INSPIRE University Transportation Center, Led by Missouri S&T

Simulation Training And Control System for Bridge Inspection

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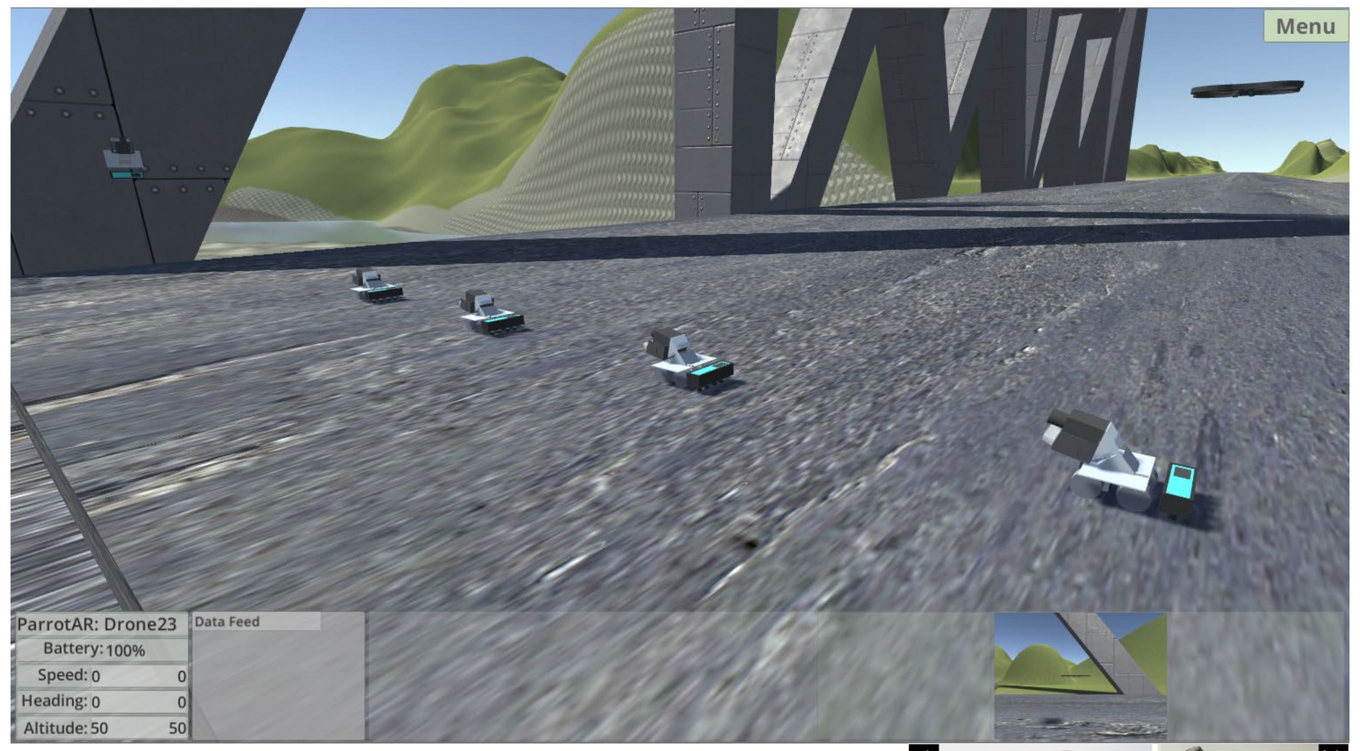
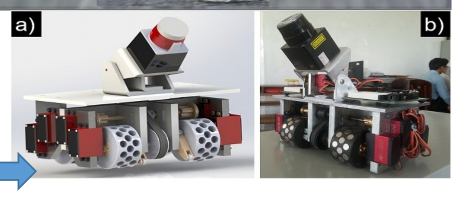
INTRODUCTION

The project goal is to develop a Training And Control System (STACS) for human operators to oversee a team of autonomous bridge inspection robots to safely, cheaply, and reliably inspect steel truss bridges. We have developed and iterated prototypes of this software, and are developing training exercises designed to teach human operators to work with the simulated robotic team to accomplish a bridge inspection task. Optimal routing for a team of climbing robots to inspect every member of the bridge is NP-Hard. We show that we can use genetic algorithms to produce near optimal routes in realistic time.

