VEHICLE LOCALISATION USING GPS AND IMU

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LOCALIZATION

- Vehicle localization is an important topic as it finds its application in a multitude of fields like autonomous navigation and tracking applications.
- By definition, localization is the determination of the position and orientation of the object under study.

SENSORS USED

- SerAccel V5 Triple-Axis Accelerometer
- FV-M11 GPS Receiver
- Crossbow DMU RGA300CA- IMU

GPS Receiver Equipment

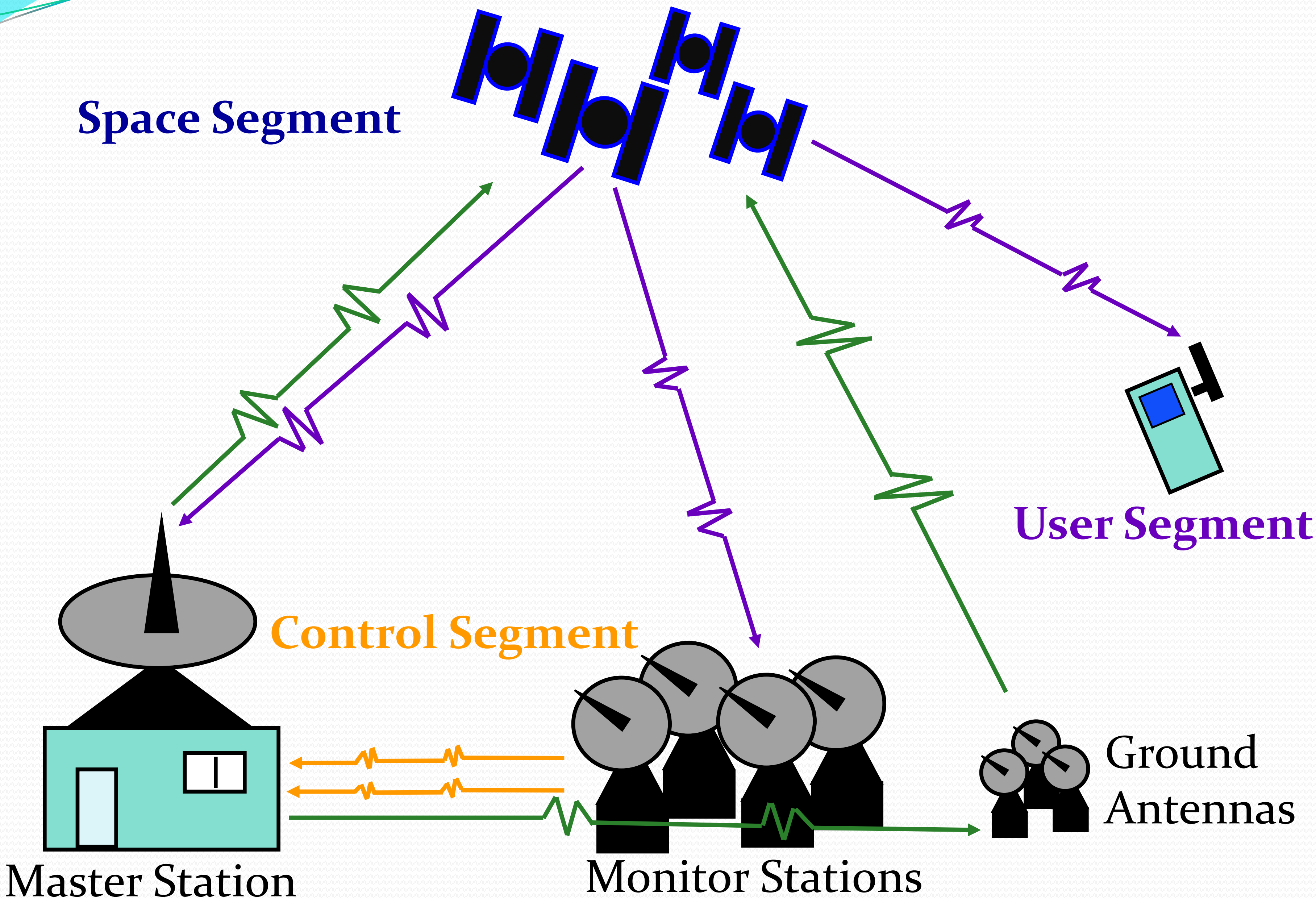
- San Jose Navigation GPS Receiver
  - 32 parallel channels
- San Jose Navigation GPS Antenna
- Sparkfun GPS Evaluation Board

Global Positioning System(GPS)

- Today GPS systems are widely used in a range of applications from missile guidance systems to navigation aid to automobile drivers.

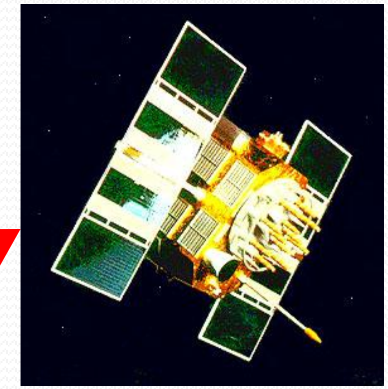
- Its was started on 1973, was fully operational on 1995. It is controlled by the US Department of Defence.

