Intelligent Pilot Intent Analysis System (IPIAS) using Artificial Intelligence Techniques

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Authors: Dick Stottler stottler@stottlerhenke.com
Bonnie Schwartz Bonnie.Schwartz@wpafb.af.mil

Presented by: Dick Stottler

Introduction/Motivation

Strong desire to operate UAVs in National Airspace (NAS)

Don’t want to sacrifice operational tempo or safety

Terminal Area of Operations (TAO) most crowded/challenging

Difficult for remote pilots to maintain situational awareness

Real pilots predict what other pilots will do (predict trajectory)

IPIAS’s onboard purpose is to predict aircrafts’ trajectories

(Based on reasoning similar to a human pilot)

- Maintain mental model of other aircraft (locations/ ATC dialog)
- Knowledge of TAO procedures / specific airport

IPIAS uses Air Traffic Control Dialog and onboard sensors

Terminal Area of Operations

Sources of Information

- Air Traffic Control (ATC) Radio Traffic to/from pilot
- Airport Standard Procedures
- Onboard sensors
- Aircraft Model capabilities/size/restrictions
- Transponder position/velocity reports (track data)
- Weather
- Air traffic control advisories, Special Use Airspace, Temporary Flight Restrictions

Very large number of airports of different types

- Each has sets of procedures largely selected by weather
- Smaller airports less structured, include pilot instruction
  - Most municipal airports have NO control
  - Touch and gos

TAO Pilot Intent Prediction Challenges

ATC/pilot utterances must be interpreted

- Tail numbers/locations/aircraft type matched to actual aircraft
- “November one two three four you are number two clear to land behind the Cessna on short final”
- Highly variable audio quality

Speech recognition includes uncertainty

Which procedures are in effect must be determined

- These can change in the middle of operations
- Generally determined by weather, VFR/IFR

Human (ATC/Pilots) Error Diversions

Diverse Pilot Professionalism/Tendencies

Aircraft interactions (avoidance, separation, wake vortex)

Life Critical -> need very high success rate

Natural Language Processing Issues

Context: Who is talking, Which channel, Whom responding to, What's happened previously

Utterances grouped into dialogs, close together in time

High degree of redundancy, important information repeated

Important communication is highly structured

Unstructured communications are unimportant/ignorable

Not every word must be understood, just main concept/gist

Example Dialogs, Ground Channel

- Pilot: Ground, Southwest 6-22, Pushback Gate 23, Information, uh, Delta
- ATC: Southwest 6-22, San Jose Ground, Push Approved
- Pilot: Push Approved, Southwest 6-22
- …
- Pilot: Ground, Southwest 6-22 Taxiing
- ATC: Southwest 6-22, San Jose Ground, Runway 3-0-Right, Taxi via Foxtrot-Yankee
- Pilot: Foxtrot-Yankee, Runway 3-0-Right, Southwest 6-22

Clutter Dialog

Pilot: Ground, 2-8, Cactus-2-80

ATC: Cactus-2-80, San Jose Ground

Pilot: OK, *now* we gotcha

ATC: Cactus-2-80, did you need something?

Pilot: No, sir, just wanted to give you--couldn't hear you before, it was, uh, my problem

…

Pilot: Atlantic Aviation, San Jose, Astro 3-8-3-0-Foxtrot

ATC: Calling, San Jose, go ahead?

