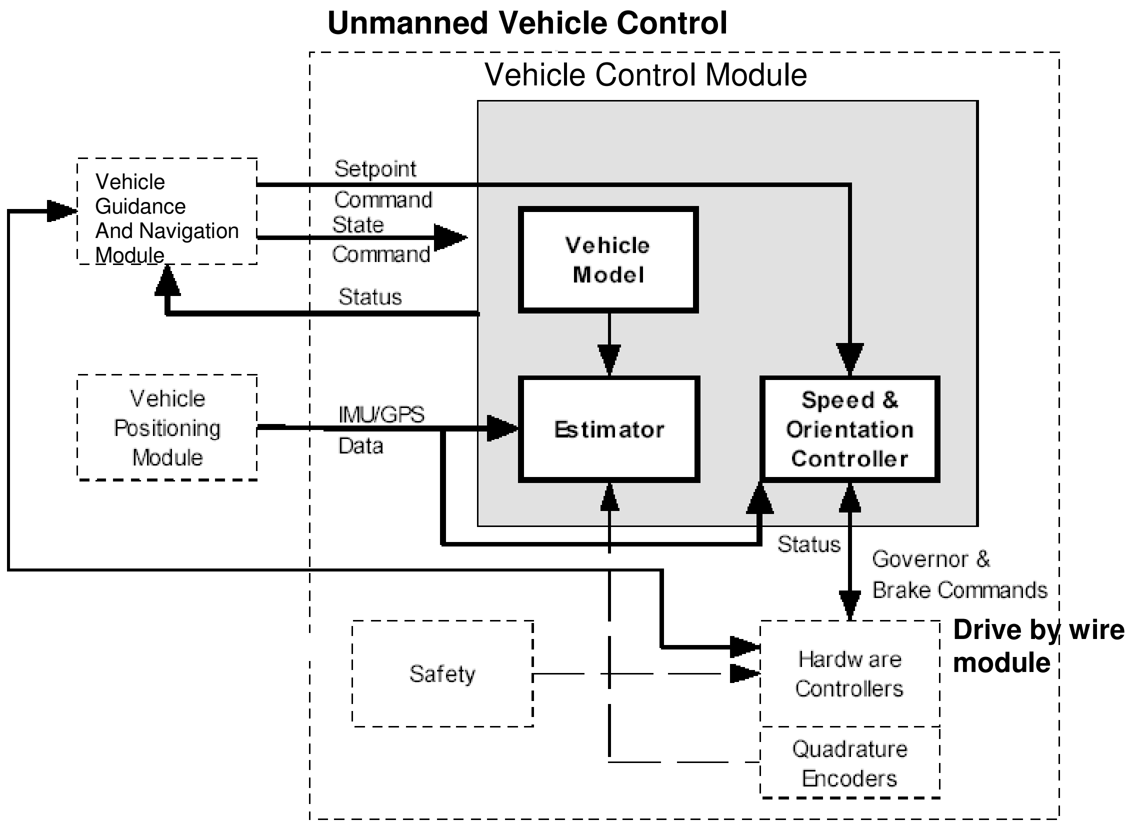
**VEHICLE CONTROL MODULE**

**1. Block Diagram of Unmanned Vehicle Control**




**Design of Unmanned Vehicle Control**

The first task is to model the vehicle. However, the accuracy of the model is always hampered by non-linearity and hystericis. The implementation of the Speed and Orientation Controller has therefore to be adaptive and robust. The estimator, on the other hand, has to be timely and accurate, which in the real case has uncertainty.

The output of the Vehicle Control Module directly commands the Drive-by-wire system. This in turns translate into vehicle motion (speed and orientation). The aim is therefore to maintain control and response, such that the platform can achieve the desire trajectory and reach the desire objective way points.

3. Sample Vehicle Model taken from a track vehicle

4.2.1.2. Kinematic Model

Figure 4-2 depicts the motion of the AUGV in a plane tangential to the local terrain. The desired forward speed $V_x$ of the vehicle in the $x$ direction, and the yaw attitude $\psi$ of the AUGV are controlled by manipulating the speeds $V_L$ and $V_R$ of the left and right tracks. The kinematic model describes the relationship between the AUGV motion and the motion of the tracks.