Three Segments of the GPS



Position is Based on Time

Signal leaves satellite at time "T"



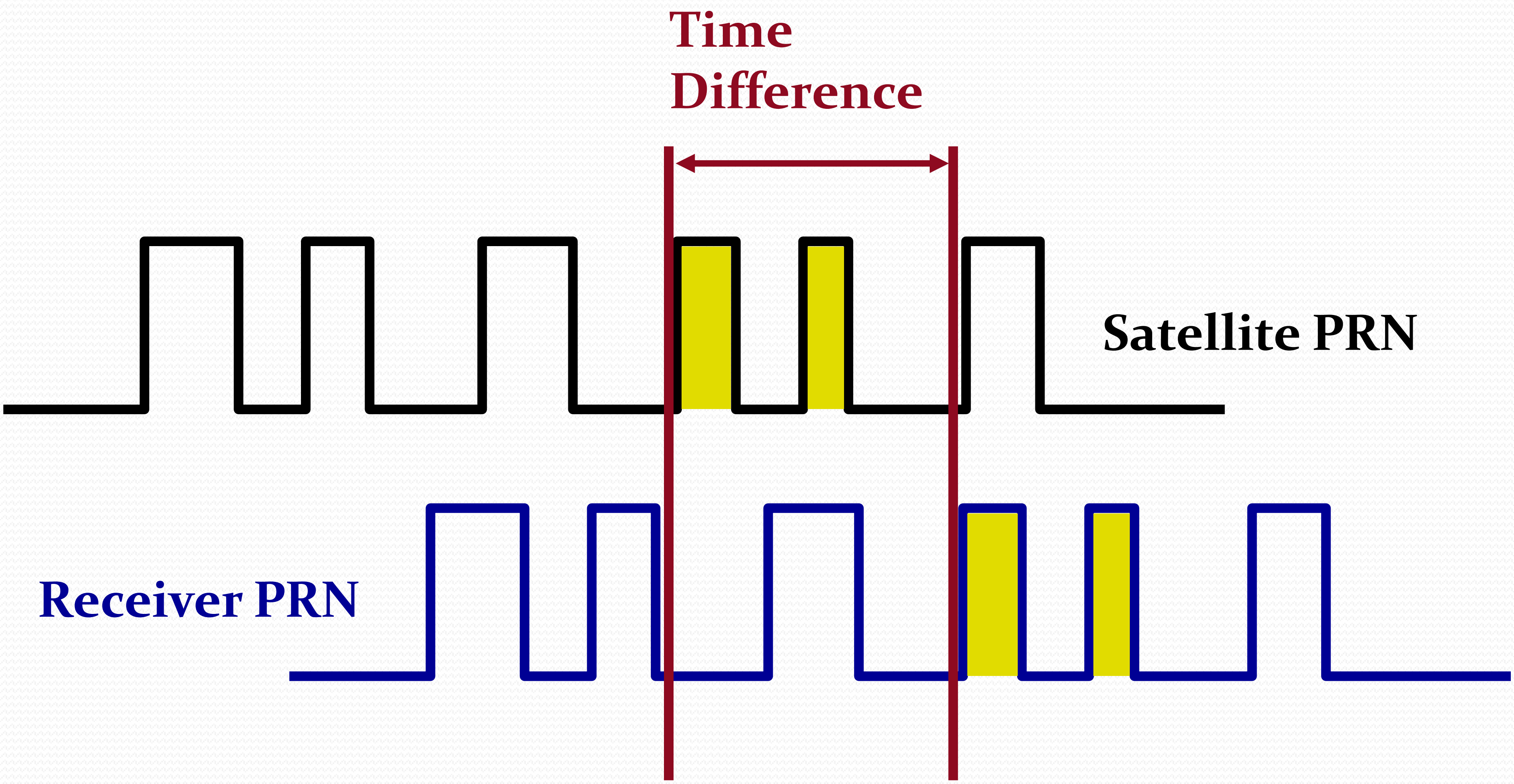
T

T + 3

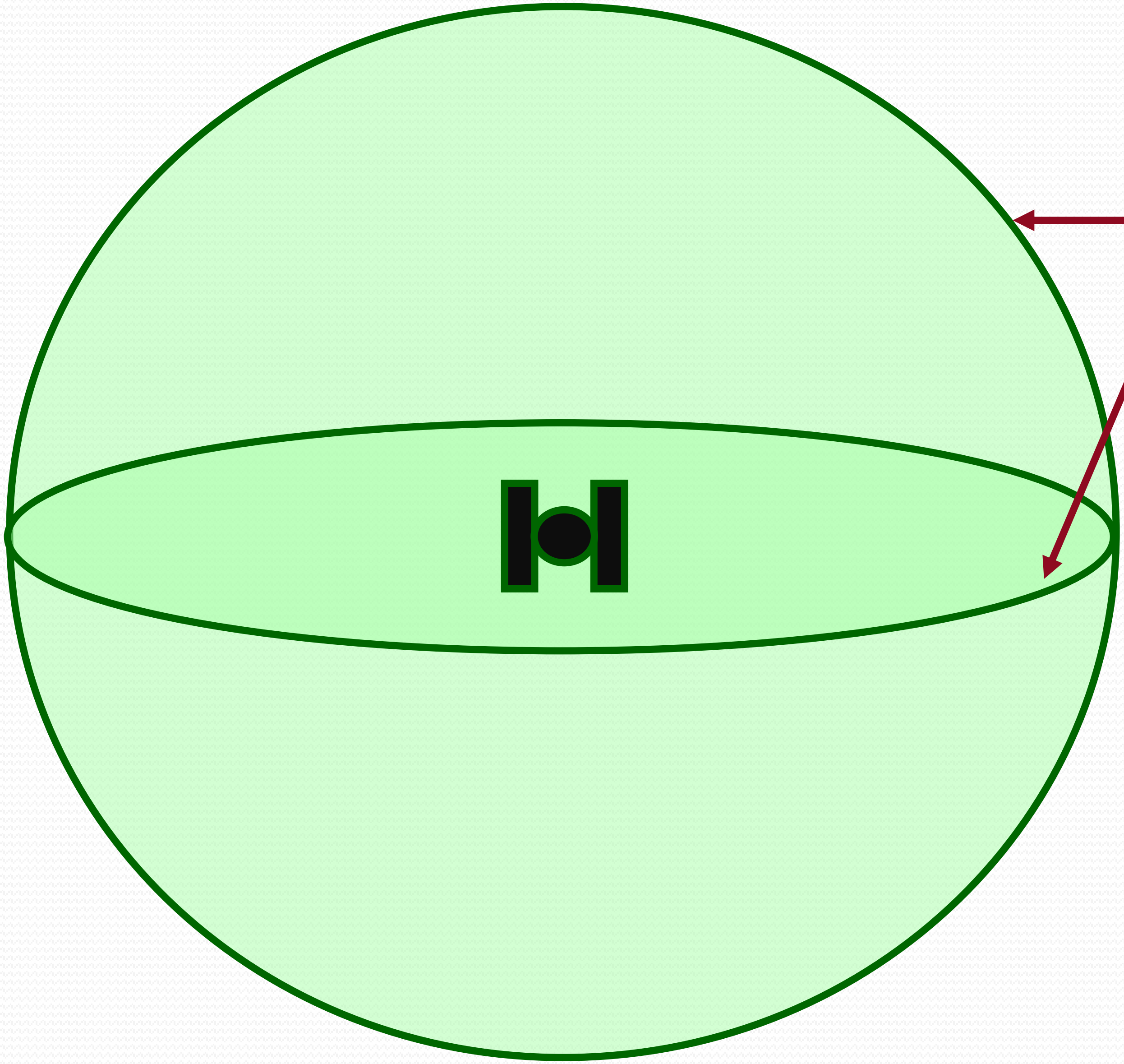
Signal is picked up by the receiver at time "T + 3"