Pilot: Atlantic San Jose, Astro 3-8-3-0-Foxtrot, uh, we'll be there in about 15 Minutes

Pilot: [indiscernible]

ATC: All right, Copy that, 15 after'll be 2, and we'll be here till Wednesday, thanks

…

Pilot: Atlantic November-8-8-Whiskey-Romeo, we're hoping to be on the Ground there in about 10 minutes, just wanna give you a heads-up

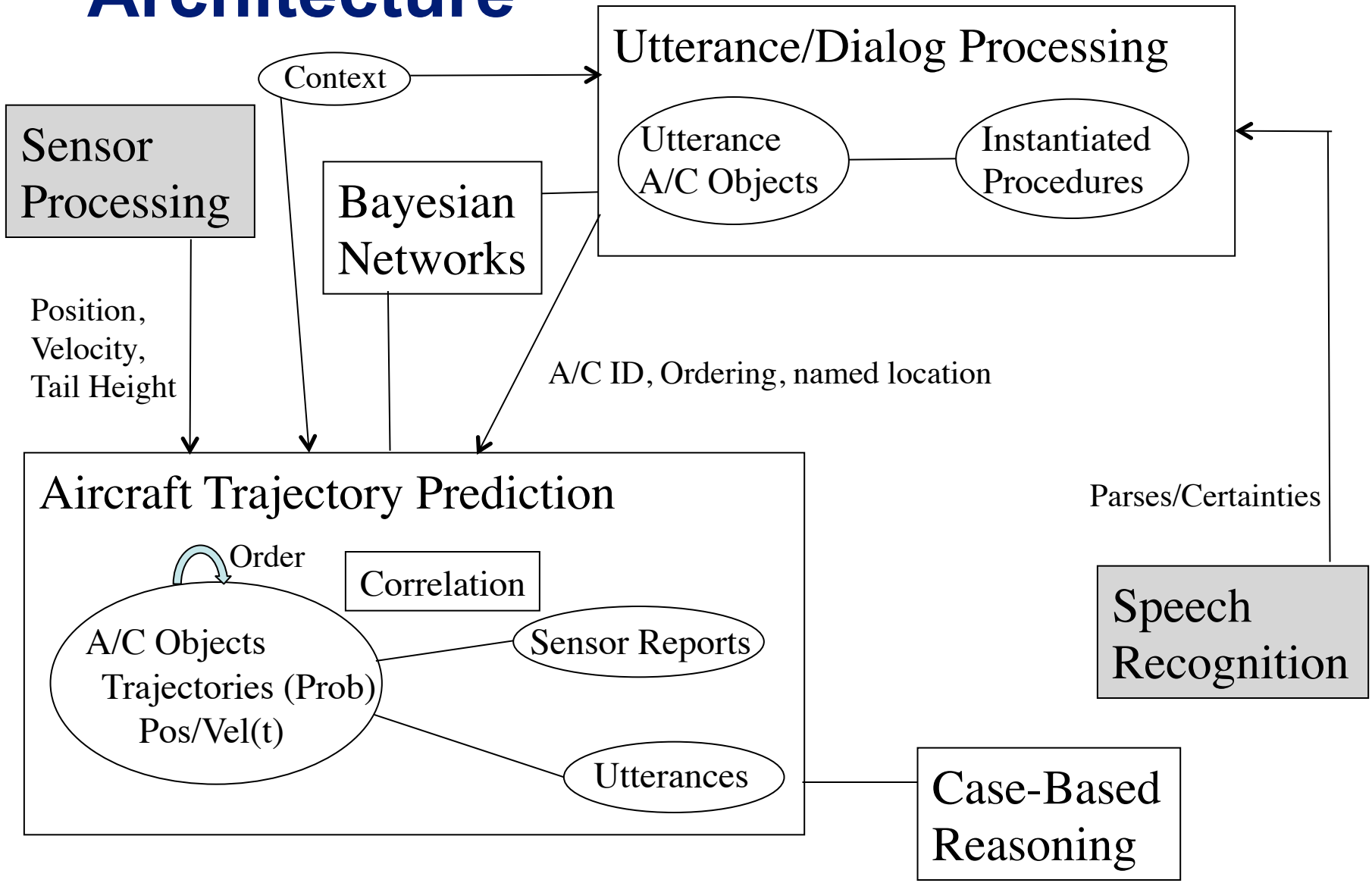
ATC: All right, thank you very much, and do you have anybody that needs a ride, do you have transportation, are you expecting that?

