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Design and Development of Braking and Transmission Systems of an Electrically Powered All-Terrain Vehicle

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Abstract : Image Processing (Machine Vision) has gained a lot of interest among the research community especially in monitoring vehicle speed in today's era. Apart from vehicle detection, tracking and its motion estimation, this algorithm can be used to monitor the traffic condition along the road or highway and anti-collision systems as well. A MATLAB algorithm is proposed and developed to associate the developed algorithm with real-time video sequence and images. The project aims to design an Electric All-Terrain Vehicle (EATV), namely eBAJA. Our goal is to design, develop and analyze a single seat, all terrain, sporting vehicle whose structure contains the driver. While sizeable research has been conducted in all-terrain vehicles powered by Petrol and diesel engines, no major research has been done in the development of ATVs powered by sustainable energy sources. As gas prices fluctuate and environmental concerns continue to be pushed to the forefront, we hear more and more about electric ATVs. For most people, however, electric off-road vehicles are still part of the great unknown. The vehicle is to be a prototype for a reliable, maintainable, ergonomic and economic production vehicle which serves a recreational user market. The vehicle should aspire to market leading performance in terms of speed, handling and ruggedness over rough terrain and off road conditions. The design report focuses towards explaining the procedure, methodology and calculations involved and utilized in designing the off road electrically powered vehicle.

Keywords : Machine Vision video image processing, Gaussian mixture model(foreign vehicle detection), Extraction of ROI(region of interest), Hogg Transform(line detection algorithm), Mean Disturbance Energy Graph Plot(w.r.t. proximity), Machine learning Training Set(sign board detection and pedestrian detection), Roll Cage, Material Selectrion, Strength, Impact, Finite Element Test.

I. INTRODUCTION

Block extraction and subtraction technique is known as one of the simplest motion detection technique. This technique has been adopted into video sequence coding for vehicle speed detection based on current and previous images. Each of the images is divided into non-overlapping square blocks to compare with the respective blocks in the current frame and previous image, each blocks are subtracted to estimate the vehicle speed. MATLAB is the mainplatform to develop the vehicle detection and tracking algorithm.

II. METHODOLOGY

The design and development of an electric all-terrain vehicle involved knowing the basics of roll cage design, braking and transmission systems. For this purpose, we conducted studies in the following areas.

- Choice and strength of material for tubing to be used for roll cage fabrication. Heat treatment processes, yield strength, tensile strength, young's modulus of different materials such as mild steel, chromoly steel, DOM steel.
- Study of A- pillars, B-pillars, triangulation to improve strength, disadvantages of bent tubes and structural integrity of T junctions.
- Welding processes, Tungsten inert gas welding, metal inert gas welding, Weld integrity.
- Study of trusses and cantilever beams, bending moments and torsion.

A. Literature Review

Recent research in roll-cage design:The researchers in the study [1] have attempted to design a chassis for an All-Terrain Vehicle and subject it to various stresses in the front, rear and side dimensions. They have selected the material for the chassis on the basis of cost and weight. The analysis of behavior of the chassis, its deformation and load bearing characteristics has been done using Finite Element Analysis in ANSYS software. This was essential to ascertain the safety and rigidity of the roll cage being used, since an off road vehicle is required to maintain structural integrity under harsh conditions and under severe shock loading.

This research paper [2] focuses on the stress analysis of the roll cage of an SAE Baja vehicle with a top speed of 55 kmphand a kerb weight of 290Kg. It shows the design process and rough calculations used to ascertain the material to be selected on the basis of maximum stress. The researchers have performed a frontal impact test using Finite Element Analysis Simulation in ANSYS Software. They have determined the factor of safety to be 1.54 in the event of a frontal impact. According to these tests, the researchers deem their design safe for the driver in the event of frontal impact.

The above research gives us an idea about the basic procedure and considerations involved in designing a chassis for our electric all-terrain vehicle. It also shows us how the designed roll cage may be tested under simulation of real life conditions to ensure the safety of the occupant.

However, under the tests conducted in [1], a roll over test has not been conducted. A roll over test is also very necessary as it is a possible scenario in off road conditions, and improper design of roof and A-pillars could cause serious injuries to the driver in the event of roll over.