Distance between satellite and receiver = "3 times the speed of light"

Pseudo Random Noise Code

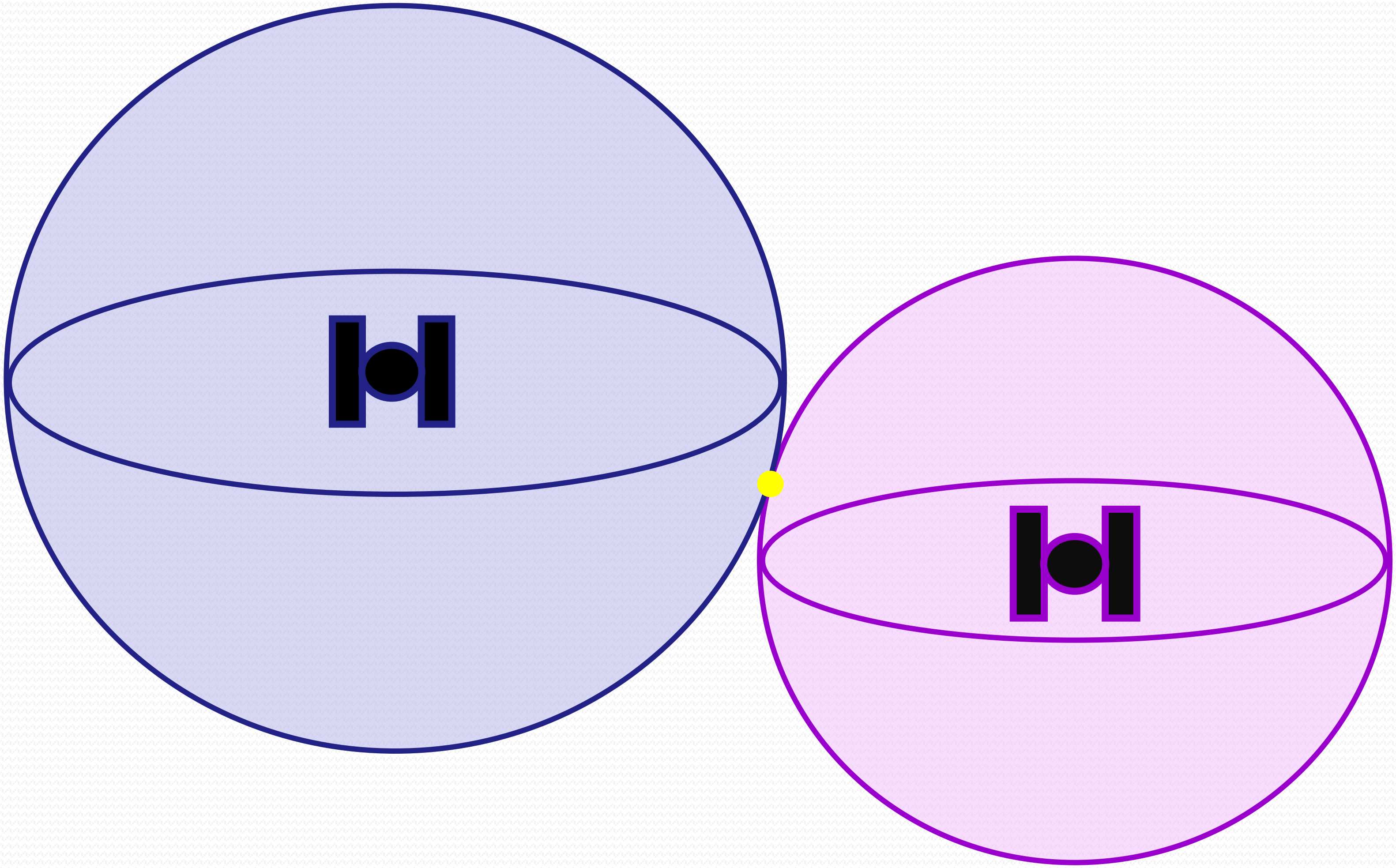


Signal From One Satellite

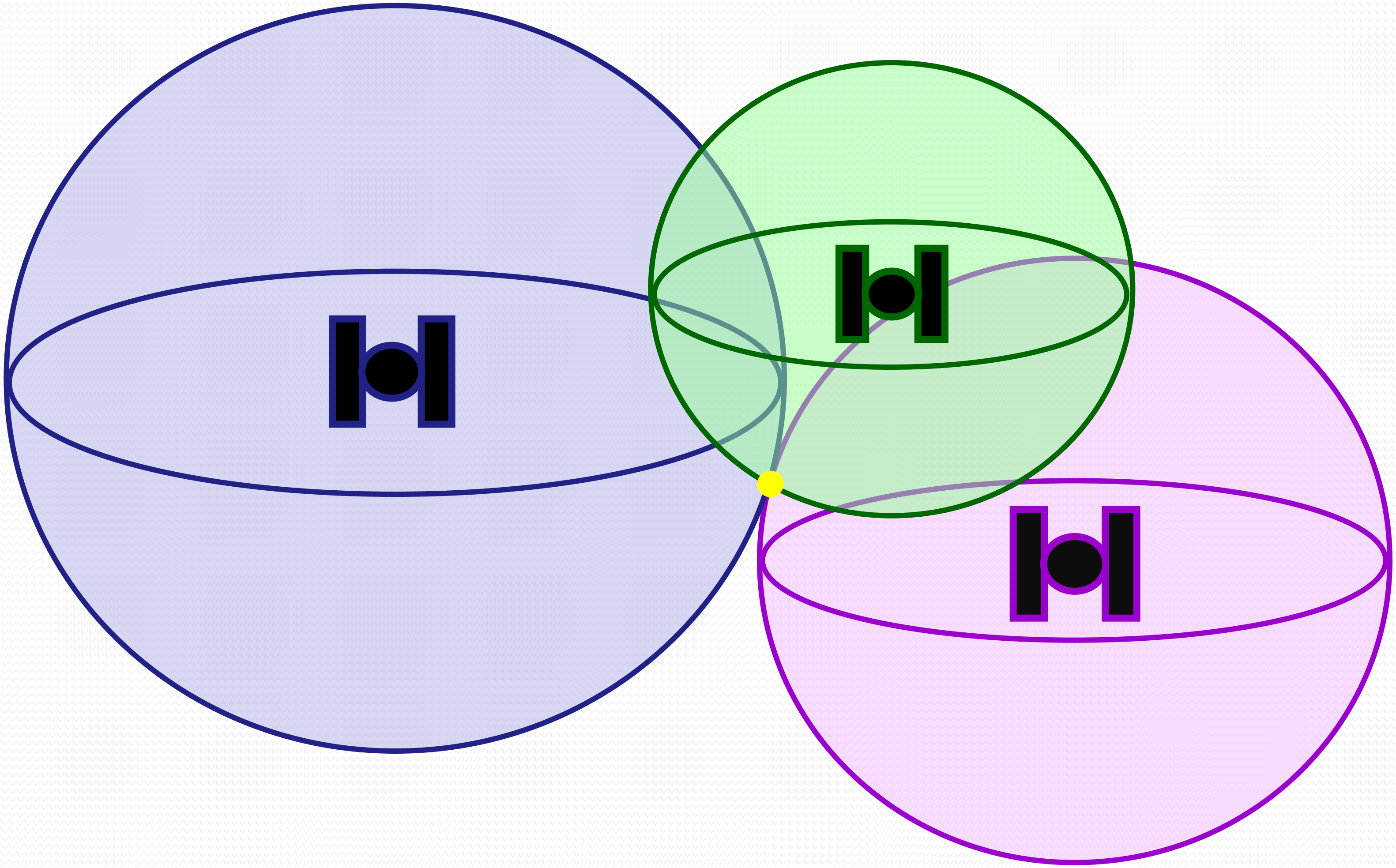


The receiver is somewhere on this sphere.