Pilot: No, we're coming in, uh, Crew Only

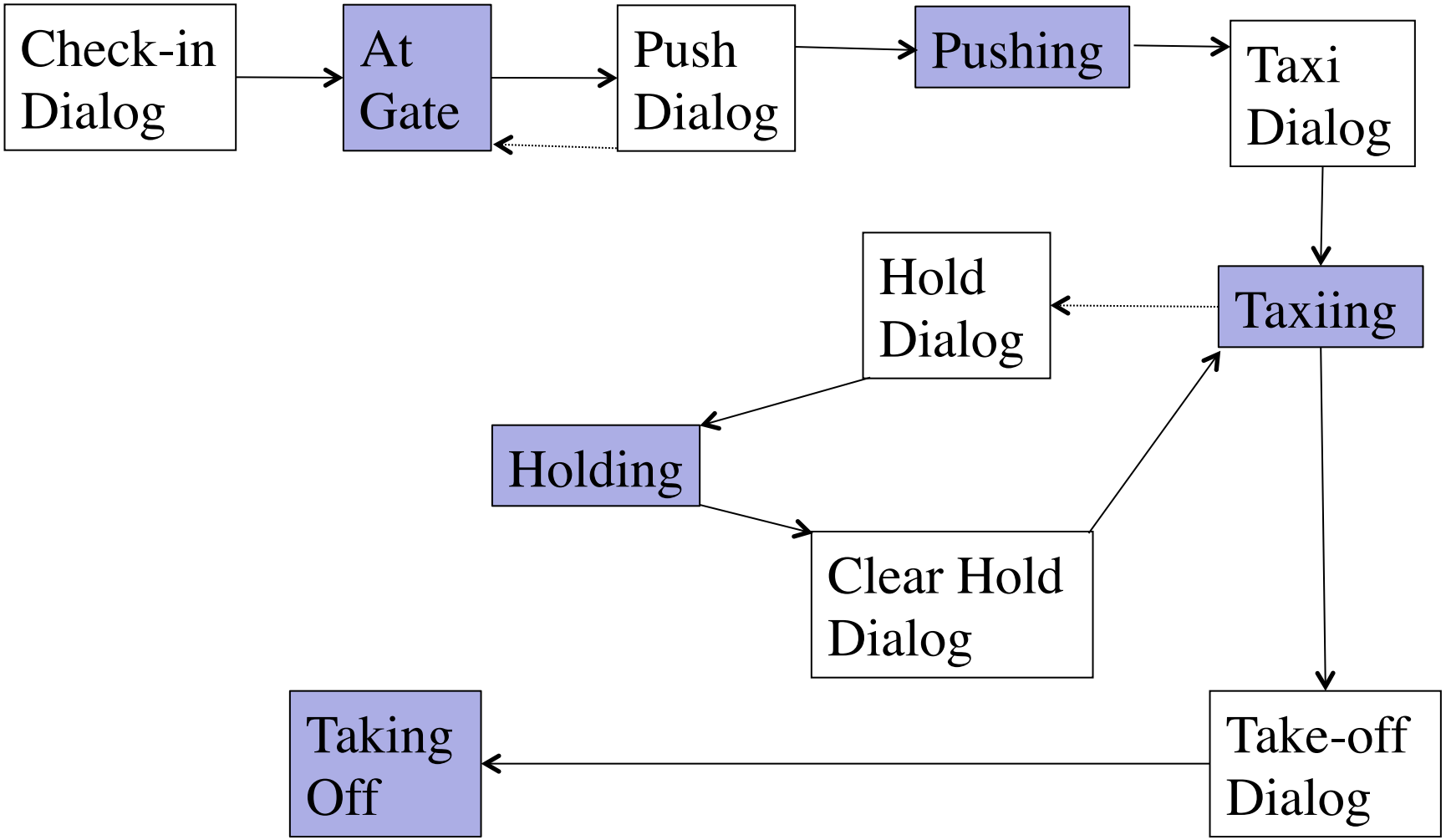
ATC: All right, that's great, uh, thank you very much