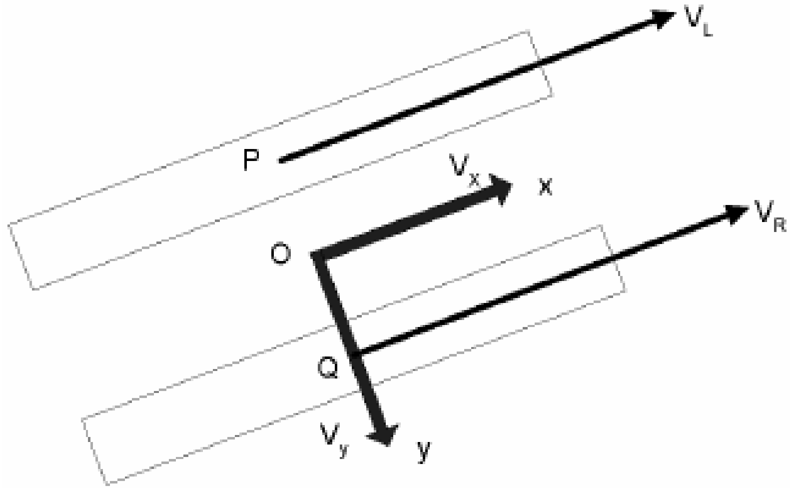



**Figure 4-2: Motion of the AUGV in a Plane Tangent to the Local Terrain.**

The forward speed of the vehicle is

$$V_x = \frac{V_L(1-i_L)+V_R(1-i_R)}{2},$$

and the angular velocity $\omega_z$ of the AUGV about the body frame z axis is

$$\omega_z = \frac{V_L(1-i_L)-V_R(1-i_R)}{b},$$

where $V_L$ and $V_R$ are the speeds of the left and right tracks and $b$ is the distance between the track centrelines. The longitudinal track slip coefficients $i_L$ and $i_R$ of the left and right track, and the lateral (side) slip $i_s$ are defined by

$$i_L = \frac{V_L - V_P}{V_L}$$
$$i_R = \frac{V_R - V_Q}{V_R} \qquad (1)$$
$$i_s = \frac{V_y}{V_x} \ ,$$

where $V_P$ and $V_Q$ are components of the velocities of points $P$ and $Q$ in the track direction. The points $P$ and $Q$ are attached to the AUGV body as shown in Figure 4-2. Values of the slip coefficients can be estimated using the information obtained from the VPM, together with the readings from the incremental encoders attached to the left and right track drive sprockets. Observe that the slip coefficients are undefined when the tracks are stationery.

The rate of change of the vehicle orientation $\psi$ is related to $\omega_z$ by

$$\dot{\psi} \approx \frac{\omega_z \cos(\phi)}{\cos(\theta)} \ ,$$

## 4. Estimator

The estimator is a Kalman-filter-based minimum mean squared error estimator. The estimator runs in a predictor-corrector algorithm fashion, using the vehicle model to make predictions of vehicle motion and the vehicle slip parameters from the previous position and slip estimates, and using the position information provided by the positioning module and the right and left encoders to make corrections. By using a comprehensive model of the evolution of the vehicle states and slip parameters, the estimator is able to infer unmeasured parameters such as track slip.

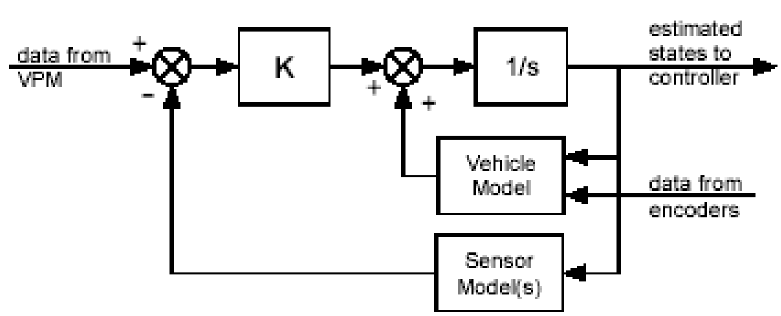



**Figure 4-4: Estimator Data Flow Diagram.**

5. Speed and Orientation Control

```
(at each time of control update step)

//Inputs validation
update actual positions and get setpoints
determine speed direction
if ( SetpointSpeed is larger than MaxSpeed ) truncate it
if ( SetpointSpeed is very small )
{
        set BrakeSetpoint full brake, set ThrottleSetpoint idle, reset controller
    send output setpoints
    end of control update
}

// Speed controller
calculate speed error
truncate integrator contribution to ThrottleSetpoint between 0% and 100%
if ( speed is less than desired or a little bit too fast )
{
        compute ThrottleSetpoint by PID control
        truncate ThrottleSetpoint between 0% and 100%
    set  MeanBrakeSetpoint to zero
}
else if ( speed is much too fast )
{
    set ThrottleSetpoint to 0
        set MeanBrakeSetpoint by P control on over speed
        truncate MeanBrakeSetpoint between 0% and 100%
}
apply throttle calibration table to linearize ThrottleSetpoint

// Orientation controller
calculate orientation error
if ( orientation error is much too large ) send EXCEPTION message
compute variable orientation control parameters
truncate integrator contribution to OrientationControl between 0% and 50%
if ( orientation error is greater than 10 degree ) reset integrator
compute OrientationControl by PID on orientation error
if ( MeanBrakeSetpoint for speed reduction exceeds twice of OrientationControl )
{
        set leftBrakeSetpoint and rightBrakeSetpoint
        based on MeanBrakeSetpoint and OrientationControl
}
else
{
        set leftBrakeSetpoint and rightBrakeSetpoint
        based by OrientationControl only
}
if ( going backwards )
    swap leftBrakeSetpoint and rightBrakeSetpoint

truncate leftBrakeSetpoint and rightBrakeSetpoint to 100%
apply brake calibration table to linearise leftBrakeSetpoint and rightBrakeSetpoint

send output setpoints
end of control update
```