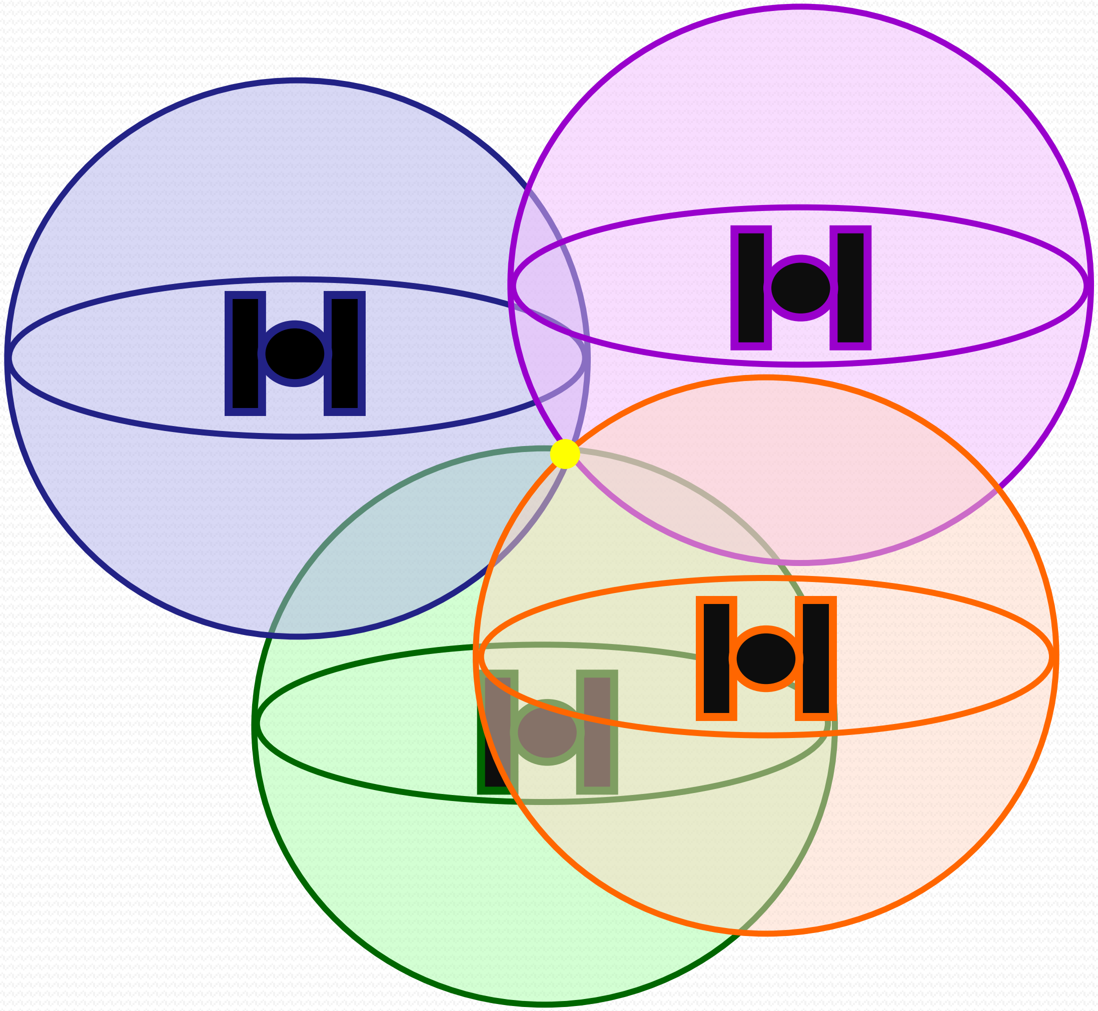
Signals From Two Satellites



Three Satellites (2D Positioning)



Three Dimensional (3D) Positioning



Determination of Position

- Theoretically the relative distance of the receiver from three satellites is sufficient to give a position fix though there will be two solutions, only one will be close to the earth's surface.
- But in practice, a minimum of four satellites are required to get an exact position fix with better accuracy by reducing the errors in time.

NMEA Communication Protocol

GGA	Global Positioning System Fix Data
GSA	GNSS DOP and Active Satellites
GSV	GNSS Satellites in View
RMC	Recommended Minimum Navigation Information
VTG	Course Over Ground and Ground Speed
GLL	Geographic Position – Latitude / Longitude
ZDA	Time & Date

String Encoding

$GPGGA

, (UTC time) , (Latitude) , (LatitudeSector) , (Longitude) , (LongitudeSector) , (GPS Quality Indicator) , (SVs used) , gga8 , (Altitude) , (Unit of Altitude) , gga11 , gga12 , gga13 , gga14 *(checksum)<CR><LF>

GPS Plot from Engineering to Arts(NUS)

