads up to 35 threads. The graph clearly illustrates a steep drop in runtime with the addition of the first few threads, and then a steady decline in runtime until about 8 threads. After 8 threads, the graph levels out without any significant improvements. Therefore, the **optimal number of threads appears to be roughly eight threads,** after which no improvements are noted.

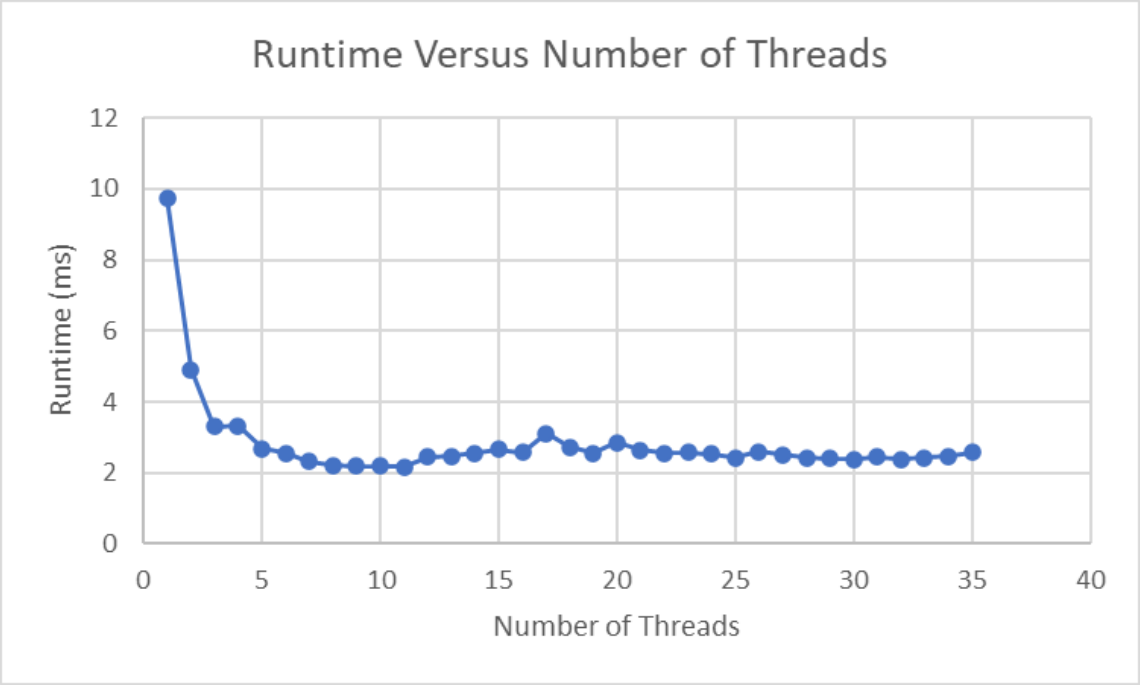

Figure 2: Runtime Versus Number of Threads for First 35 Threads

The trend continues when observing 250 threads. After a sharp decline in runtime initially, the runtime levels out without any benefits to having more than eight threads. If anything the system appears to slightly slow down with an abundance of unnecessary threads.