Moreover, no clear information is provided in [1] regarding the selection of steel tube diameter, or the design process. The researchers have not shown any supporting calculations to show that the steel tubes can bear the bending moment loads under load.

The researchers in [2] have not taken into account the torsional bending stresses while performing calculations for the diameter of steel tubing. High torsional stresses exist in steel members under load and they should be strong enough not to deform under these conditions.

Based on the above observations and tests, we designed a roll cage for use in an electric all-terrain vehicle, which is then subjected to simulation tests. The material for the roll cage design is selected considering its cost, weight, and properties. The major difference in an Electric all-terrain vehicle is that the weight of the drivetrain components and the battery is much higher than the petrol engine considered in the existing research. Hence due care needed to be taken to ensure proper weight distribution and maintain a low center of gravity.

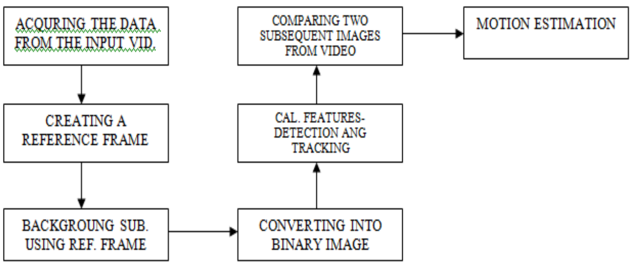

Fig 1: The key stages in the vehicle identification

This section presents the technology inputs and processing steps needed in the transitionfrom raw video frames to moving vehicle identification, tracking.

Figure below shows the key stages in the vehicle identification and tracking process. Each of these steps is described in detail below.

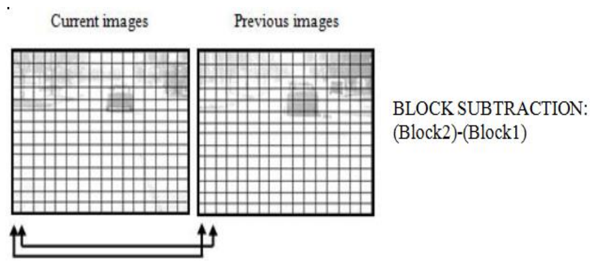

Fig 2: Tracking process

B. Machine Vision

i. Algorithm Development Approach

(*Gaussian Mixture Model and motion analysis)

Video consists of a sequence of static images representing scenes in motion at one time. The video encoding process includes the transformation of the video into sequence of static images. Two extracted images are selected to apply the motion estimation process in the developed MATLAB algorithm. Fig. shown describes the development process of vehicle speed detection algorithm. Standalone images is searched for the required region of interest(ROI) and further acted upon by blob extraction wherein bounding boxes are created around the foreign vehicle. Furthermore the centroid coordinates are compared with those of the previously attained image to quantify the distance travelled.

STEPS:

1. Read the Input Video:

After recording the video in the MATLAB workspace, the video must be read using- (*Vision.VideoFileReader*) function which read the video from MATLAB workspace. The past function doesn't display the video in any form; its only work is to prepare the video for the next steps

2.Taking Reference Image:

We must have one reference image of which we have compare after with each frame of the video for feature extraction.

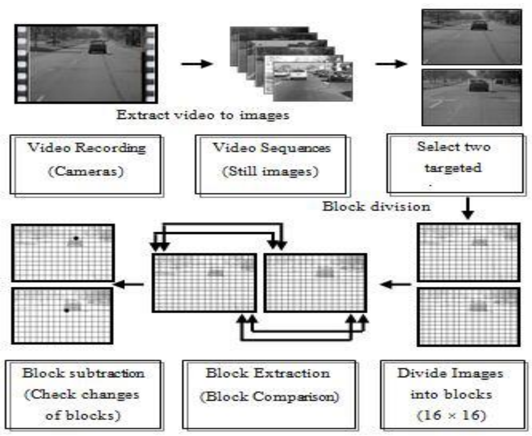

Fig 3: Video identification

3. Comparison with Subsequent Image.

4. Bounding Box Extraction:
We do this by constructing a bounding box. This bounding box is used to isolate the area of interest in the image and is similar to window (or key region) processing. This can be easily made by calling the (*Bounding Box*) property of the (*regionprops*) function. Feature extraction is used to extract the feature and locate the position of the moving object in the frames, which will be estimated using function like 'regionprops'

5. Calculate the Displacement:
After finding the location of the object the next step is to calculate the displacement of the object in two consecutive frames.
The distance between (x1,y1) and (x2,y2) is :

$$D = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

*When the vehicle travels a predefined fixed distance the number of frames that is necessary to travel that distance in the image is calculated and it is compared to a ground truth which is the number of frames that is necessary to vehicle to travel the same distance in order to achieve certain speed.