Engineering

Arts

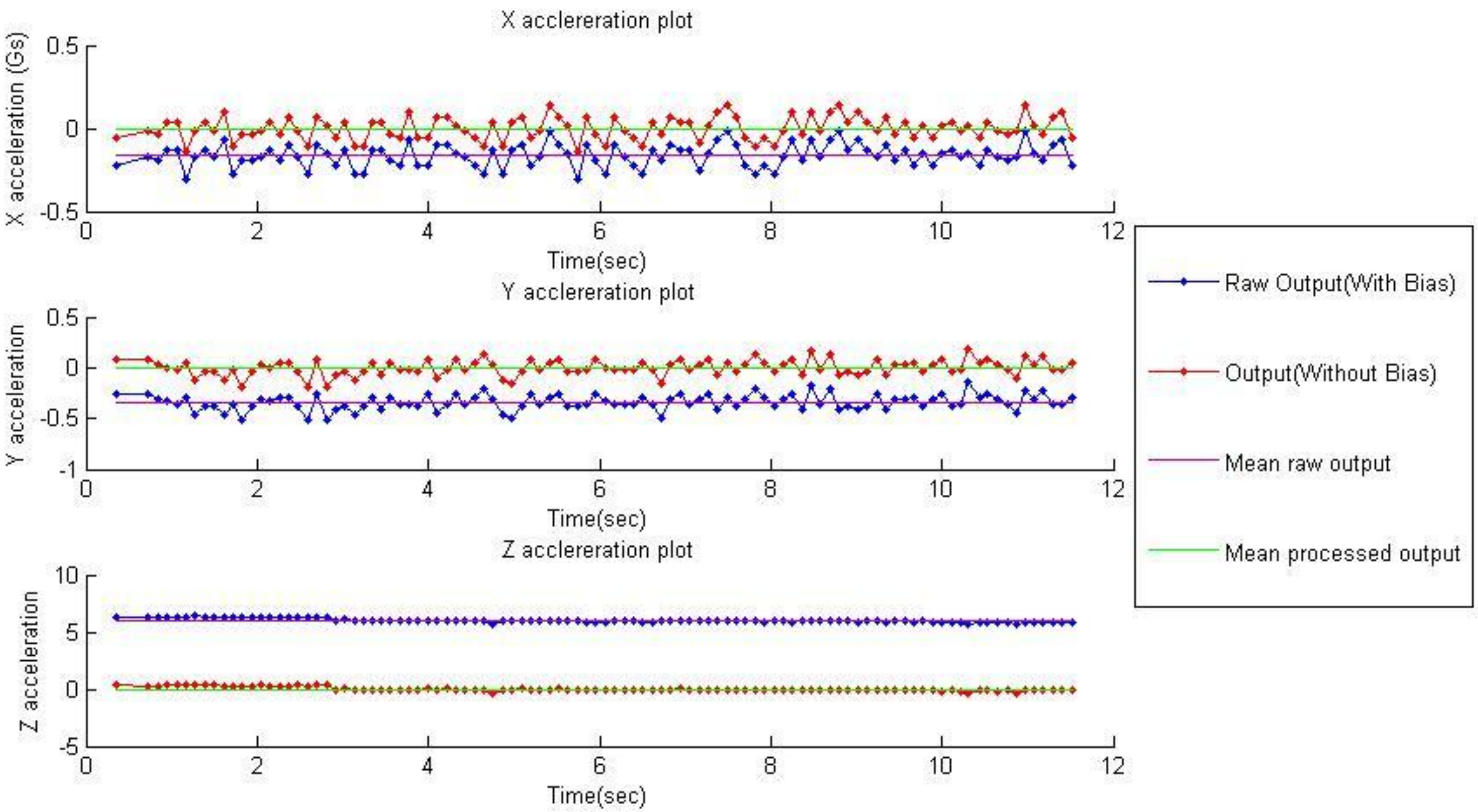
SerAccel V5 Triple-Axis Accelerometer

- Triple axis accelerometer- Gives the accelerations in mutually perpendicular X,Y & Z axes.
- It had to be calibrated before it was used with the help of the inbuilt firmware.
- It was used as a tilt sensor.

Accelerometer Biases(Stationary)

Bias Values(g)