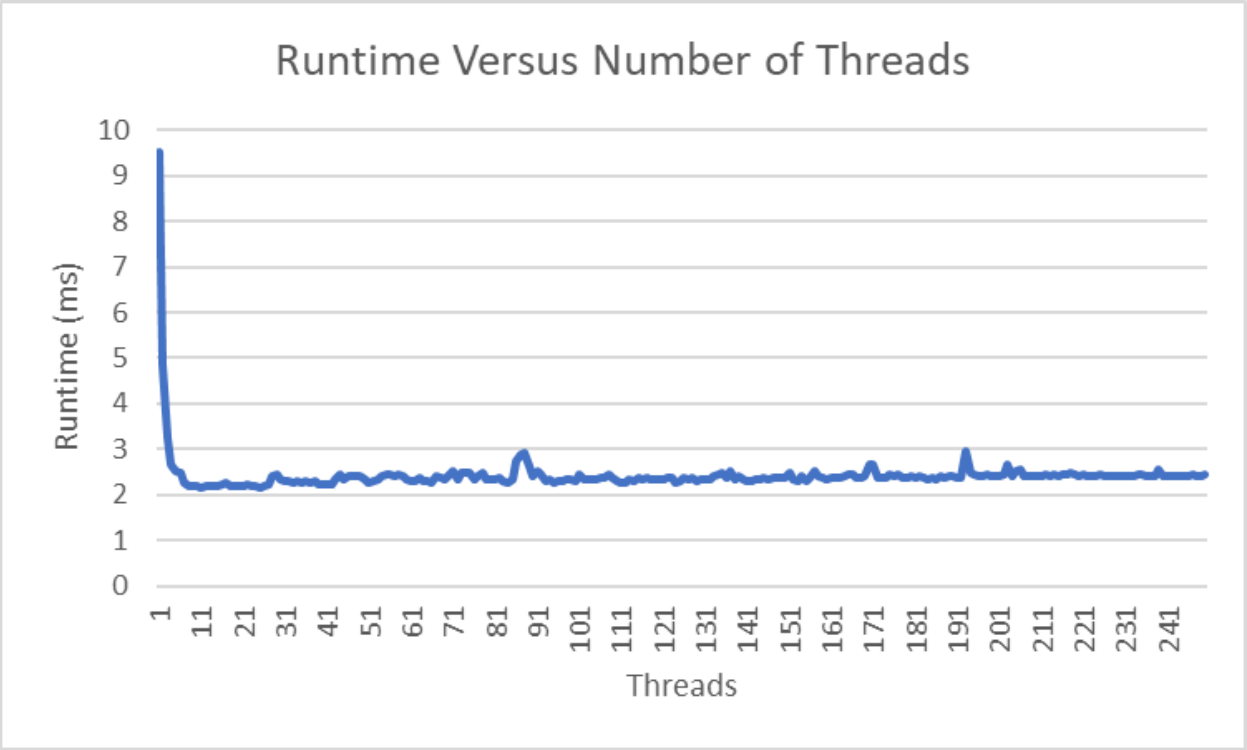

Figure 3: Runtime Versus Number of Threads for First 250 Threads

Section 3: Raw Data

The following outputs are taken directly from the terminal, if interested. The graphic representations above are much easier to interpret, however.

Terminal Output Testing up to 35 Threads:

```
brentpalmer@Brents-MacBook-Pro Project-2 % go run planeRANSAC.go "PointCloud1.XYZ" 0.99 0.5 0.5
Average elapsed time with 1 threads: 9.754539ms
Average elapsed time with 2 threads: 4.901433ms
Average elapsed time with 3 threads: 3.309784ms
Average elapsed time with 4 threads: 3.318146ms
Average elapsed time with 5 threads: 2.682341ms
Average elapsed time with 6 threads: 2.555169ms
Average elapsed time with 7 threads: 2.32658ms
Average elapsed time with 8 threads: 2.224343ms
Average elapsed time with 9 threads: 2.187074ms
Average elapsed time with 10 threads: 2.185709ms
Average elapsed time with 11 threads: 2.174658ms
Average elapsed time with 12 threads: 2.444627ms
```

Average elapsed time with 13 threads: 2.462001ms
Average elapsed time with 14 threads: 2.551776ms
Average elapsed time with 15 threads: 2.6722ms
Average elapsed time with 16 threads: 2.570411ms
Average elapsed time with 17 threads: 3.117773ms
Average elapsed time with 18 threads: 2.716979ms
Average elapsed time with 19 threads: 2.553856ms
Average elapsed time with 20 threads: 2.863716ms
Average elapsed time with 21 threads: 2.643653ms
Average elapsed time with 22 threads: 2.557991ms
Average elapsed time with 23 threads: 2.570358ms
Average elapsed time with 24 threads: 2.527719ms
Average elapsed time with 25 threads: 2.415779ms
Average elapsed time with 26 threads: 2.608815ms
Average elapsed time with 27 threads: 2.511793ms
Average elapsed time with 28 threads: 2.437994ms
Average elapsed time with 29 threads: 2.414223ms
Average elapsed time with 30 threads: 2.387717ms
Average elapsed time with 31 threads: 2.453041ms
Average elapsed time with 32 threads: 2.385105ms
Average elapsed time with 33 threads: 2.432083ms
Average elapsed time with 34 threads: 2.479665ms
Average elapsed time with 35 threads: 2.566797ms

