PROJECT CHRONO

Autonomous Vehicle Simulation Support in Chrono

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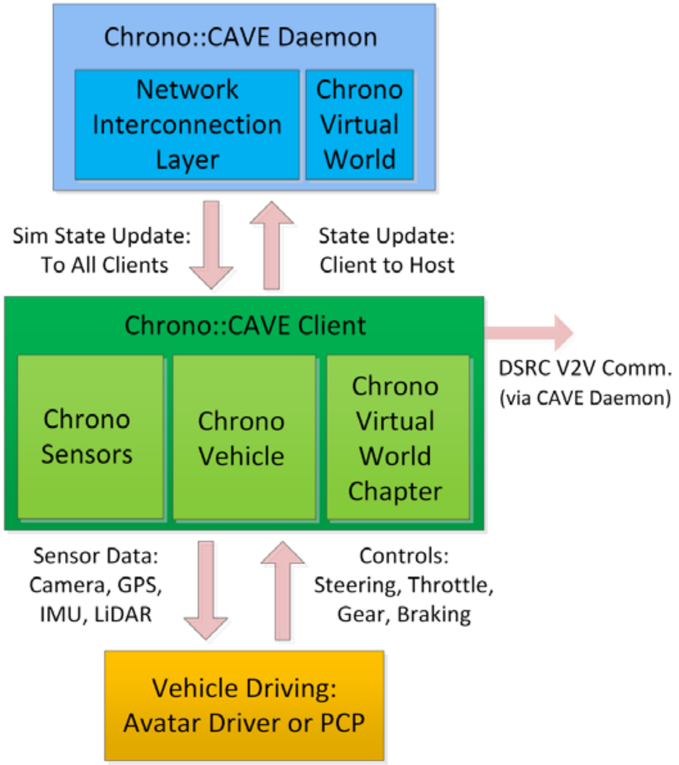
Connected Autonomous Vehicle Emulator

- Connected Autonomous Vehicle Emulator (CAVE)
  - Connected – simulated connectivity, V2V
  - Autonomous – Chrono sensors
  - Vehicle – Chrono vehicle support
  - Emulator – virtual world support

- Chrono::CAVE


Chrono::CAVE Daemon
Network Interconnection Layer
Chrono Virtual World
Sim State Update: To All Clients
State Update: Client to Host
Chrono::CAVE Client
Chrono Sensors
Chrono Vehicle
Chrono Virtual World Chapter
DSRC V2V Comm. (via CAVE Daemon)
Sensor Data: Camera, GPS, IMU, LiDAR
Controls: Steering, Throttle, Gear, Braking
Vehicle Driving: Avatar Driver or PCP