X=-0.1642
Y=-0.3385
Z=+5.9899



Accelerometer as Tilt Sensor

- Tilt Calculation

$$tilt = (180/\pi) * \cos^{-1}(accl_{xyz} / accl_z)$$

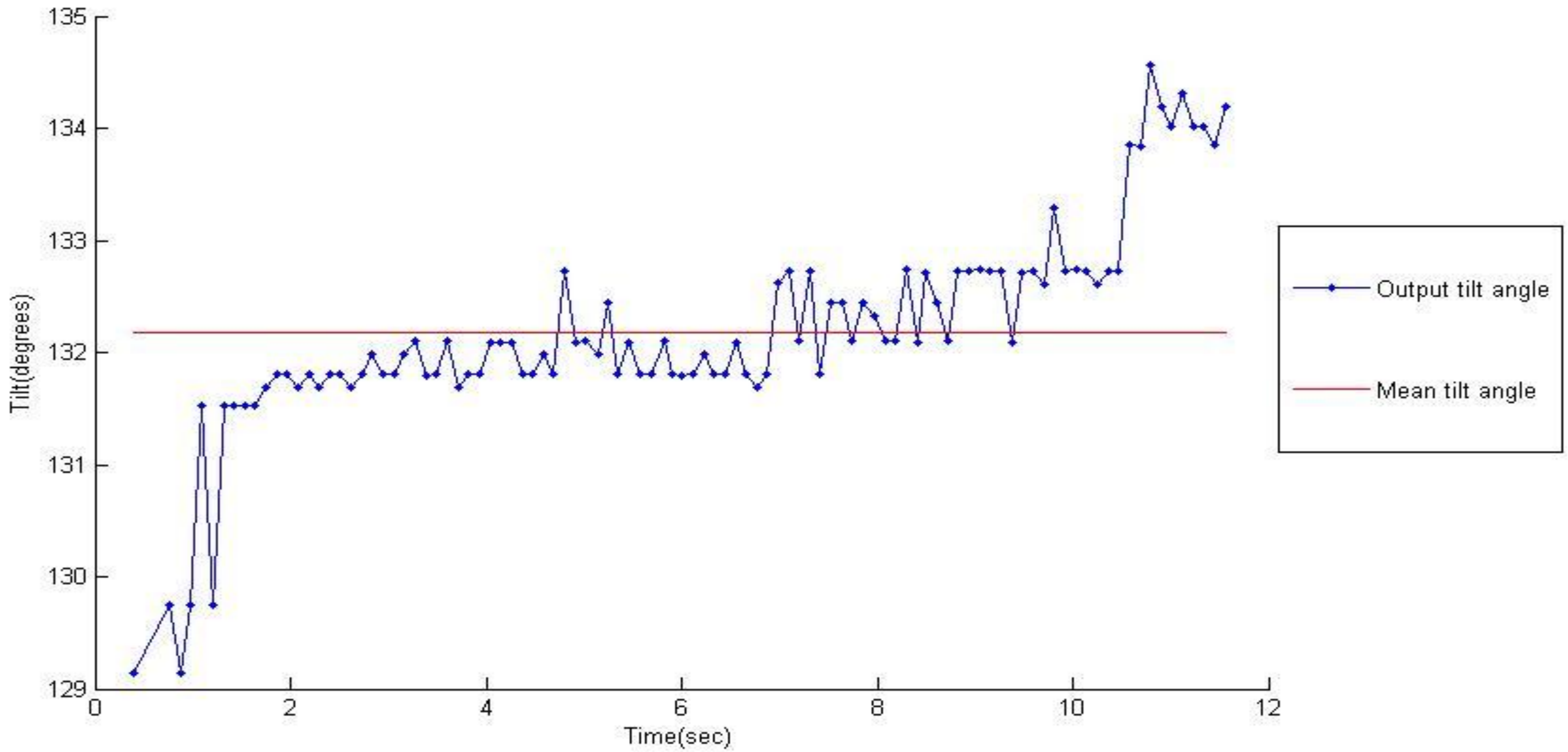
Where,

$$accl_{xy} = \sqrt{accl_x^{\ 2} + accl_y^{\ 2}}$$

$$accl_{xyz} = \sqrt{accl_{xy}^{\ 2} + accl_z^{\ 2}}$$

accl represents the acceleration and the subscripts refer to the axis.