Terminal Output Testing up to 250 Threads:

brentpalmer@Brents-MacBook-Pro Project-2 % go run planeRANSAC.go "PointCloud1.XYZ" 0.99 0.5 0.5
Average elapsed time with 1 threads: 9.515252ms
Average elapsed time with 2 threads: 4.857793ms
Average elapsed time with 3 threads: 3.238191ms
Average elapsed time with 4 threads: 2.666896ms
Average elapsed time with 5 threads: 2.515918ms
Average elapsed time with 6 threads: 2.476259ms
Average elapsed time with 7 threads: 2.288588ms
Average elapsed time with 8 threads: 2.196999ms
Average elapsed time with 9 threads: 2.191879ms
Average elapsed time with 10 threads: 2.213941ms
Average elapsed time with 11 threads: 2.175577ms
Average elapsed time with 12 threads: 2.193168ms
Average elapsed time with 13 threads: 2.196943ms
Average elapsed time with 14 threads: 2.199203ms
Average elapsed time with 15 threads: 2.19582ms
Average elapsed time with 16 threads: 2.232105ms
Average elapsed time with 17 threads: 2.27589ms
Average elapsed time with 18 threads: 2.191623ms
Average elapsed time with 19 threads: 2.195537ms
Average elapsed time with 20 threads: 2.202238ms
Average elapsed time with 21 threads: 2.192591ms
Average elapsed time with 22 threads: 2.220413ms
Average elapsed time with 23 threads: 2.191696ms
Average elapsed time with 24 threads: 2.19957ms
Average elapsed time with 25 threads: 2.142125ms
Average elapsed time with 26 threads: 2.19468ms
Average elapsed time with 27 threads: 2.223747ms
Average elapsed time with 28 threads: 2.40325ms
Average elapsed time with 29 threads: 2.458743ms
Average elapsed time with 30 threads: 2.331001ms

Average elapsed time with 31 threads: 2.30948ms
Average elapsed time with 32 threads: 2.291ms
Average elapsed time with 33 threads: 2.28355ms
Average elapsed time with 34 threads: 2.291133ms
Average elapsed time with 35 threads: 2.289436ms
Average elapsed time with 36 threads: 2.296829ms
Average elapsed time with 37 threads: 2.279998ms
Average elapsed time with 38 threads: 2.292137ms
Average elapsed time with 39 threads: 2.222234ms
Average elapsed time with 40 threads: 2.239835ms
Average elapsed time with 41 threads: 2.235572ms
Average elapsed time with 42 threads: 2.245581ms
Average elapsed time with 43 threads: 2.342551ms
Average elapsed time with 44 threads: 2.463165ms
Average elapsed time with 45 threads: 2.354361ms
Average elapsed time with 46 threads: 2.397588ms
Average elapsed time with 47 threads: 2.398601ms
Average elapsed time with 48 threads: 2.425811ms
Average elapsed time with 49 threads: 2.421009ms
Average elapsed time with 50 threads: 2.358699ms
Average elapsed time with 51 threads: 2.263848ms
Average elapsed time with 52 threads: 2.302591ms
Average elapsed time with 53 threads: 2.348142ms
Average elapsed time with 54 threads: 2.431271ms
Average elapsed time with 55 threads: 2.466641ms
Average elapsed time with 56 threads: 2.449185ms
Average elapsed time with 57 threads: 2.398772ms
Average elapsed time with 58 threads: 2.436487ms
Average elapsed time with 59 threads: 2.398471ms
Average elapsed time with 60 threads: 2.353412ms
Average elapsed time with 61 threads: 2.323227ms
Average elapsed time with 62 threads: 2.295648ms
Average elapsed time with 63 threads: 2.362676ms
Average elapsed time with 64 threads: 2.317889ms
Average elapsed time with 65 threads: 2.295869ms
Average elapsed time with 66 threads: 2.257378ms
Average elapsed time with 67 threads: 2.41088ms
Average elapsed time with 68 threads: 2.37106ms
Average elapsed time with 69 threads: 2.341454ms
Average elapsed time with 70 threads: 2.43746ms
Average elapsed time with 71 threads: 2.505198ms
Average elapsed time with 72 threads: 2.330975ms
Average elapsed time with 73 threads: 2.472123ms
Average elapsed time with 74 threads: 2.477061ms
Average elapsed time with 75 threads: 2.49423ms
Average elapsed time with 76 threads: 2.334023ms
Average elapsed time with 77 threads: 2.431349ms
Average elapsed time with 78 threads: 2.500575ms
Average elapsed time with 79 threads: 2.355667ms
Average elapsed time with 80 threads: 2.33105ms
Average elapsed time with 81 threads: 2.348606ms
Average elapsed time with 82 threads: 2.379722ms
Average elapsed time with 83 threads: 2.31136ms
Average elapsed time with 84 threads: 2.270515ms
Average elapsed time with 85 threads: 2.341955ms
Average elapsed time with 86 threads: 2.738353ms
Average elapsed time with 87 threads: 2.887761ms