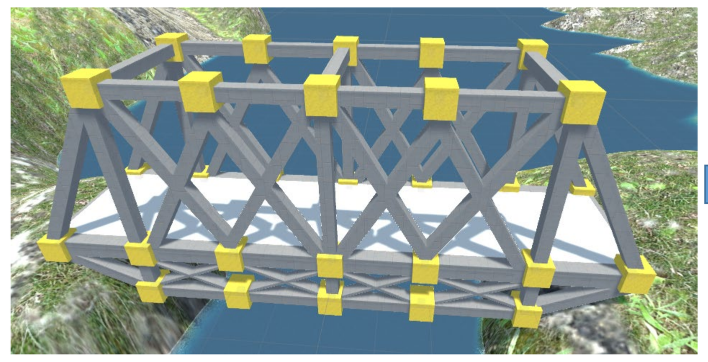


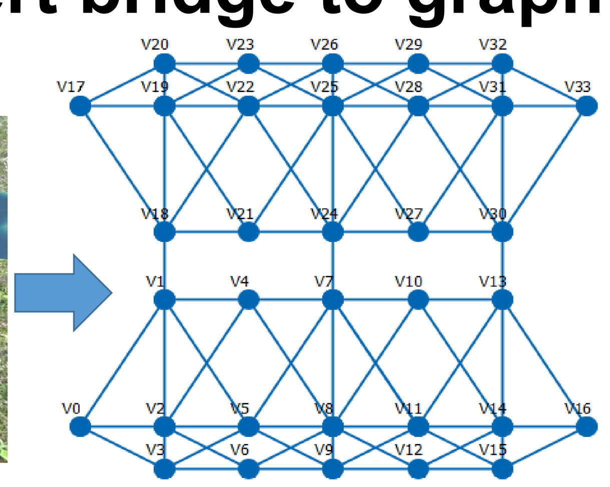


Screenshot from the STACS2 interface with 5 climbing robots and one UAV.

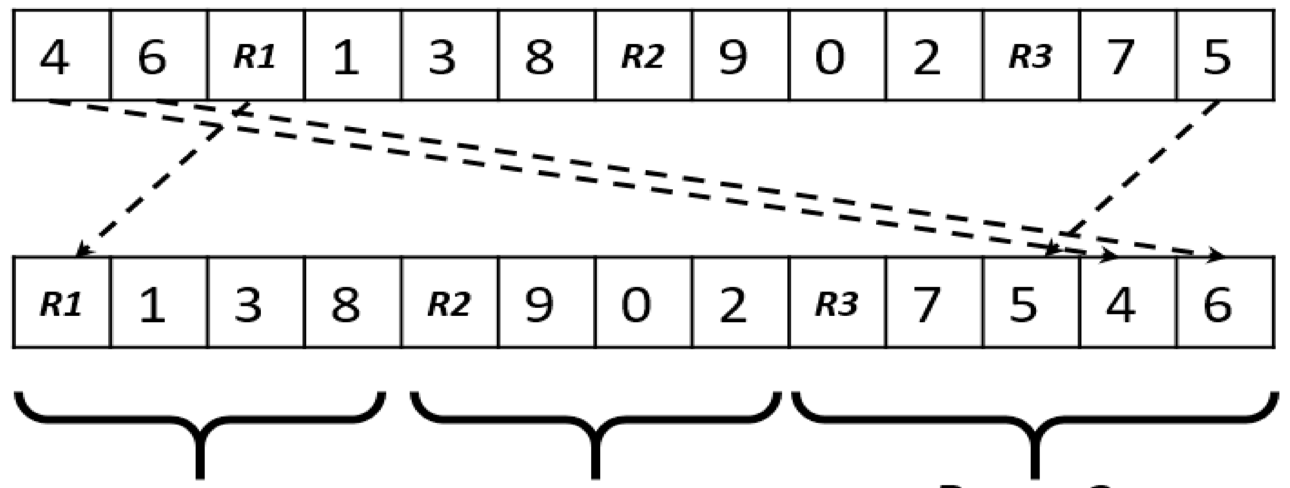
Dr. Hung La's climbing robot

METHODS – Convert bridge to graph





Run GA with encoding below and find route



RESULT 1

We can find routes within 2% of optimal on model bridge for one robot. Speedup with additional robots is close to linear

	1-CPP Optimal	1-CPP GA	2-CPP GA	5-CPP GA
Result	51,268	51,974	26,634	11,682
Speedup	-	-	1.951	4.449

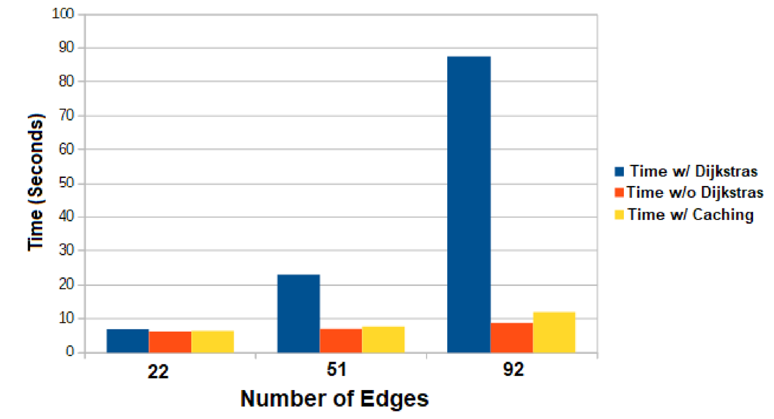
RESULT 2

We are within 7% of a theoretical lower bound in finding routes on benchmarks problems in the literature. Speedup is still close to linear! 5 robots take about 1/5 the time for inspecting a bridge