6. Motion Estimation (Calc. Speed): After finding the displacement of the object we can multiply it with the total number of frames to give total displacement in the whole time, then we can divide it with the total time of the video to give total displacement covered in on sec, which is nothing but the speed of the object.

Speed=Dist./Time

ii. Lane Departure Systems via Machine Vision

The above mentioned technique equips the processing system to visualize weather the vehicle is being driven in proper lanes on the road. If not it implicateswater it is going right or left by giving an indication of Right Departure or Left Departure accordingly.
The methodology involves detecting white solid and broken lines via machine vision with the help of an algorithm namely HOGG transform.
This technology clubbed with control systems can yield the introduction of automated indicators via machine vision/image processing into automobiles.

i. Pedestrian Detection and Tracking

This technology employs machine learning. The machine learning training set of the human body is fed to the compiler and is trained subsequently. Furthermore the region of interests (ROI) extracted from the test image/video is compared with the models in the training set. If the percentage resemblance exceeds to more than 60% the match is confirmed and thereafter the human body(i.e the pedestrian is confirmed). As a result the processor gives an alarm to the driver to indicate that a pedestrian is in the vicinity.
This technology adds up to the concept of intelligent drive.

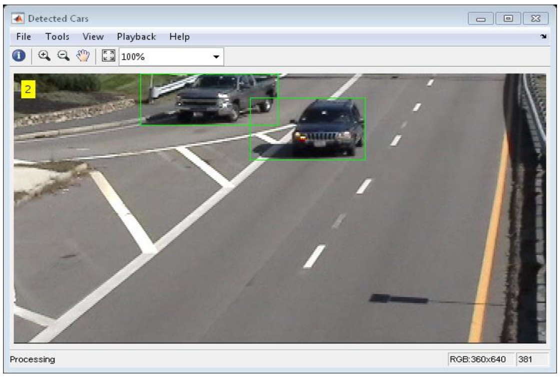

Fig 4: Image processing 1

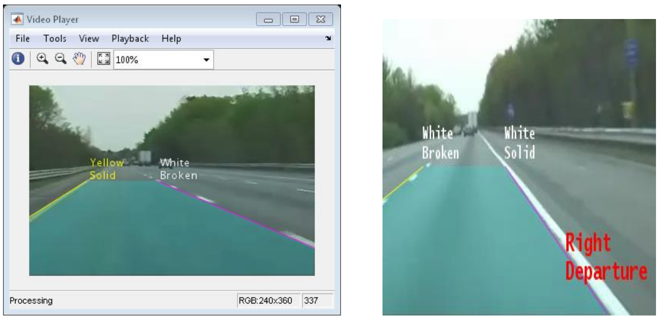

Fig 5: Image processing 2

ii. Warning Sign Detection and Recognition

This technology employs machine learning. The compiler is fed with the machine learning training set of traffic warning signs. Eventually when a traffic warning sign comes into the aperture of the camera, it is detected by the virtue of the machine learning training set and is further compared with the fed models to determine the nature of the warning sign. As a result, by the help of this technology, the driver gets a notification on its own by the processor if there is any traffic warning sign if she/he fails to observe it while driving.

iii. Mean Disturbance Graph of our vehicle with respect to other vehicle

As any foreign vehicle or body approaches our vehicle, we can sketch the graph in real time of the distance and the relative rate of displacement of the two using the above mentioned techniques. This interpretation would further help to enhance our anti-collision system, wherein the system will give an alarm or indication to the driver when the foreign body/vehicle is at a minimum critical distance from our vehicle which is not expected to be safe.

