Design of GNSS Aided Inertial Navigation System

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Introduction

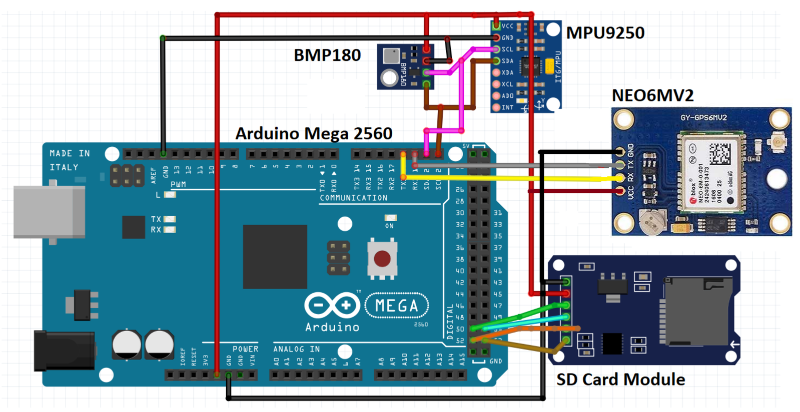
- This project integrates INS and GPS technologies into a robust navigation system, enhancing accuracy and reliability across various applications.
- By leveraging INS for high-frequency data and GPS for globally-referenced positioning, the system provides precise vehicle state estimation.
- Key components include an Inertial Measurement Unit (IMU) for acceleration and orientation, alongside GPS for speed and position calculations.
- This integrated system offers cost-effective solutions for precise navigation and positioning needs, contributing to ongoing advancements in navigation technology.

Specifications and Design Requirements

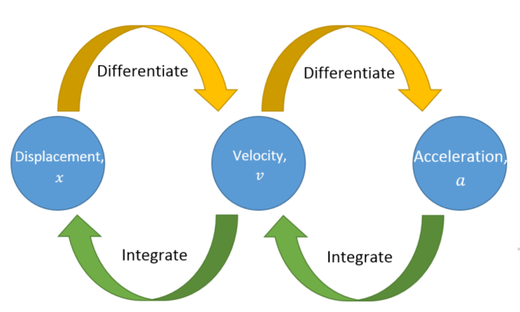
- The system includes a GPS module for location data, an IMU for position, velocity, and attitude (PVA) information, a microcontroller for data processing, a battery for power, and a display module for real-time visualization. Designed to operate continuously for 48 hours, the system must provide location data at a minimum frequency of 20 Hz, and the total weight should be under 1 kg for portability. The project balances cost, quality, and performance with affordable, high-quality components like the MPU-9250 IMU and GY-NEO6MV2 GPS. The design ensures compatibility and ease of integration, with future upgrades like solar power and rugged enclosures for extended use.

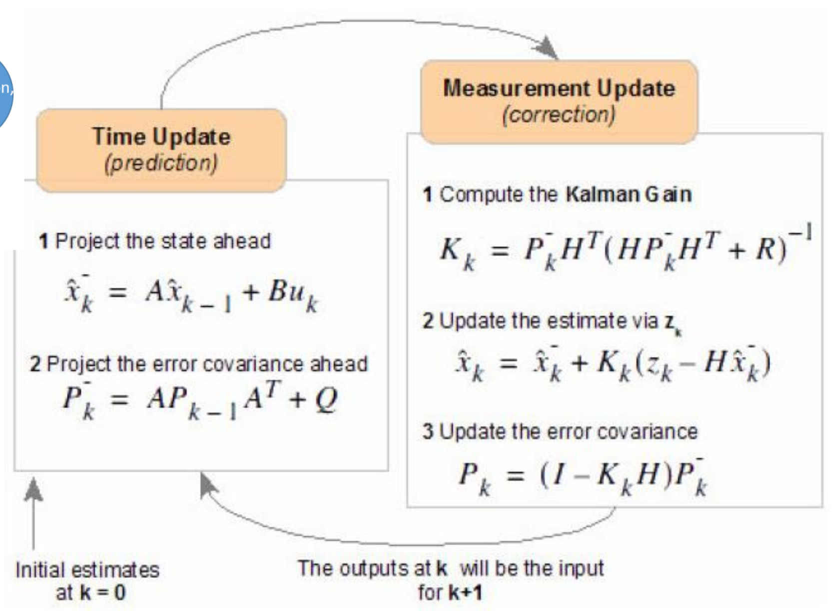
Solution Methodology

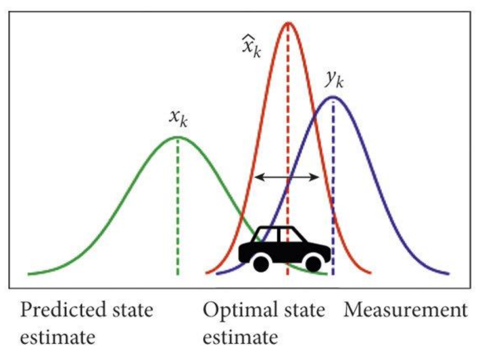
- For the mechanical solution, the MPU9250 was chosen for the 9-axis IMU, the NEO 6MV2 GPS was selected for its cost-effectiveness and ease of data processing, and the BMP180 pressure sensor was used to acquire altitude data. The Arduino Mega 2560 was chosen for its ample memory capacity, and an SD card was utilized for data recording. The Arduino IDE and C programming language were used for development.

