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AN APPLICATION OF DSRC BETWEEN CONNECTED VEHICLES AND INTELLIGENT TRANSPORTATION SYSTEMS

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Introduction

ITS optimization algorithm

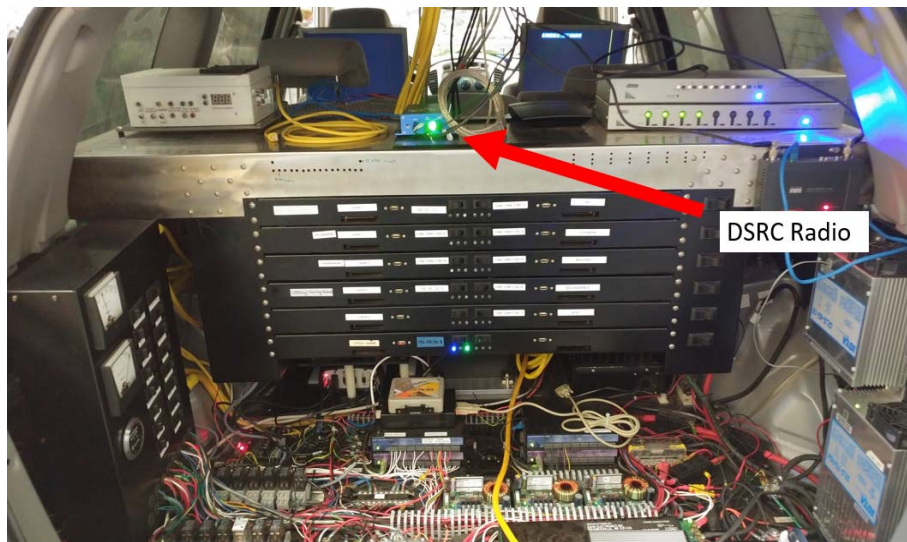
- Speed, Heading, Position, Size, Capabilities and Intent
- Works with connected and non connected vehicles
- Determines a recommended trajectory for DSRC Vehicles

Autonomous Connected Vehicle

- Navigator: Participated in 2007 DARPA Urban Challenge
- Uses Joint Architecture for Unmanned Systems (J.A.U.S.)
- OBU will act as sensor that reports to Situation Assessment Specialist



OBU/RSU



Navigator



Ubuntu Server

Connected Approach Message

Element	Data Type
MsgCount DHour DMinute Lane Number Served DSRCmsgID	uint8_t
DSecond VehicleLength MaxAcceleration MaxDeceleration Speed Heading Dsecond Lat Uncertainty Long Uncertainty	uint16_t
TemporaryID	uint32_t
Latitude Longitude	int32_t

```

ConnectedApproachMessage ::= SEQUENCE {
    msgID          DSRCmsgID,          -x- 1 byte

    -- Sent as a single octet blob
    blob1         CSMBlob,
    --
    -- The blob consists of the following 33 packed bytes
    --
    -- msgCnt      MsgCount,           -x- 1 byte
    -- id         TemporaryID,         -x- 4 bytes
    -- hourMark   DHour,               -x- 1 byte
    -- minMark    DMinute,             -x- 1 byte
    -- secMark    DSecond,             -x- 2 bytes

    -- pos PositionLocal2D,
    --   lat      Latitude,            -x- 4 bytes
    --   long     Longitude,           -x- 4 bytes
    --   head     Heading,             -x- 2 bytes
    --   latU     LatUncert,           -x- 2 bytes
    --   longU    LongUncert,          -x- 2 bytes

    -- direct Direction
    --   speed    Speed,               -x- 2 bytes
    --   laneNumb LaneNumber,          -x- 1 byte

    -- info VehicleInfo
    --   length   VehicleLength,       -x- 2 bytes
    --   maxAcc   MaxAcceleration,     -x- 2 bytes
    --   maxDec   MacDeceleration,     -x- 2 bytes
    --   served   Served,              -x- 1 byte
    ... -- # LOCAL_CONTENT
}

```

Intersection Approach Message

IAM Blob

ASN.1 Representation:

```
IAMblob ::= OCTET STRING (SIZE(24))
-- Made up of the following 24 packed bytes
-- msgCnt           MsgCount,           -x- 1 byte
-- intID            IntersectionID,      -x- 2 bytes
-- hourMark         DHour,              -x- 1 byte
-- minMark          DMinute,            -x- 1 byte
-- secMark          DSecond,            -x- 2 bytes
-- tmpID            TemporaryID,        -x- 4 bytes
-- lat              Latitude,           -x- 4 bytes
-- long             Longitude,          -x- 4 bytes
-- firMin           DMinute,            -x- 1 byte
-- firSec           DSecond,            -x- 2 bytes
-- sigCol           SignalColor,        -x- 1 byte
-- poiCnt           Count,              -x- 1 byte
```