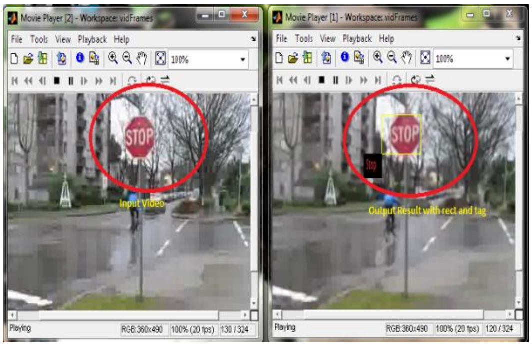

Fig 6: Image processing 3

*the graph shown depicts the relative disturbance in the input video and further gives the distance between the video input source and the object displaced relatively (i.e. the foreign vehicle/body and our vehicle).

C. Roll Cage Design

i. Material Selection

As per the constraint given in the rulebook, the roll cage material must have at least 0.18% carbon content. After an exhaustive market survey, the following materials which are commercially available and are currently being used for the roll cage of an ATV are shortlisted.

A comparative study of these shortlisted materials is done on the basis of strength, availability and cost. The shortlisted materials are as follows.

- AISI 1018
- AISI 4130
- AISI 1020

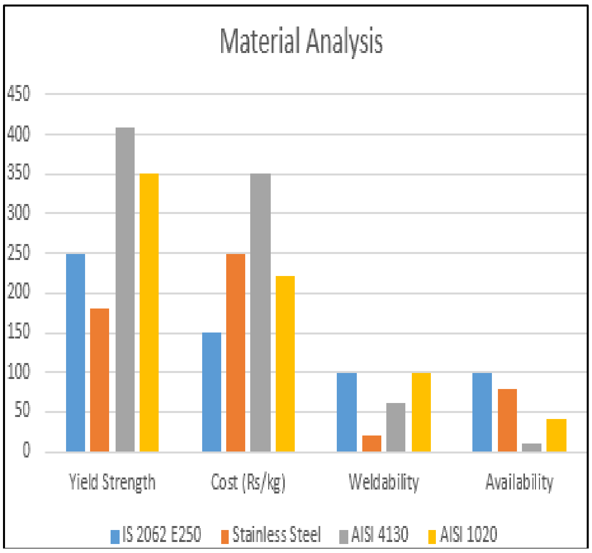

Fig 7: Material analysis

AISI 1020 is selected for the chassis as it easily available at a reasonable cost.

Properties of AISI 1020:

Tensile Strength, Ultimate	394.72 MPa
Tensile Strength, Yield	294.74 MPa
Elongation at Break (in 50 mm)	36.5 %

Chemical composition of AISI 1020:

Element	Content
Carbon, C	0.17 - 0.230 %
Iron, Fe	99.08 - 99.53 %
Manganese, Mn	0.30 - 0.60 %
Phosphorous, P	≤ 0.040 %
Sulfur, S	≤ 0.050 %

Fig 8: AISI 1020 Properties

ii. Design of Roll-Cage

The design and development comprises of material selection, chassis and frame design, cross section determination, determining strength requirements of roll cage, stress analysis and simulations to test the ATV against failure. The roll cage of eBaja vehicle should be sufficiently rigid to carry the higher weight of battery pack and motor, so it is suitably designed. The objective of the project is to design, develop and fabricate the roll cage for all – Terrain Vehicle. Material for the roll cage is selected based on strength, cost and availability. The roll cage is designed to incorporate all the automotive sub-systems. A software model is prepared in CATIA V5R19.

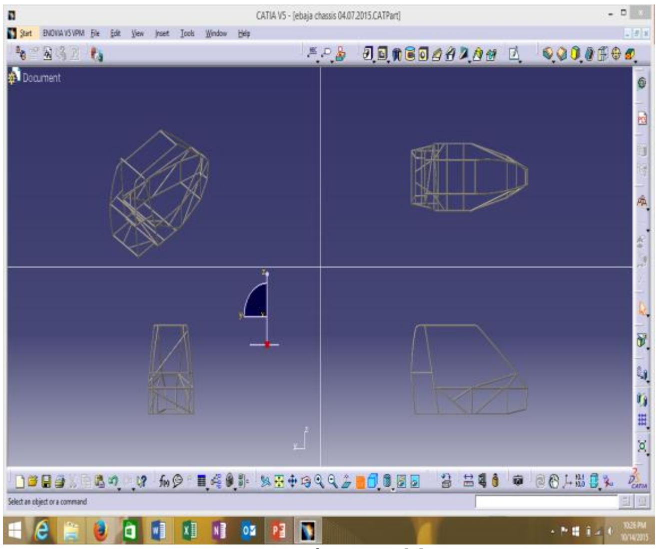

Fig 9: Software model

Views Of Design And Process

iii. Impact Testing Of Roll Cage

Finite Element Analysis: After finalizing the frame along with its material and cross section, it is very essential to test the rigidity and strength of the frame under severe conditions. The frame should be able to withstand the impact, torsion, roll over conditions and provide utmost safety to the driver without undergoing much deformation. This is done by using Finite Element Analysis in CATIA V5R19.