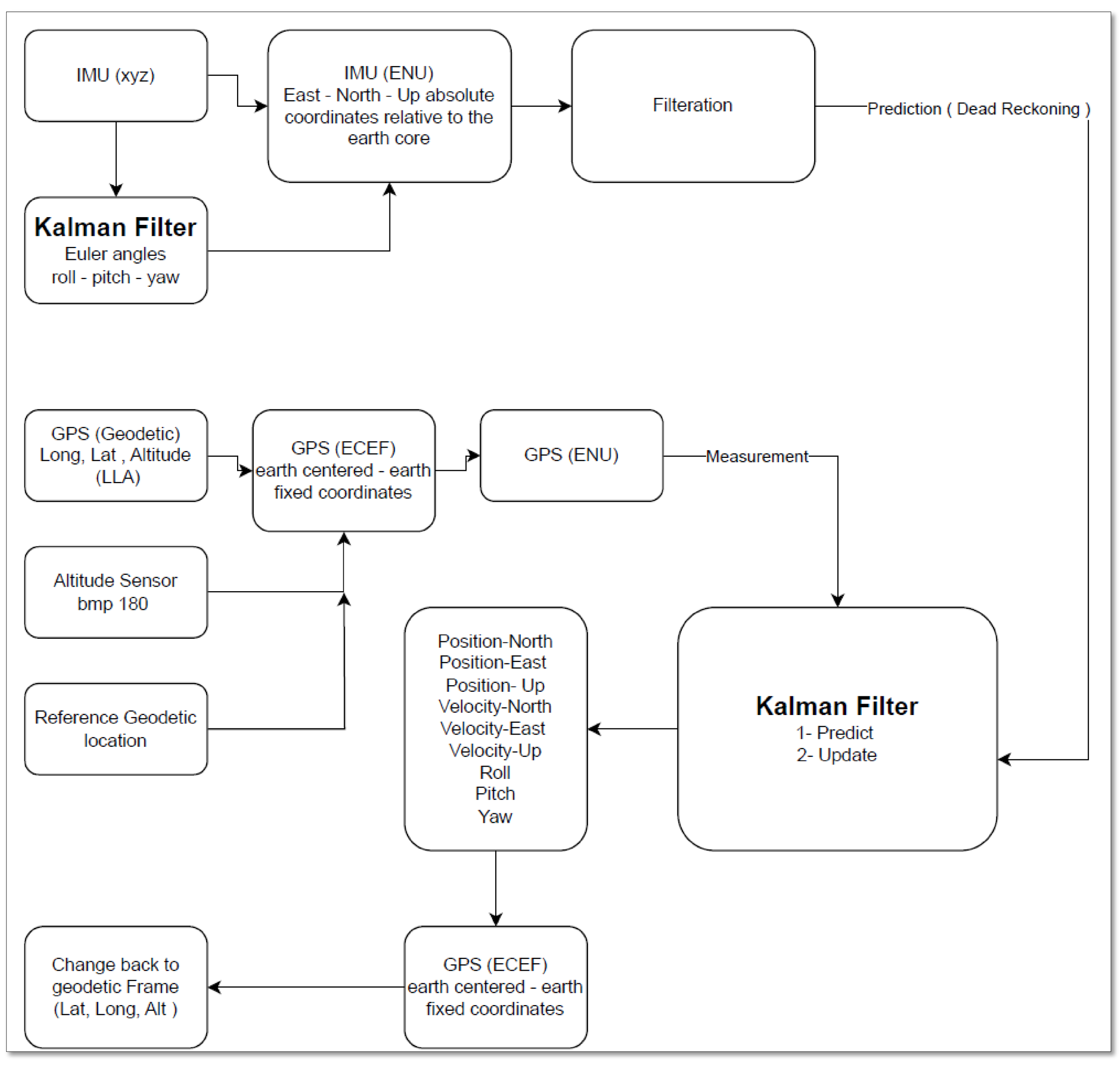


- To process and compare the data obtained from the IMU with the data from the GPS, double integration and Kalman filters were employed. This approach allows for achieving low error rates and stable results. Additionally, the IMU data enables the measurement of angles, velocities, and accelerations in three axes, which are also included in the Kalman filtering process to minimize errors.