Position Points

ASN.1 Representation:

```
PositionPoints ::= OCTET STRING (SIZE(6..38))
-- To be made up of packed bytes as follows:
-- latOffset INTEGER (-32768..32767) (16 signed bits)
-- longOffset INTEGER (-32768..32767) (16 signed bits)
--   in 1/10th micro degrees
--   value 32767 to be used for 32767 or greater
--   value -32767 to be used for -32767 or less
--   value -32768 to be used for unavailable lat or long
-- timeOffset INTEGER (0..65535), (16 unsigned bits)
--   LSB units of 10 mSec
--   value 65534 to be used for unavailable
```


Flavet Field



Satellite Image

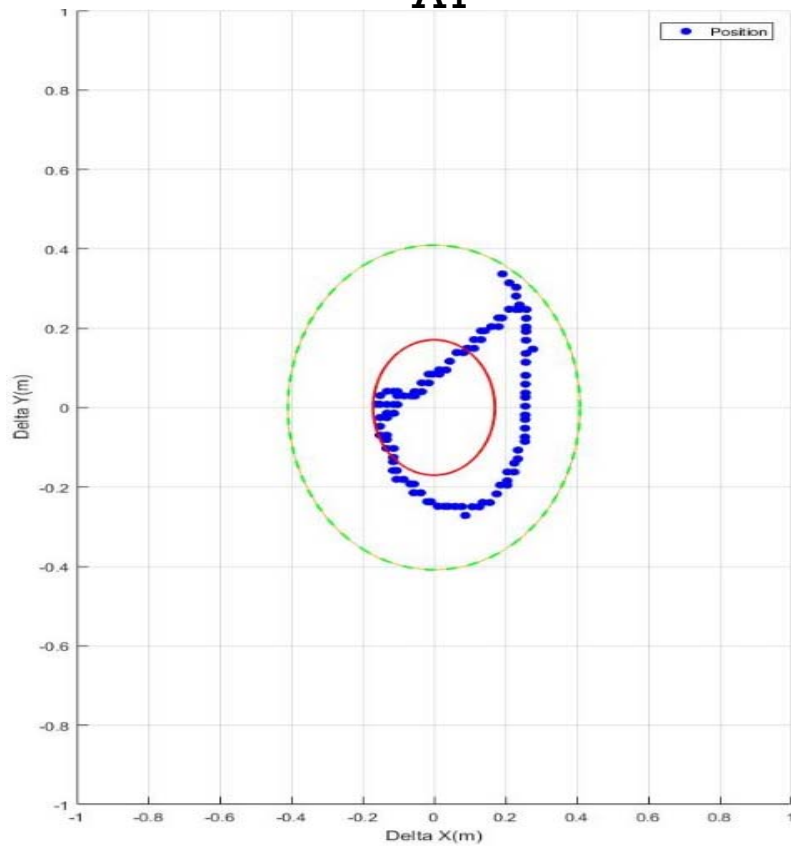


Marker embedded in the ground

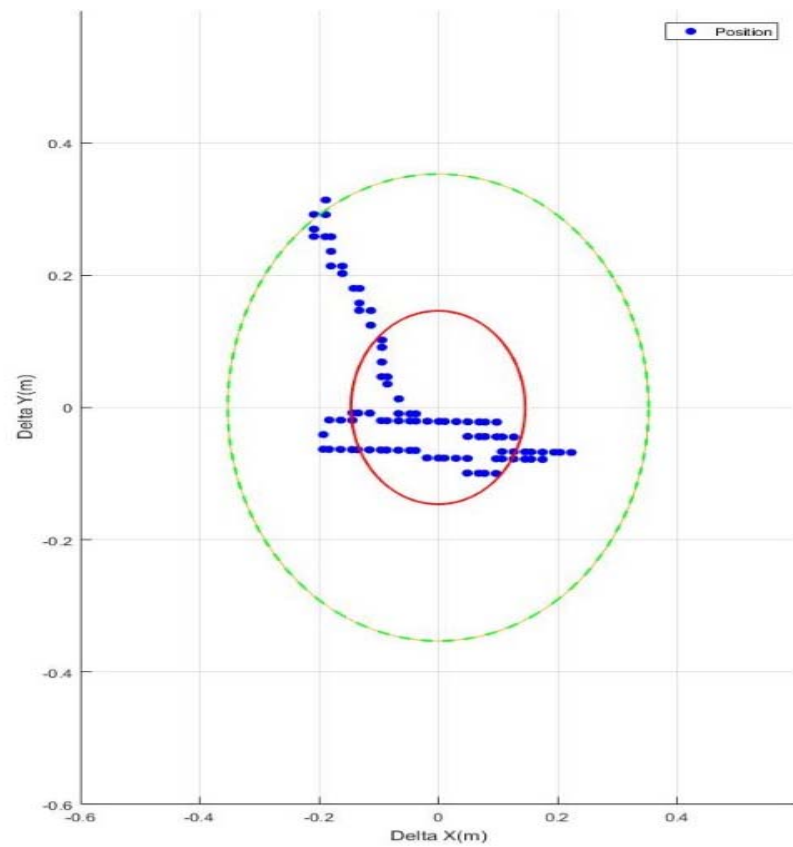
Note: Geomatics Markers have an accuracy of 10cm