Average elapsed time with 88 threads: 2.934582ms
Average elapsed time with 89 threads: 2.617543ms
Average elapsed time with 90 threads: 2.42764ms
Average elapsed time with 91 threads: 2.529714ms
Average elapsed time with 92 threads: 2.441803ms
Average elapsed time with 93 threads: 2.323651ms
Average elapsed time with 94 threads: 2.34184ms
Average elapsed time with 95 threads: 2.263339ms
Average elapsed time with 96 threads: 2.315073ms
Average elapsed time with 97 threads: 2.291447ms
Average elapsed time with 98 threads: 2.329369ms
Average elapsed time with 99 threads: 2.333482ms
Average elapsed time with 100 threads: 2.316478ms
Average elapsed time with 101 threads: 2.437406ms
Average elapsed time with 102 threads: 2.332353ms
Average elapsed time with 103 threads: 2.34637ms
Average elapsed time with 104 threads: 2.34093ms
Average elapsed time with 105 threads: 2.353108ms
Average elapsed time with 106 threads: 2.369186ms
Average elapsed time with 107 threads: 2.372984ms
Average elapsed time with 108 threads: 2.444892ms
Average elapsed time with 109 threads: 2.371388ms
Average elapsed time with 110 threads: 2.318703ms
Average elapsed time with 111 threads: 2.282648ms
Average elapsed time with 112 threads: 2.279472ms
Average elapsed time with 113 threads: 2.356659ms
Average elapsed time with 114 threads: 2.305304ms
Average elapsed time with 115 threads: 2.364692ms
Average elapsed time with 116 threads: 2.347621ms
Average elapsed time with 117 threads: 2.368544ms
Average elapsed time with 118 threads: 2.355803ms
Average elapsed time with 119 threads: 2.358193ms
Average elapsed time with 120 threads: 2.342598ms
Average elapsed time with 121 threads: 2.341695ms
Average elapsed time with 122 threads: 2.371305ms
Average elapsed time with 123 threads: 2.37168ms
Average elapsed time with 124 threads: 2.274943ms
Average elapsed time with 125 threads: 2.295136ms
Average elapsed time with 126 threads: 2.393133ms
Average elapsed time with 127 threads: 2.351593ms
Average elapsed time with 128 threads: 2.378509ms
Average elapsed time with 129 threads: 2.317798ms
Average elapsed time with 130 threads: 2.357404ms
Average elapsed time with 131 threads: 2.357048ms
Average elapsed time with 132 threads: 2.357209ms
Average elapsed time with 133 threads: 2.422645ms
Average elapsed time with 134 threads: 2.454657ms
Average elapsed time with 135 threads: 2.498512ms
Average elapsed time with 136 threads: 2.386719ms
Average elapsed time with 137 threads: 2.5181ms
Average elapsed time with 138 threads: 2.325183ms
Average elapsed time with 139 threads: 2.434249ms
Average elapsed time with 140 threads: 2.358794ms
Average elapsed time with 141 threads: 2.2905ms
Average elapsed time with 142 threads: 2.290781ms
Average elapsed time with 143 threads: 2.333895ms
Average elapsed time with 144 threads: 2.356915ms