Accelerometer Tilt Plot



Approximately 130 degrees about x axis(example)

Inertial Measurement Unit(IMU)

- Crossbow DMU RGA300CA was used for acceleration and orientation measurements.
- It gives accelerations about XYZ axes and the roll, pitch and yaw rates of the dynamic system.
- The firmware has an option to detect the biases and correct them.

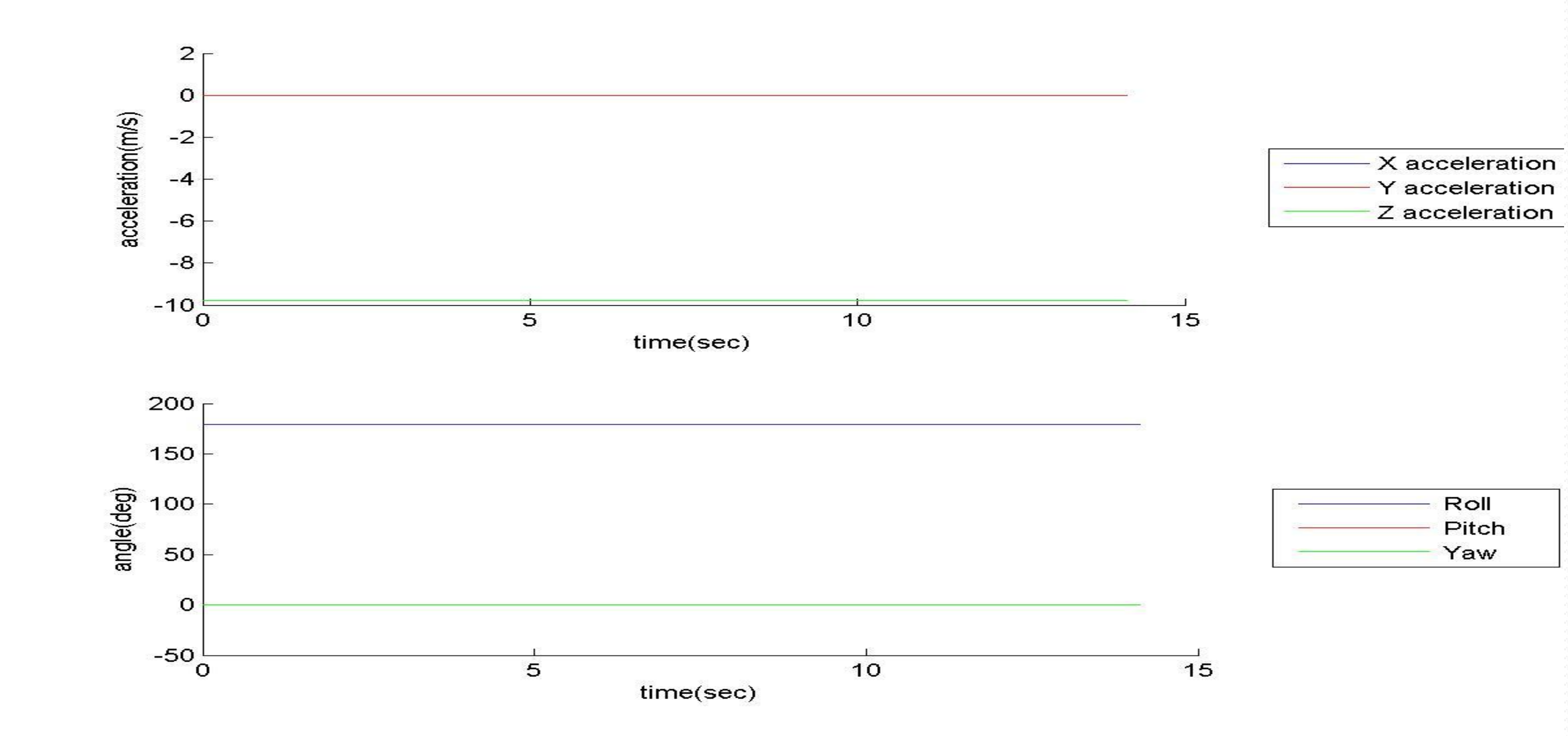
IMU Data-Packet

Bit	Data	Bit	Data
0	Header(0xAA)	12	Acceleration Z(MSB)
1	Header (0x55)	13	Acceleration Z(MSB)
2	Roll Angle(MSB)	14	Time(MSB)
3	Roll Angle(LSB)	15	Time(LSB)
4	Pitch Angle(MSB)	16	Temp Voltage(MSB)
5	Pitch Angle(LSB)	17	Temp Voltage(LSB)
6	Yaw Rate(MSB)	18	Part Number(MSB)
7	Yaw Rate(LSB)	19	Part Number(LSB)
8	Acceleration X(MSB)	20	Bit(MSB)
9	Acceleration X(LSB)	21	Bit(LSB)
10	Acceleration Y(MSB)	22	Checksum(MSB)
11	Acceleration Y(LSB)	23	Checksum(LSB)

IMU Commands

Command ASCII	Response	Description
R	H	Ping: Pings DMU to verify communications.
P	None	Change to polled mode. Data packets sent when a G is received by the DMU.
C	None	Change to continuous data transmit mode
G	Data Packet	Get Data: Requests a packet of data from the DMU.
z <0-255>	Z	Calibrate and set zero bias for rate sensors by averaging over time.
b	Change baud rate	Autobaud detection.
S	ASCII String	Query DMU serial number.
v	ASCII String	Query DMU version ID string.

