Project Proposal

Project Title:	Optimizing In-Line Automotive Inspection with the Laser Radar
Group Members:	Kartik Sreenivasan
	Matthew Crepea
	Talha Sultan
	Eric Brandt

1. Brief description of the problem. If you'll be using real data, where will you find it and how much will you need?

The Nikon Laser Radar is a high accuracy, large volume, non-contact, 3D measurement device used in manufacturing that is gaining considerable adoption in the automotive industry for in-line car body inspection. Adoption within the industry has outpaced software capability to optimize measurement plans to ensure cycle times can meet assembly line time constraints.

Nikon Laser Radar

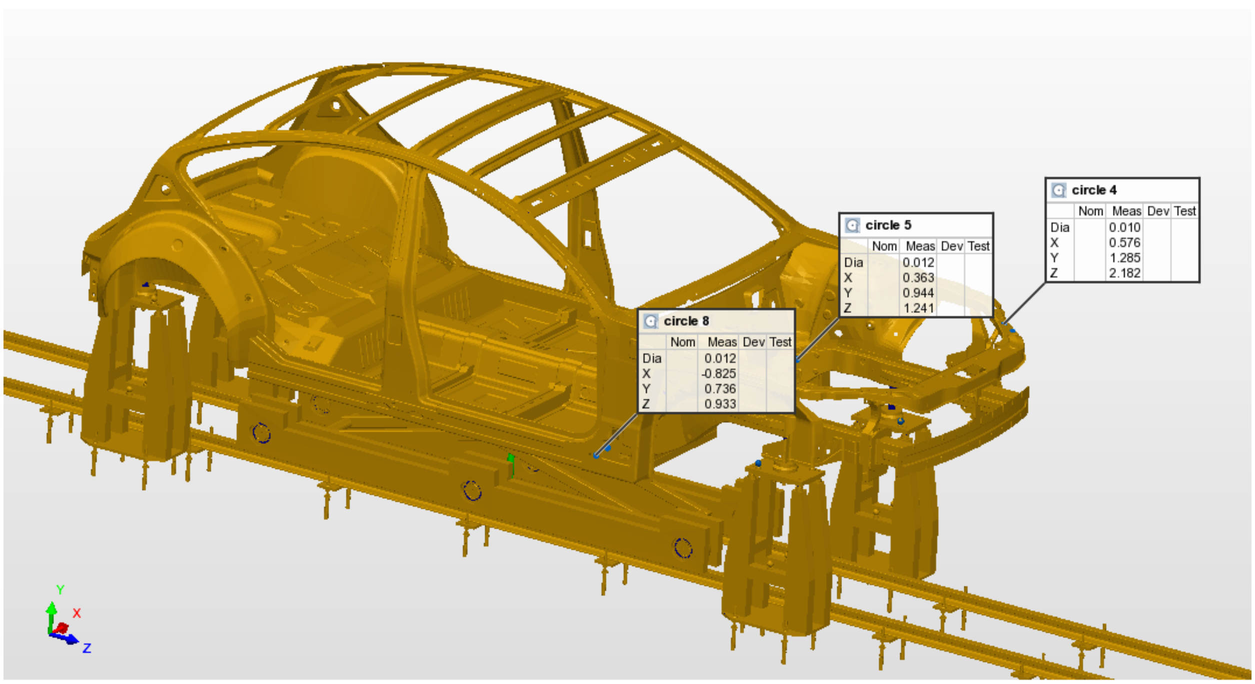
Automotive engineers routinely specify geometric features that must be inspected on a car body. Inspection involves measuring the 3D locations and dimensions of 200-300 holes, slots, studs, surfaces, etc relative to fixed locations on the car. The task of scanning each feature and extracting the geometry relative to a global 'car coordinate system' is already well handled by existing Nikon software.

The opportunity to optimize this scenario lies in several sub-problems:

1. Pointing the measuring laser of the device to each feature location requires moving a mirror in azimuth and elevation, both of which have known velocity and acceleration profiles and limits. The optimization task is: For a given fixed laser radar location relative to the car, find an ordering of a given list of features to be measured that minimizes total measurement time.

2. Each feature type that is measured (hole, slot, stud, etc) has certain line-of-sight geometry characteristics that affect the confidence in the accuracy of the final measurement. For example, stud features achieve best accuracy when the laser's line of sight has a particular angle relative to the stud's normal direction. Holes, on the other hand, are most accurate when the laser's line of sight is closer to the normal direction of the hole. The optimization task is: Given the line-of-sight geometry characteristics for each type of feature geometry, find an optimal placement of the Laser Radar device such that the accuracy of measurement of all *n* features (of varying types) in a given list is maximized.
3. (Possible Project Extension (hard)): In most installations, the Laser Radar is mounted on a 6-axis industrial robot, allowing the Laser Radar to be moved to arbitrary locations relative to the car. A more involved optimization task is this: Given a time constraint to measure N features, determine a) how many positions the laser radar should be moved to, and b) the location of those positions, such that a given list of features is measured with the highest confidence subject to #2 above.

The data for this problem will come from a CAD model of a Car 'Body-In-White'. From this CAD model, we will use a software modeling package to export the location of many geometric features from the CAD model. We will use different subsets of the nominal geometric features as our data sets for the optimization problems.



Car Body-In-White Showing Several Features To Be Inspected

2. Type of model (LP, QP, MIP, etc.) and an approximate count of the number of variables and constraints in the model:

1. The first sub-problem can be thought of as a variant of a Traveling Salesman Problem (TSP) where we are essentially moving the laser's target through the given feature locations. Since we know the max velocities and accelerations in both elevation and azimuth, the time taken to shift from measuring one feature to another is a function of the "distance" between the two feature locations. We are trying to find the best ordering of these features so as to minimize measurement time or equivalently distance. (NOTE: Distance here is not Euclidean distance!) The TSP can be solved as a MIP by considering a binary variable for each edge joining two locations. Since you can go from each feature to any other feature, the total number of variables is n^2 where n is the number of features we are trying to measure.
   a. Model: MIP
   b. Variable Count: $O(n^2)$ (approx $50^2 = 2500$ to start with. The actual problem involves 300 features)
   c. Constraints: $O(n^2/2)$ Basic physics constraints dealing with how fast we can go from one feature location to another and potentially accuracy constraints to ensure we spend enough time measuring each feature.
2. This problem will likely involve constraints with respect to distances and angles and hence will be a QP or an SOCP. We shall assume it as an SOCP right now since it is more general. The variables will include the location of the device in 3-dimensional space and a variable for accuracy of each feature measurement given this location (which can be computed) = $n+3 \cong n$ variables.
   a. Model: SOCP
   b. Variable Count: $O(n)$
   c. Constraints: $O(n)$ Constraints regarding how accuracy is affected based on the line of sight of the device and the type of feature we are trying to measure.
3. This problem would essentially be solving the second problem for all possible subsets of the given feature list and then solving the first problem (partially) for each of these positions until the total time taken for feature measurement satisfies the constraint. The main variables would be the locations of each of those positions as well as the variables needed to solve the above two subproblems.
   a. Model: MIP
   b. Variable Count: $O(n^2)$
   c. Constraints: $O(n^2)$