Flavet Field

A1

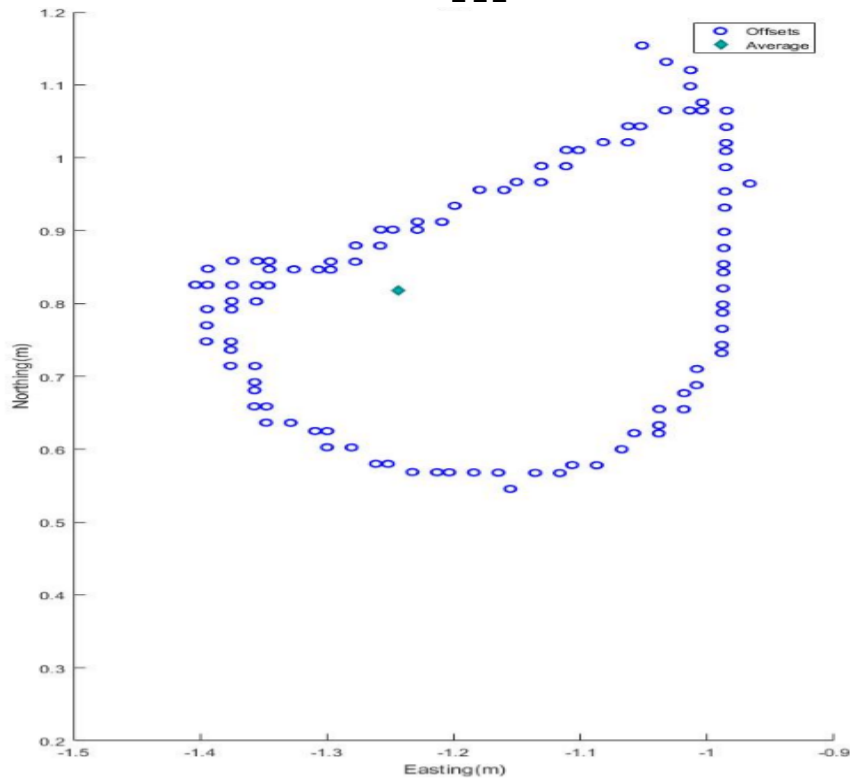


A2

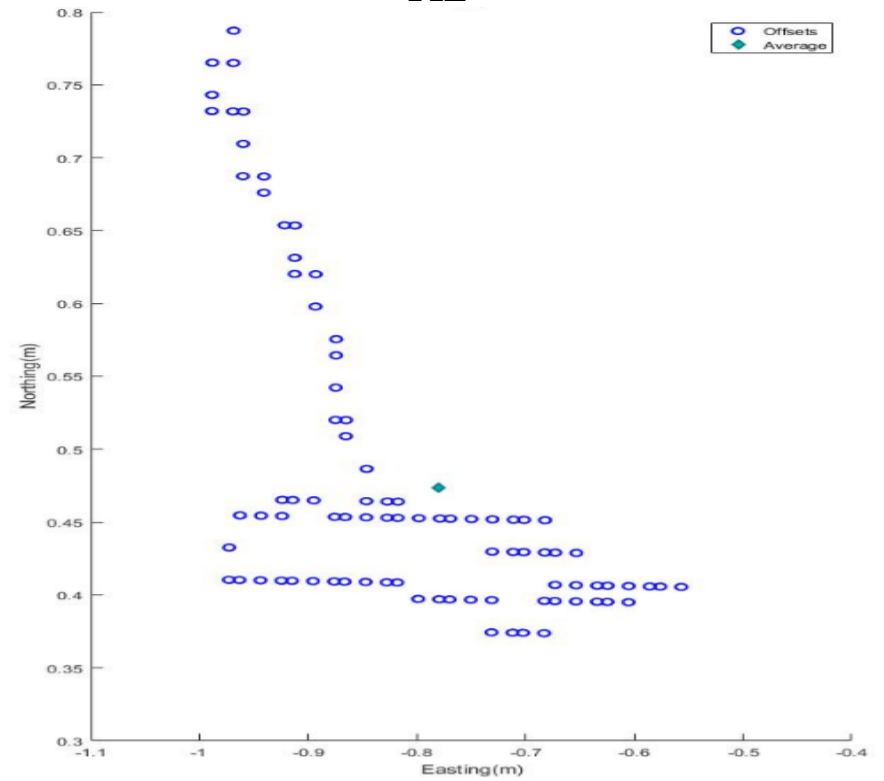


Flavet Field

A1



A2



Flavet Field

$$\sigma = \sqrt{\frac{1}{N} \sum_{i=1}^N (x_i - \mu)^2}$$

$$CEP = 0.59(\sigma_x + \sigma_y)$$

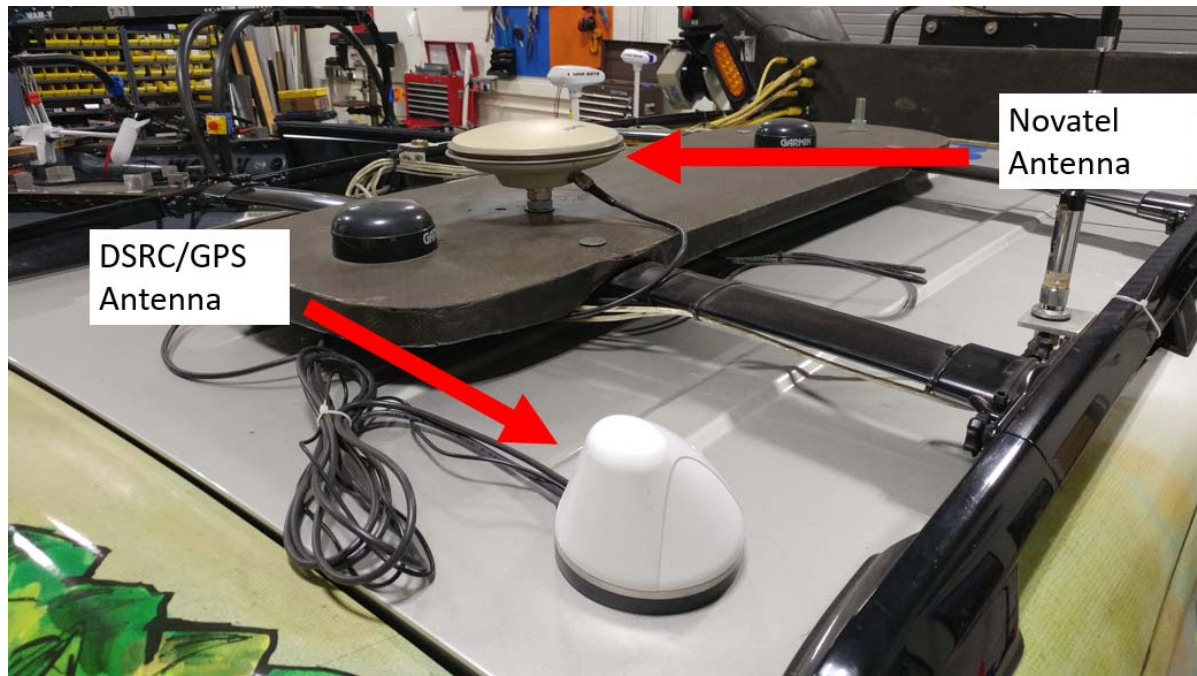
$$2DRMS = 2\sqrt{\sigma_x^2 + \sigma_y^2}$$

$$\mu = \frac{1}{N} \sum_{i=1}^N A_i$$

$$Var = \frac{1}{N-1} \sum_{i=1}^N |A_i - \mu|^2$$

Marker/Trial	A1	A2	F1	F2	G1	G2
CEP (cm)	17.0	14.6	25.4	23.4	20.9	13.2
2DRMS(cm)	40.1	35.3	64.6	57.9	50.4	31.7
Offset(m)	1.49	0.91	0.53	0.68	0.72	1.18
Variance(cm)	2.96	2.27	8.71	6.60	4.64	1.81

