NAVIGATING THE SPORTS FIELD
Purpose

- Car Racing
- Television Broadcast Enhancement
- Internet Simulcast
Challenges

- Track 43 race cars in real time
- Real time telemetry
- Better than 1 meter accuracy
- High vibration and temperature environment
- Integrate with live video broadcast
- Rapid installation
- High reliability
Tracking Technologies

- GPS
- Optical tracking in video
- Manual tracking in video
- Custom RF based system
- Timing loops
System overview

GPS Rx

GPS Rx

GPS Rx

Telemetry

Telemetry

Telemetry

Telemetry

Telemetry

Telemetry

Telemetry

Telemetry

Telemetry

Video Time Code

GPS 1PPS

Video/GPS Timing

Database and data Server

Video Graphics Generator

GPS Base Station
Time Synchronization

- Need to know GPS time when camera shutter is open
- Measures relative time between video time (VITC) and GPS time
GPS Segment

- L1/L2 Survey Grade Receiver (NovAtel)
- RTK
- Runs in Differential, RT20 and RT2
- Local Reference Base Station
GPS Environment

- Track banked as much as 33 degrees blocks satellites
- Overhanging chain link fence
- High vibration
- 4 g acceleration
- Obstructions from structures
- High multipath
- Bridges over track
COTS GPS Deficiencies

- Subject to changes in satellite constellation
- Bridges caused outages
- Fence obstructs satellites
- RTK ambiguity resolution too slow
Visible Satellites

2001-07-15 17:00:00
Navigation Improvements

- Inertial navigation
- Track model constraint
- P/V filter
- Make up the data using inferences (reference lap)
Track Model

- Track elevation model accurate to 10cm
- Load track model into GPS receiver NVRAM
- Height model constraint in Diff and RT20
- Speeds RT2 ambiguity resolution from average of 55 sec to 24 sec
- Can track with 3 satellites
GPS Antenna

- L1/L2 active antenna
- Must not effect aerodynamics of car
- Metal roof car
- Install antenna in metal “soap dish”
- Fiberglass window
Inertial Navigation System

- Significantly improves performance
- Honeywell HG1700 5deg/hr
- Closely coupled integration
- IMU to antenna alignment
- Vehicle to body frame alignment
- Inertial frame alignment
Vehicle to Body Frame

- All IMUs are installed in “active lid”
- Active lid installation not consistent from car to car
- Manually measure vehicle to body frame
Body to Geographic Frame

- INS software can converge if body to geographic frame is known within 45 deg
- Faster alignment if initialization is within 20 deg
- Alignment time dependent upon acceleration dynamics
- Track model aids alignment (pitch and roll)
- GPS measures heading
GPS Antenna to IMU Alignment

- Test fixture
- Measure azimuth, elevation, and distance between IMU and antenna
- Compute x, y, z offset
Racecar Performance Measurements

- GPS gives accurate velocity vector of car travel
- IMU gives car orientation
- Slip is difference between direction car is traveling and direction car is pointing
- Driving line
Broadcast Segment

- Instrument broadcast camera to measure pan, tilt, and zoom (ptz) once per video frame (29.97 hz)
- Sample ptz synchronous with video frame
- Encode time and camera ID in video vertical blanking interval (VBI)
Camera Registration

- Location \((x,y,z)\) of camera
- Tilt level
- Pan offset
- Field of view map
Camera Model

- Registration parameters allow computation of transformation matrix between 2d video image and 3d world
- Pinhole camera model
- Camera location z coordinate changes with tilt
- Nodal position changes with zoom
Field Surprises

- Tandy TV antennas
- In-car camera telemetry transmitter interference
- GPS basestation interference from Homeland security camera