Average elapsed time with 145 threads: 2.366648ms
Average elapsed time with 146 threads: 2.359589ms
Average elapsed time with 147 threads: 2.36447ms
Average elapsed time with 148 threads: 2.376489ms
Average elapsed time with 149 threads: 2.364219ms
Average elapsed time with 150 threads: 2.394795ms
Average elapsed time with 151 threads: 2.496045ms
Average elapsed time with 152 threads: 2.356453ms
Average elapsed time with 153 threads: 2.302857ms
Average elapsed time with 154 threads: 2.415954ms
Average elapsed time with 155 threads: 2.312132ms
Average elapsed time with 156 threads: 2.372574ms
Average elapsed time with 157 threads: 2.535475ms
Average elapsed time with 158 threads: 2.396694ms
Average elapsed time with 159 threads: 2.363856ms
Average elapsed time with 160 threads: 2.354616ms
Average elapsed time with 161 threads: 2.369789ms
Average elapsed time with 162 threads: 2.382901ms
Average elapsed time with 163 threads: 2.378656ms
Average elapsed time with 164 threads: 2.430303ms
Average elapsed time with 165 threads: 2.454769ms
Average elapsed time with 166 threads: 2.435041ms
Average elapsed time with 167 threads: 2.394865ms
Average elapsed time with 168 threads: 2.38561ms
Average elapsed time with 169 threads: 2.423362ms
Average elapsed time with 170 threads: 2.680234ms
Average elapsed time with 171 threads: 2.680775ms
Average elapsed time with 172 threads: 2.39073ms
Average elapsed time with 173 threads: 2.38862ms
Average elapsed time with 174 threads: 2.385266ms
Average elapsed time with 175 threads: 2.449463ms
Average elapsed time with 176 threads: 2.417339ms
Average elapsed time with 177 threads: 2.464999ms
Average elapsed time with 178 threads: 2.385131ms
Average elapsed time with 179 threads: 2.387321ms
Average elapsed time with 180 threads: 2.402565ms
Average elapsed time with 181 threads: 2.387659ms
Average elapsed time with 182 threads: 2.396742ms
Average elapsed time with 183 threads: 2.367214ms
Average elapsed time with 184 threads: 2.346302ms
Average elapsed time with 185 threads: 2.368924ms
Average elapsed time with 186 threads: 2.348563ms
Average elapsed time with 187 threads: 2.404005ms
Average elapsed time with 188 threads: 2.391306ms
Average elapsed time with 189 threads: 2.398325ms
Average elapsed time with 190 threads: 2.409716ms
Average elapsed time with 191 threads: 2.382721ms
Average elapsed time with 192 threads: 2.394746ms
Average elapsed time with 193 threads: 2.974053ms
Average elapsed time with 194 threads: 2.497258ms
Average elapsed time with 195 threads: 2.450458ms
Average elapsed time with 196 threads: 2.395087ms
Average elapsed time with 197 threads: 2.404135ms
Average elapsed time with 198 threads: 2.46359ms
Average elapsed time with 199 threads: 2.399257ms
Average elapsed time with 200 threads: 2.409902ms
Average elapsed time with 201 threads: 2.402333ms

Average elapsed time with 202 threads: 2.453311ms
Average elapsed time with 203 threads: 2.659531ms
Average elapsed time with 204 threads: 2.401289ms
Average elapsed time with 205 threads: 2.515662ms
Average elapsed time with 206 threads: 2.569796ms
Average elapsed time with 207 threads: 2.430827ms
Average elapsed time with 208 threads: 2.412975ms
Average elapsed time with 209 threads: 2.419389ms
Average elapsed time with 210 threads: 2.411662ms
Average elapsed time with 211 threads: 2.412297ms
Average elapsed time with 212 threads: 2.442631ms
Average elapsed time with 213 threads: 2.397445ms
Average elapsed time with 214 threads: 2.457727ms
Average elapsed time with 215 threads: 2.40417ms
Average elapsed time with 216 threads: 2.464155ms
Average elapsed time with 217 threads: 2.466444ms
Average elapsed time with 218 threads: 2.488048ms
Average elapsed time with 219 threads: 2.448124ms
Average elapsed time with 220 threads: 2.410484ms
Average elapsed time with 221 threads: 2.456216ms
Average elapsed time with 222 threads: 2.400781ms
Average elapsed time with 223 threads: 2.415412ms
Average elapsed time with 224 threads: 2.421305ms
Average elapsed time with 225 threads: 2.459255ms
Average elapsed time with 226 threads: 2.430078ms
Average elapsed time with 227 threads: 2.408491ms
Average elapsed time with 228 threads: 2.403367ms
Average elapsed time with 229 threads: 2.40776ms
Average elapsed time with 230 threads: 2.415923ms
Average elapsed time with 231 threads: 2.414653ms
Average elapsed time with 232 threads: 2.416137ms
Average elapsed time with 233 threads: 2.414651ms
Average elapsed time with 234 threads: 2.441644ms
Average elapsed time with 235 threads: 2.455131ms
Average elapsed time with 236 threads: 2.403268ms
Average elapsed time with 237 threads: 2.428025ms
Average elapsed time with 238 threads: 2.414111ms
Average elapsed time with 239 threads: 2.55731ms
Average elapsed time with 240 threads: 2.404021ms
Average elapsed time with 241 threads: 2.411059ms
Average elapsed time with 242 threads: 2.410216ms
Average elapsed time with 243 threads: 2.407486ms
Average elapsed time with 244 threads: 2.418163ms
Average elapsed time with 245 threads: 2.41241ms
Average elapsed time with 246 threads: 2.428043ms
Average elapsed time with 247 threads: 2.440522ms
Average elapsed time with 248 threads: 2.409646ms
Average elapsed time with 249 threads: 2.42028ms
Average elapsed time with 250 threads: 2.454066ms