Orientation Using IMU



Z axis pointing up(Upside down)

IMU Formulae

- Acceleration,

$$accel = data*(GR*1.5)/2^{15}$$

- Angular rate,

$$rate = data*(AR*1.5)/2^{15}$$

- Angle,

$$angle = data*(SCALE)/2^{15}$$

GR= 2 (G Range)
AR=100 (Angular Rate Range)
SCALE=180 (Angular Range)

Kalman Filter

Salient Features:-

- Noise smoothing (improve noisy measurements)
- State estimation (for state feedback)
- Recursive (computes next estimate using only most recent measurement)

Kalman Filter Formulation

$$\mathbf{x}(k) = \mathbf{F}(k)\mathbf{x}(k-1) + \mathbf{B}(k)\mathbf{u}(k) + \mathbf{G}(k)\mathbf{v}(k)$$ **-System Model**

$$\mathbf{z}(k) = \mathbf{H}(k)\mathbf{x}(k) + \mathbf{w}(k)$$ **- Update Model**

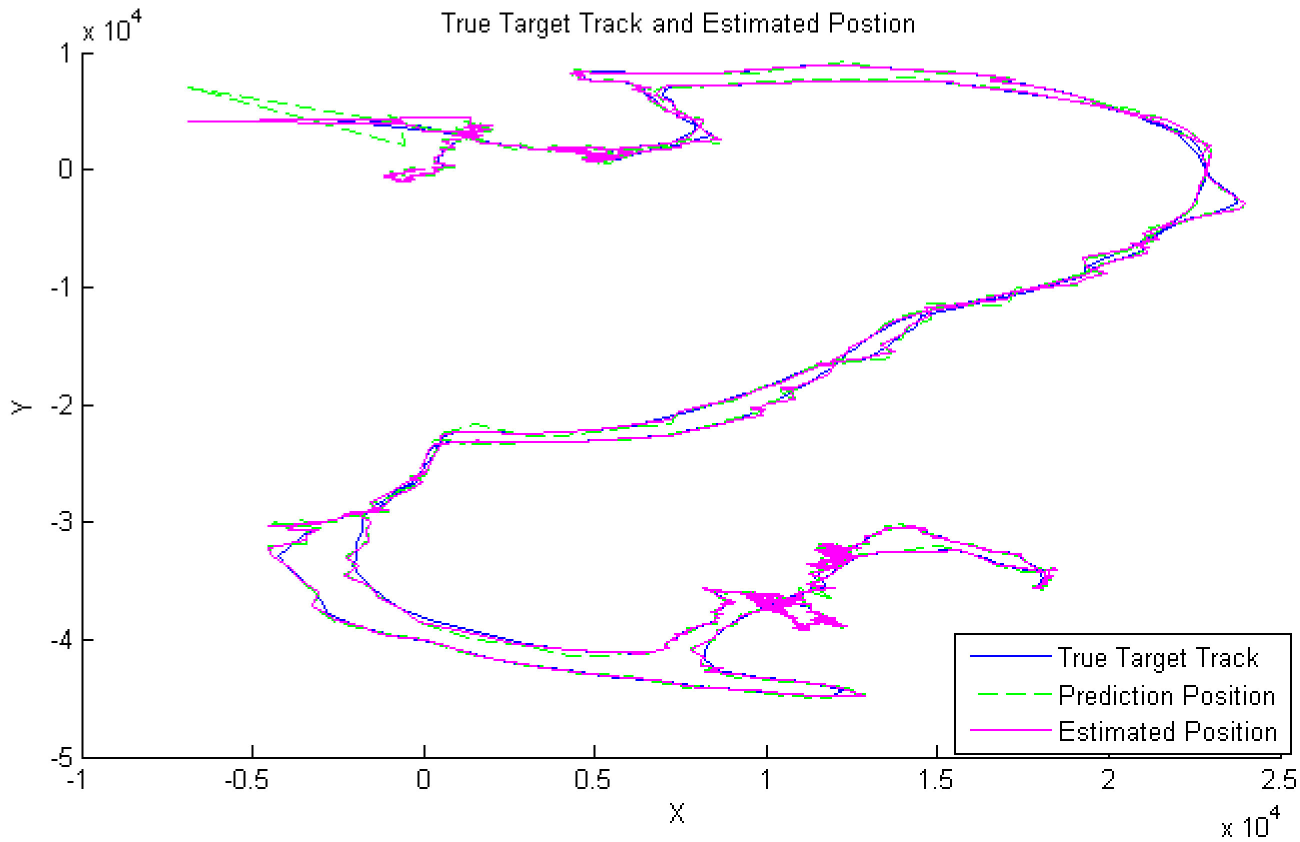
- x is state matrix
- z is observation
- u is an input (or control) vector
- v is some additive noise
- w is observation noise
- H is observation matrix
- B and G are input and noise transition matrices
- F is the state transition matrix
- k,k-1 are time steps

Kalman Filter Steps

- Project the state ahead $$x(k/k-1) = F * x(k-1)$$
- Project the covariance ahead $$P(k) = F * P(k-1) * F^T + Q$$
- Compute the kalman gain $$W(k) = P(k) * H^T * (H * P(k) * H^T + R)$$
- Update the state estimate $$x(k/k) = x(k/k-1) + W(k) * \left(z(k) - H * x(k/k-1)\right)$$
- Update the covariance $$P(k) = \left(I - W(k) * H\right) * P(k-1)$$

P is covariance matrix, Q and R are covariances of errors in state and observation models.

GPS Kalman Filtered Data



GPS path plot of Engineering Auditorium to Arts Canteen

- **Conclusions**
  - Accelerometer was used as a tilt sensor
  - GPS was used to track the position
  - INS was used to find the orientation

- **Further Improvements**
  - Implementation of an extended kalman filter to get the orientation and position from the INS

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THANK YOU