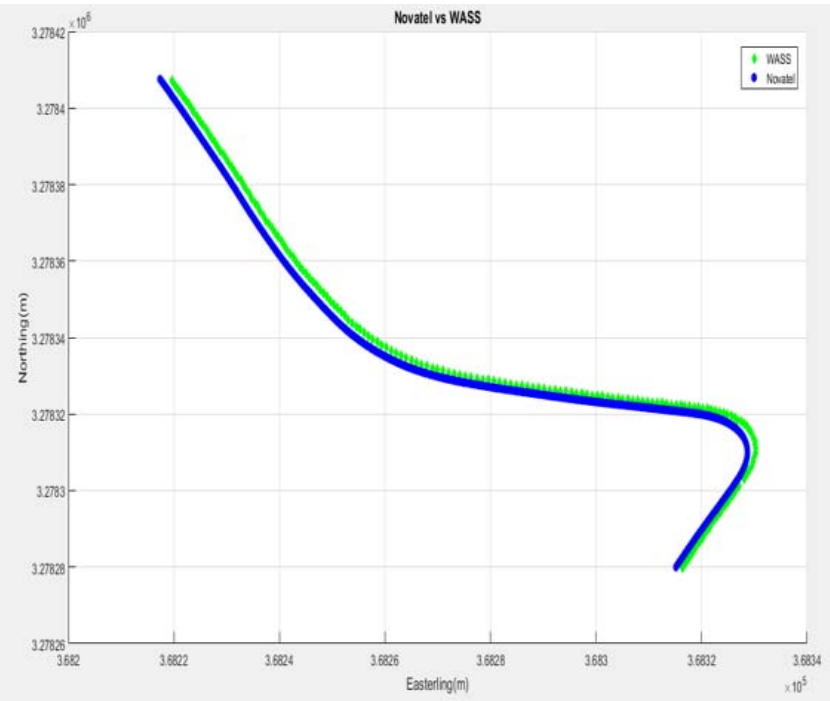
Solar Park



Solar Park



Satellite Image



UTM Plot

Traffic Engineering Research Laboratory (TERL)



$$\text{PER} = \frac{N_{IRx}}{N_{Rx}}$$

$$\text{TOA} = t_{Decoded} - t_{UTC}$$

Lane-Trial	2-1	2-2	2-3	8-1	8-2	8-3	1-1
PER (%)	0	0	0	0	0	0	0
Tx Pkts	542	557	562	613	576	586	2121
Lost Pkts	5	5	11	5	0	0	0
Bad Pkts	3	0	0	2	4	1	2
Max TOA	284	452	332	282	272	262	245
Min TOA	182	181	192	182	202	212	192
Avg TOA	188	226	207	224	207	215	196

Note: All reported TOA values are in units of milliseconds (mSecs)

Conclusion

GPS Accuracy and Precision

- 50% chance within 19.1cm
- 95% chance within 47.7cm
- Average offset $86.6 \pm 4.5\text{cm}$
- Novatel vs WAAS RMS: $2.25\text{m} \pm 50\text{cm}$

Communication Effectiveness

- 0% PER
- Average TOA: 206ms
- 5557 Tx Packets, 26 Lost (<0.5%Tx)
- 12 Bad Packets – all at the beginning

Future Work

Map Message

- OBU recognize ITS intersection
- Starts conversation

Human Driver Interface

- Improbable for human driver to follow trajectory
- Give them a recommended speed

```
ASN.1 Representation:
MapData ::= SEQUENCE {
msgID                DSRCmsgID2,
msgSubID             DSRCmsgSubID                OPTIONAL,
msgIssueRevision    MsgCount,
layerType           LayerType                   OPTIONAL,
layerID             LayerID                      OPTIONAL,
intersections       IntersectionGeometryList    OPTIONAL,
-- All Intersection definitions
-- NOTE:
-- other map data will be added here as it is defined
-- (curve warnings, construction routes, etc.)
-- as an example of this:
roadSegments        RoadSegmentList            OPTIONAL,
-- All roadway descriptions
dataParameters      DataParameters             OPTIONAL,
-- Any meta data regarding the map contents
restrictionList     RestrictionClassList       OPTIONAL,
-- Any restriction ID tables which have
-- established for these map entries
regional            RegionalMapData            OPTIONAL,
-- regional extensions
crc                 MsgCRC                     OPTIONAL,
-- The crc may be provided by other layers
-- and when encoding in UPER is not to be used
... -- # LOCAL_CONTENT
}
```



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