Initial velocity u=16.67m/s Final velocity v=0 in automotive industry, the impact time is of the range 0.15 to 0.2 s. Taking time of impact as 0.18s. By applying Newton's 2nd law, F = change in momentum/time F= (m*(v-u))/t F= (350*(0-16.67))/0.18 F = 32413N Hence a gross load of 32kN is applied at the front corners constraining the rear members.

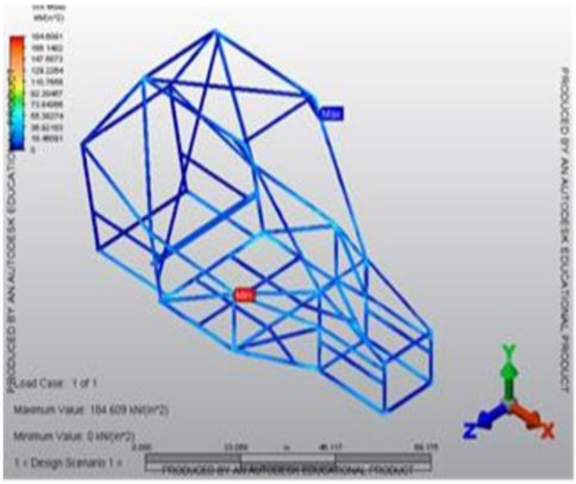

Fig 10: Model analysis 1

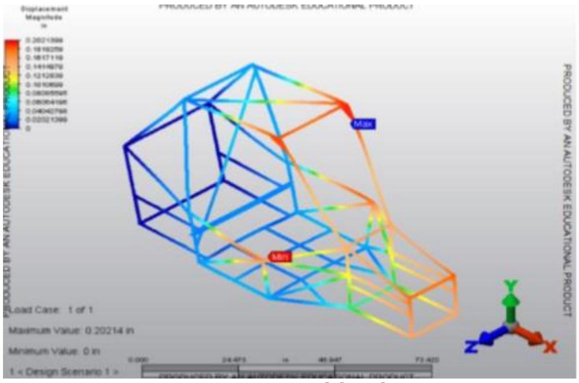

Fig 11: Model analysis 2

Stress And Deformation Analysis.

iv. Results of Impact Test

Table 1: Results of tests

FACTOR OF SAFETY	STRESS (MPa)	MAXIMUM DEFORMATION (mm)	LOADING FORCES (kN)	TYPE OF IMPACT TEST
1.2	245.61	9.416	40	Front
1.5	196.49	7.590	14 at 45^0 with side plane	Side
2.6	113.36	5.135	12 at 45^0 with base	Roll-over
1.3	226.72	9.936	30	Rear

III. CONCLUSION

This project helps us to understand the vital components of designing. As mentioned above the yield strength of the material which we are using is 294.8 MPa. The maximum value of stress generated while frontal impact on rollcage is 191.299 MPa which is well within the limits. And therefore, the factor of safety of our rollcage is 1.54. Safety is of utmost concern in every respect; for the driver, crew & environment. Considerable factor of safety (FOS) or design factors is applied to the rollcage design to minimize the risk of failure & possible resulting injury. This FOS value implies the safe value of applied loads and deformations.

Thus the roll cage is safe to operate under the required conditions and can support the weight of the battery, motor and suspension.

Motion estimation technique can be involve into video-based algorithm to measure and estimate moving vehicle velocity as well as calculate the distance between the user's vehicle and any foreign object. Developing and integrating a MATLAB based algorithm to process the video images to detect, track and estimate the velocity of vehicles would help in enhancing the concept of intelligent drive in numerous aspects (anti-collision systems, racing, traffic analysis etc.).

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