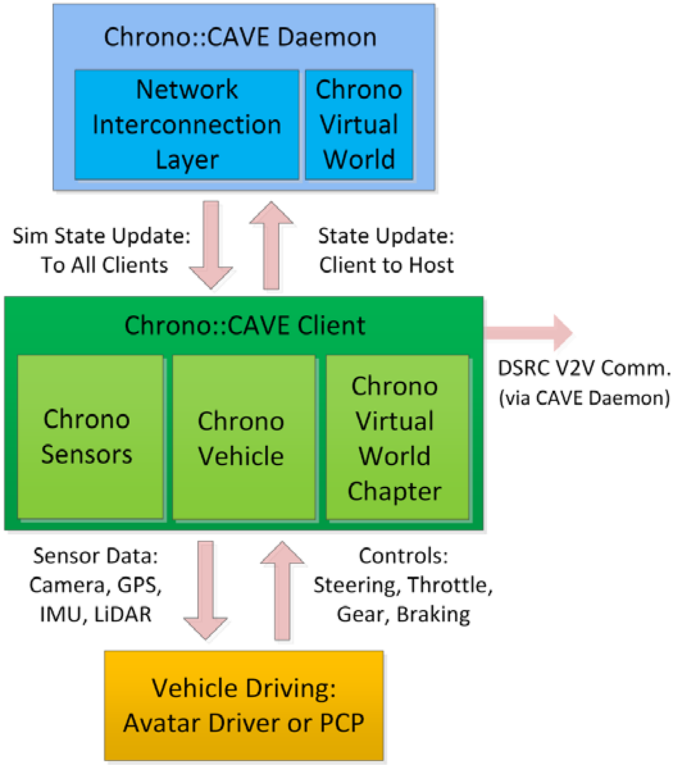
Server and Client

- Distributed Simulation
  - Server in Madison
  - Clients anywhere in world

- Server does not handle any physics

- Server passes agent and world data to Clients

- Clients pass agent data to Server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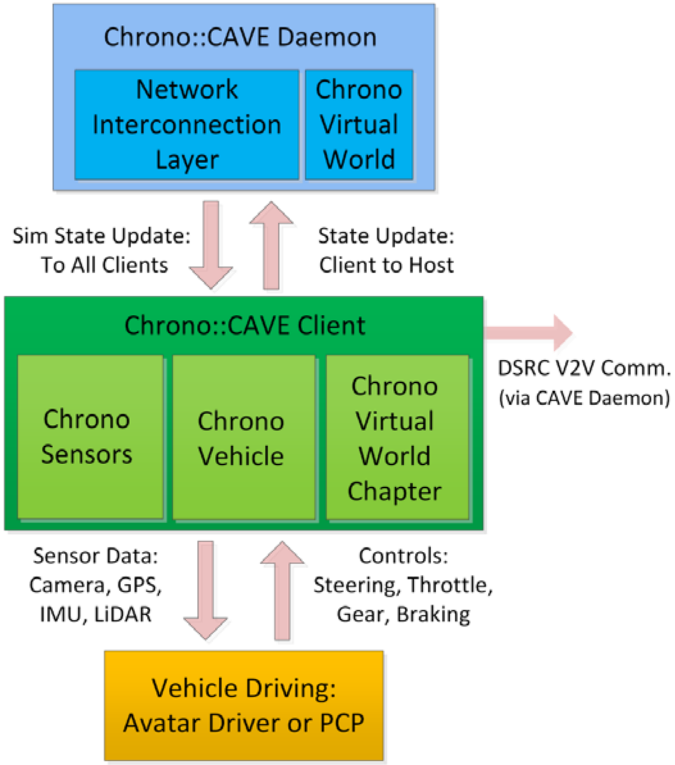
Server and Client

- Heartbeat
  - Agents must be able to reach next “real-world time” marker within a ΔT amount of computational time
    - “real-world time” marker are δt apart
    - ΔT called heartbeat
  - Fast agents sleep
- Interactive time for human agents
  - Soft real time
- Agents to play in Server
  - Autonomous vehicles
  - Avatar vehicles
  - Avatar pedestrians
  - Bicyclists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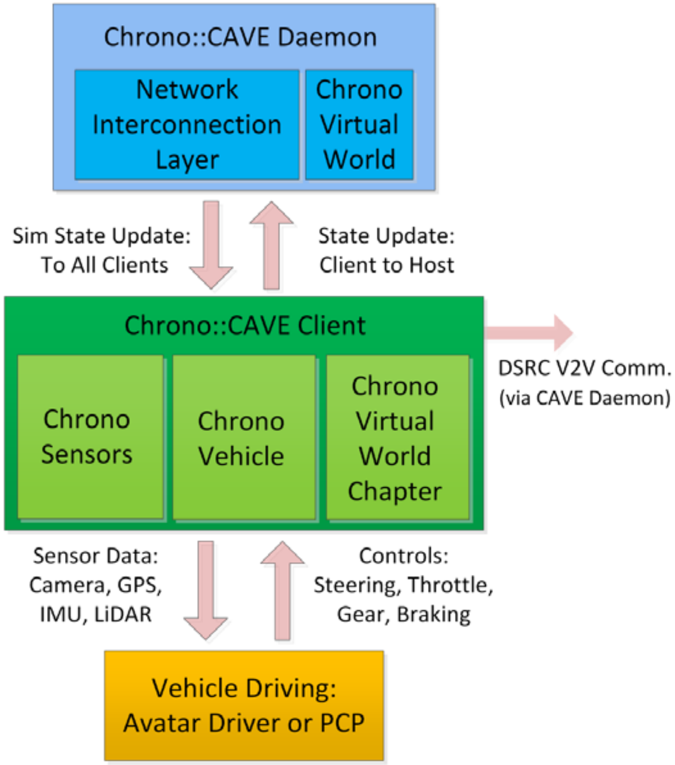
Simulating Connectivity in Chrono

- Simulated Connectivity
  - Vehicles send data directly to nearby agents
  - V2V communication

- Draws on a *Dedicated Short Range Communication* (DSRC) protocol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Sensor Support in Chrono

- Need to be able to simulate sensing
  - LiDAR
    - Sensor implemented without noise
    - Uses collision detection to determine ray length
  - GPS
    - Barebones sensor implemented
  - IMU
    - Barebones sensor implemented
  - Camera
    - Not currently supported, but next in line
    - Dependent on render engine

Sensor Construction (LiDAR)