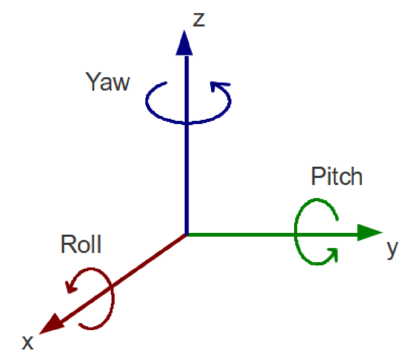
Application Areas

- The project is crucial for applications in satellites, autonomous vehicles, radar systems, military technologies, search and rescue operations, and map design. GNSS support further enhances reliability, making the system suitable for diverse industrial and military applications.

Results and Discussion

- Using the designed device, a pre-determined route was navigated by car. The recorded map data was satisfactory in most areas, though losses occurred at certain points due to buildings, trees, and overpasses along the route, as shown in the figure.

- The table displays data reflecting changes in yaw angle and the route direction, allowing the direction of magnetic north to be determined. However, it is not feasible to include all the data here. In addition to position and angle, the device accurately records angular velocity, angular acceleration, and altitude with low error margins. For instance, while the altitude of the route is between 880-890 meters, measurements were taken at 850-860 meters.



OutLAT	OutLONG	OutALT	K_VelE	K_VelN	K_VelU	K_Roll	K_Pitc	K_Yaww
39.91515731811	32.86330413818	4404581.500000	-0.011031	-0.000486	-1324942.500000	1.100564	-5.830266	3.352586
39.91515731811	32.86330413818	2904149.500000	-0.009858	-0.000283	-2198453.500000	1.128477	-5.842186	3.434333
39.91507720947	32.86354064941	852.000000	0.039587	0.089541	0.539584	0.572619	-5.617130	0.327428
39.91507720947	32.86354064941	852.000000	0.020739	0.176605	0.405369	0.531129	-5.603765	0.395842
39.91509246826	32.86363601684	852.500000	0.575413	0.805039	-0.648987	2.219060	-6.404551	-10.260207
39.91509246826	32.86363601684	852.500000	0.483388	0.741277	-0.642077	2.226911	-6.381000	-10.592989
39.91509246826	32.86363220214	853.000000	0.373994	0.058710	-0.047451	2.607161	-6.308275	-37.225875
39.91509246826	32.86363220214	853.000000	0.384543	0.082317	-0.135846	2.614608	-6.307820	-37.709320
39.91509246826	32.86363220214	853.000000	0.338937	0.033019	0.302164	2.991895	-6.334848	-63.212814
39.91509246826	32.86363220214	853.000000	0.334312	0.018673	0.327027	2.994378	-6.334864	-63.435901
39.91514587402	32.86357498168	852.000000	0.349347	0.031346	0.012170	3.195854	-6.346333	-79.398590
39.91514587402	32.86357498168	852.000000	0.340388	0.003825	0.109490	3.196264	-6.347496	-79.463157
39.91508865356	32.86342620849	851.500000	0.365562	0.035109	-0.081168	3.280148	-6.363314	-84.893997
39.91508865356	32.86343002319	851.500000	0.352479	0.001521	0.055213	3.280931	-6.362181	-84.885162
39.91511154174	32.86344909667	852.500000	0.766458	-0.471367	0.084846	2.927591	-7.304505	-89.812759
39.91511154174	32.86344909667	852.500000	0.919392	-0.389473	0.004424	3.018569	-7.260530	-89.626541
39.91512680053	32.86345672607	852.500000	-0.874085	0.030548	0.793745	1.642068	-5.794146	-72.825500
39.91512680053	32.86345672607	852.500000	-0.754975	0.105290	0.594894	1.724107	-5.836759	-71.958984
39.91517639160	32.86338043212	852.000000	-0.925068	0.204625	0.762724	0.770638	-6.820237	-56.490459
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39.91517639160	32.86338424682	851.000000	0.187523	-0.292789	0.481506	2.998745	-4.586620	-22.873538
39.91517639160	32.86338424682	851.000000	0.189889	-0.224351	0.415501	3.038007	-4.505433	-21.263156
39.91518020629	32.86338806152	851.000000	0.233202	-0.030371	-0.053518	1.997936	-5.062545	32.299926
39.91518020629	32.86338424682	851.000000	0.225029	-0.027289	0.052132	2.014822	-5.080649	32.786041
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39.91518020629	32.86338424682	851.000000	0.219649	-0.055223	0.094716	1.332813	-5.905180	63.117393
39.91518020629	32.86338424682	851.500000	0.286761	0.022213	0.763901	0.719837	-6.048598	82.807518
39.91518020629	32.86338424682	851.500000	0.096092	-0.044386	0.681906	0.721248	-6.001598	83.484619

- The device records data at a minimum frequency of 30 Hz. Based on the current consumption, the used power bank provides an operational duration of 100 hours.
- **Development Potential:** The project could be further improved with a better GPS antenna, a custom-designed circuit board, and a 3D-printed enclosure tailored to the project. With a good budget, this project could deliver excellent results, and even in areas where GPS signals are weak, the IMU data alone could resolve positioning issues.

References

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