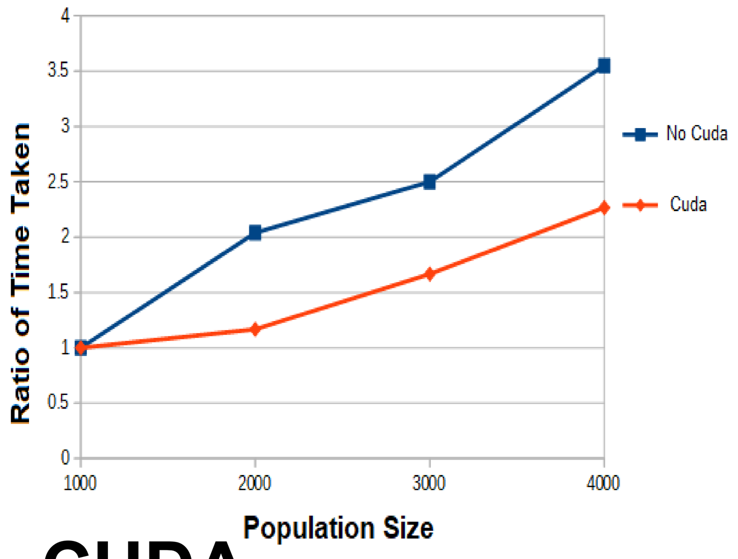
Problem	$\|V\|$	$\|E\|$	Lower Bound	Best $k=1$	Percent Above Lower Bound	Best $k=2$	Speedup $k=2$	Best $k=5$	Speedup $k=5$
gdb1	12	22	252	270	7.143 %	130	2.077	53	5.094
gdb2	12	26	291	298	2.405 %	146	2.041	63	4.73
gdb3	12	22	233	246	5.579 %	120	2.05	49	5.02
gdb9	27	51	219	236	7.763 %	119	1.983	53	4.453
gdb10	12	25	252	260	3.175 %	128	2.031	53	4.906
gdb11	22	45	356	374	5.056 %	192	1.948	77	4.857
gdb12	13	23	334	356	6.587 %	173	2.058	70	5.086
gdb17	8	28	84	89	5.952 %	44	2.023	19	4.684
gdb18	9	36	158	164	3.797 %	80	2.05	32	5.125
gdb19	8	11	45	47	4.444 %	23	2.043	10	4.7
val4	41	69	343	381	11.079 %	194	1.964	89	4.281
val5	34	65	367	401	9.264 %	219	1.831	105	3.819
val7	40	66	249	273	9.639 %	146	1.870	78	3.5
val8	30	63	347	386	11.239 %	202	1.911	88	4.386
val9	50	92	278	309	11.151 %	169	1.828	97	3.186
Averages	-	-	-	-	6.952%	-	1.981	-	4.522

RESULT 3

Caching intermediate computations speeds up time to find near optimal routing. We can get an order of magnitude improvement. Parallellizing the code to take advantage of the thousands of graphics cores in modern graphics cards also results in much faster runtimes and enables larger population sizes leading to improved solution quality as well as faster speeds



Caching

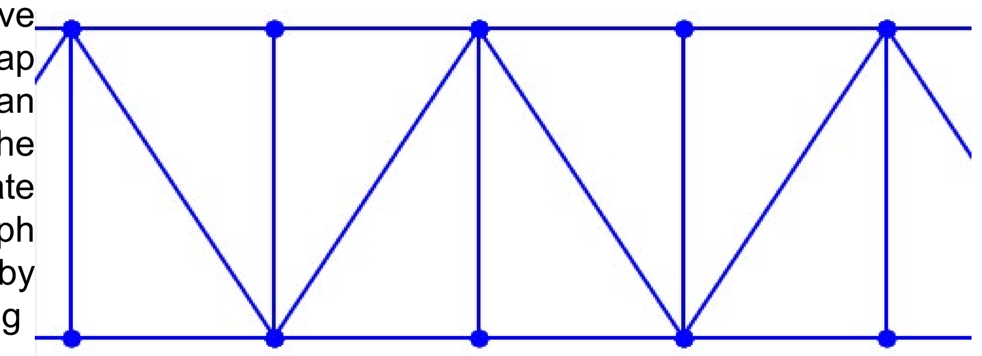


CUDA parallellization

CONCLUSIONS

We have developed version two of the STACS prototype with climbing robots and UAVs for eddy current based steel inspection by climbing robtos and visual camera based inspection by flying robots. We have shown that we can get linear speedup as we increase the size of the truss inspection robot team. Assuming a conservative inspection speed of 0.25 m/sec or .82 feet/sec, a team of 10 robots could inspect the 57,044 feet or nearly 11 miles of the roadbed truss of the Golden Gate bridge in less than 2.5 hours!

Software tools have been developed to map the truss structure of an existing bridge like the iconic Golden Gate bridge to the graph representation used by our optimizer for routing



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