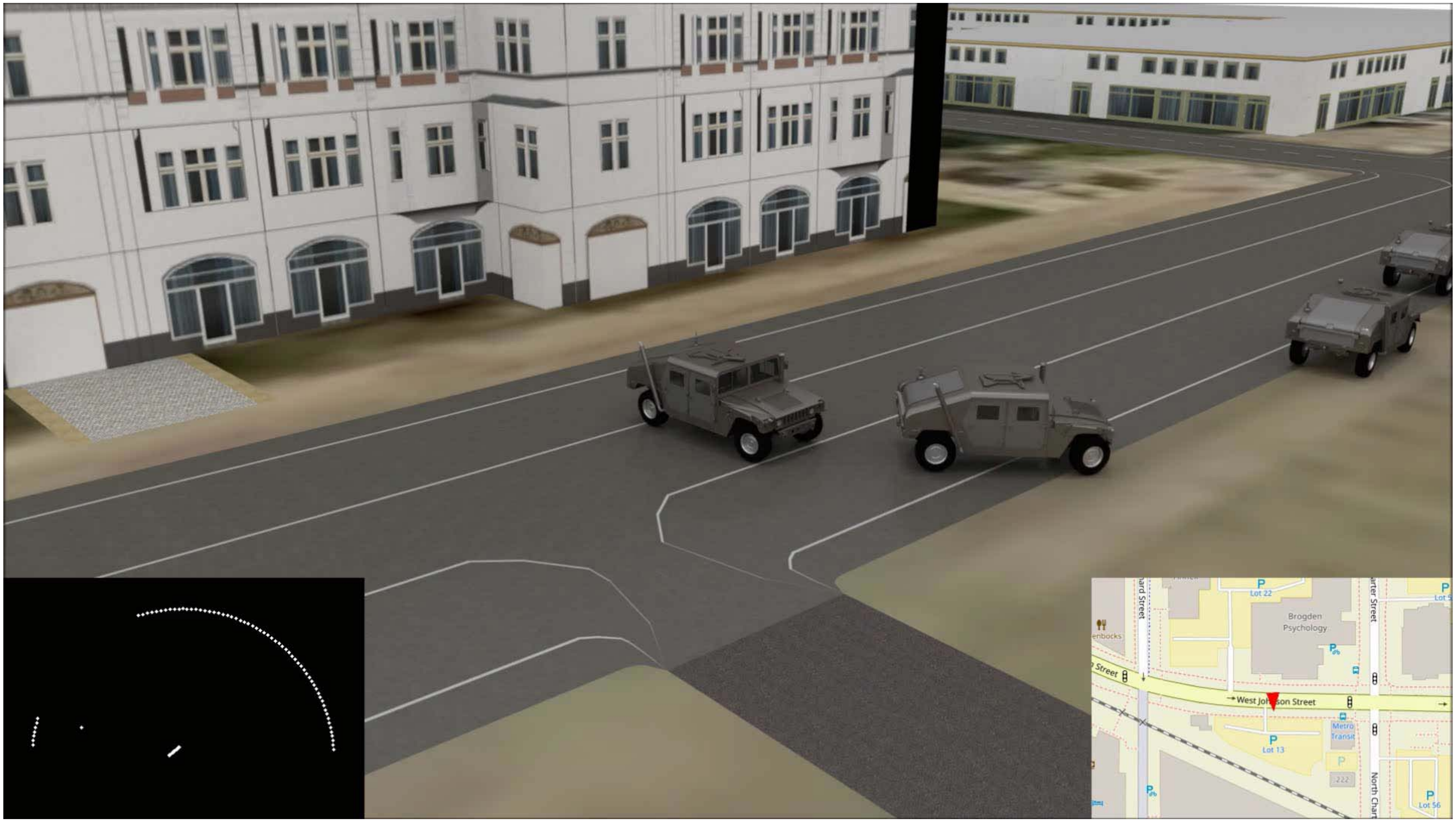
```
//In simulation setup
    std::shared_ptr<ChRaySensor> lidar = std::make_shared<ChRaySensor>(
        //parent body, update rate, visualize
        my_hmmwv.GetChassis()->GetBody(), 30, true);

    lidar->Initialize(chrono::ChCoordsys<double>(
        //offset position
        chrono::ChVector<double>({2.3, 0, 0}),
        //offset orientation
        chrono::ChQuaternion<double>(Q_from_NasaAngles({0, 0, 0}))),
        //samples about y, samples about z, y min/max angle,
        //z min/max angle, min dist, max dist
        1, 100, 0, 0, -1.5, 1.5, .2, 25);

//During simulation loop
    lidar->Update();

//To Get Data
    lidar->Ranges(); //returns vector containing distance for each ray
```

Virtual World

- Madison mesh in Chrono from Infraworks/Open Street Maps

- Future Virtual World
  - Based on physical world
    - Buildings, trees, terrain, signs, etc.
  - Environmental effects
    - Rain, snow, ice, fog, etc.

CAVE Demonstration



Future Work

- Server
  - Heartbeat to mandate consistent simulation progression
  - Scaling to allow multi-agent connectivity

- Sensors
  - Expanded sensor capabilities as a module for feedback in Chrono
    - Camera
  - Physically realistic noise models

- Virtual World
  - Physically realistic virtual world
  - Chunk loading management in Chrono
  - Environmental effects