**Figure 4-7: Pseudocode Representation of Speed and Orientation Control Algorithm.**

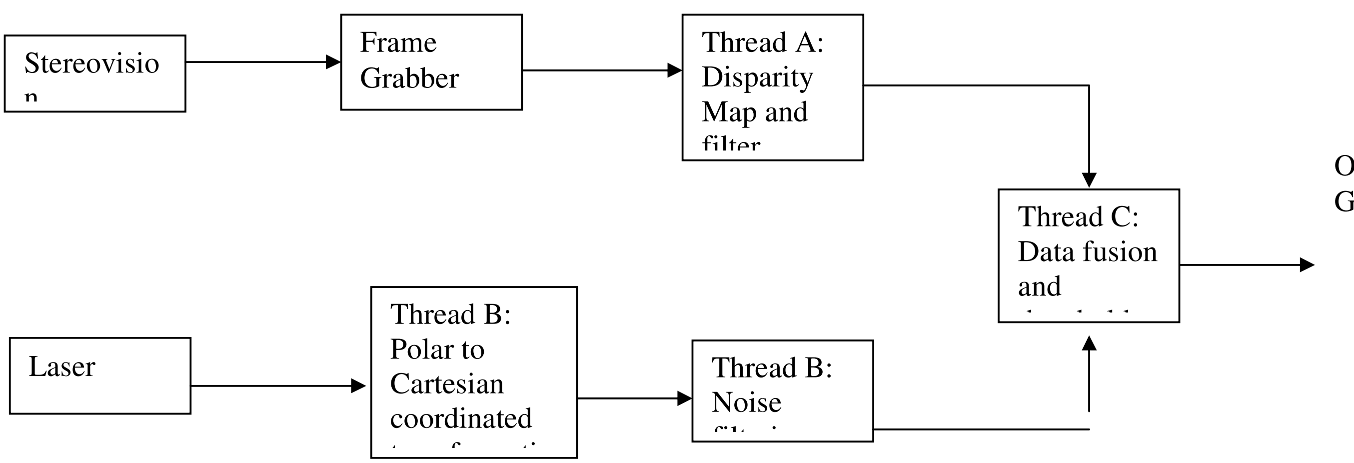
The controllers employed and experimented vary from PID to sliding mode control.

6. Challenges and Lesson Learnt

The target large tracked vehicle is designed for manually driving. To convert the vehicle to an autonomous one, an automatic vehicle control system has to be developed and implemented on the vehicle first. The conversion of a conventional manual driving tracked vehicle into a drive-by-wire vehicle is a very important achievement. The overall conceptual design of the Vehicle Control System (VCS) is proven feasible and the system development is successful.

The Vehicle Control Module (VCM) is the "brain" for the vehicle movement control. The main function of the VCM is to generate proper commands for the driving actuators to execute. The driving actuators execute the given commands and act on the vehicle's manual-driving levers, which makes the vehicle to move at the desired speed and direction. The dynamics of the large tracked vehicle is highly complicated, highly nonlinear, and highly uncertain. As a result of the skid steering of the tracked vehicle, the vehicle forward running and the rotating speeds are strongly correlated. Conventional Proportional-Integral-Derivative (PID) control methods cannot achieve satisfactory system performances.

In the development of VCM, an innovative and effective algorithm for speed and heading control of the tracked vehicle has been developed. The unique multi-input-multi-output (MIMO) control algorithm takes into account the system non-linearities inherent with the tracks, brakes, vehicle skid-steer behaviors and also the mechanical dead-bands, and is able to eliminate the negative effects of the interactions between the vehicle forward and the rotating speeds. Heuristic rule-based switching and controller parameter-varying methods are used in this algorithm. The controller is able to switch among different suitable control algorithms based on various vehicle running conditions. With the algorithm implemented, the vehicle control system is able to control the vehicle to operate on equatorial jungle-like natural terrain. A large volume of field test record shows that the VCM functions remarkably well and the control algorithm is effective and robust with excellent performances under various environment situations.



- The inputs to the Perception Module (a rugged high performance PC) are stereovision and laser.
- Both the stereovision and laser will be seated on a stabilized platform.
- A frame grabber (a two channels hardware) capture the video frame from the stereovision two individual cameras.
- Three processing threads are run within the Perception module in parallel: Thread A, Thread B and Thread C
- The output is an obstacle grid map.

# LIGHT STRIKE VEHICLE
## Type: Robotic

### KEY FEATURES

- Full tele-operation with driving video feedback
- Capable of semi-autonomous navigation behaviors (point seeking, way-points navigation, path following, tele-guidance, dynamic obstacle avoidance)
- Remote insertion and operation of mission payloads
- Drive encoders (for dead reckoning)
- DGPS and IMU (for localization)
- Dynamic obstacle avoidance algorithms
- Sensor fusion algorithms
- Operational up to 65°C

### TECHNICAL SPECIFICATIONS

| | |
|---|---|
| Platform technical specifications: | as per Light Strike Vehicle |
| Tele-operation speed: | 60km/h |
| Semi-autonomous navigation speed: | 20km/h |
| Operation range:<br>(based on current modem specifications) | up to 2km LOS (data)<br>800m LOS (video) |