Pilot: You bet, thanks

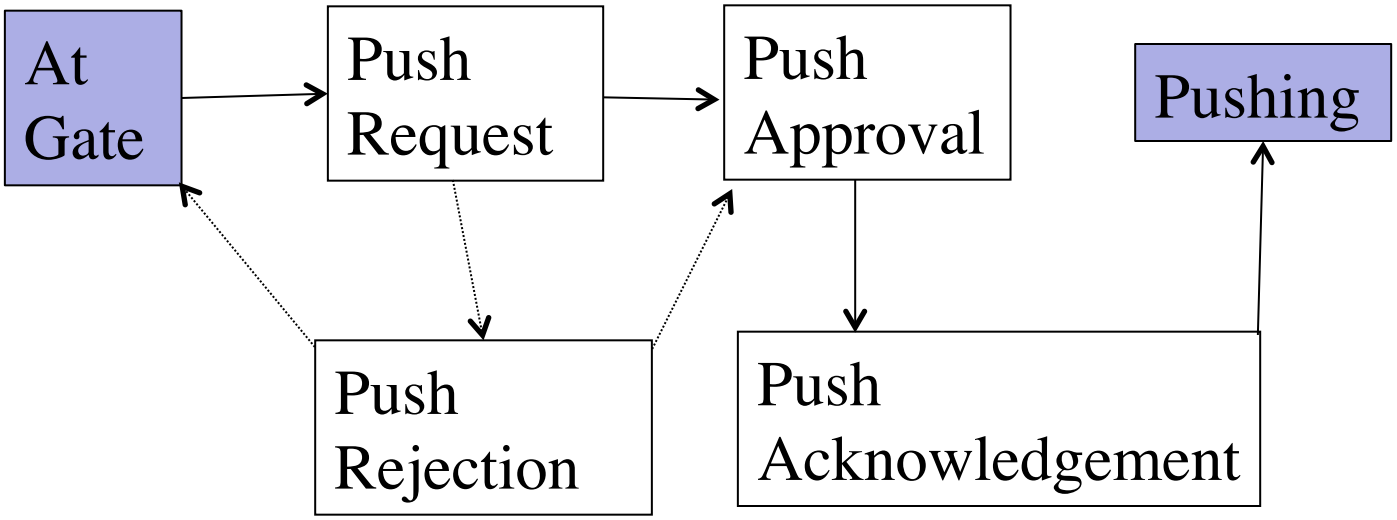
Architecture



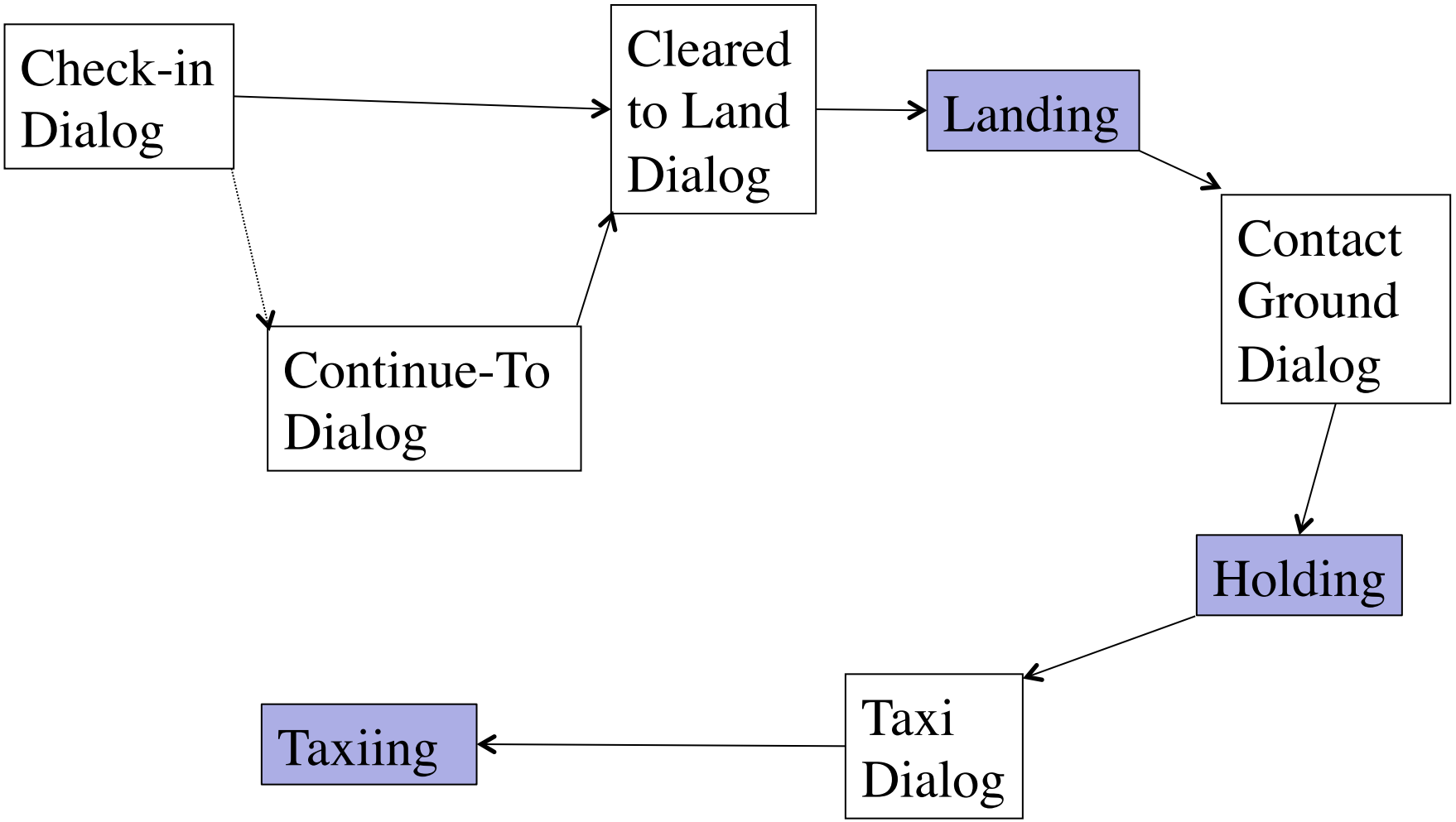
Departure Procedure



Push Dialog Graph



Arrival Procedure



Departing Dialogs

Departure Check-In

Pushback

- Request Pushback (Ground/Pilot: “push”, gate/door #, flight #)
- Pushback Approval (Ground/ATC: “push” “approved”, flight #)
- Approval Acknowledgement (Ground/Pilot: “approved”, flight #)
- Optional pushback direction

Taxiing

- Request Taxi (Ground/Pilot: “taxi”, flight #)
- Taxi Approval (Ground/ATC: “Runway”, runway, route, flight #)
- Route/Runway Copy (Ground/Pilot: runway, route, flight #)

Optional Lineup and Wait: ATC: “Line up and wait”

Taking Off

- Clearance (Tower/ATC: runway, flight #, “Cleared for Takeoff”)
- Acknowledgement (Tower/Pilot, runway, flight #)

Departing: ATC: “Contact NorCal departure”

Arrival Dialogs

Arrival Check-In

- Pilot: “San Jose Tower” <greeting> aircraft-identifier (location | type-of-landing runway-name)

<Continue to>

- ATC: aircraft-identified, “San Jose Tower”, Runway, “Continue Traffic”, “will be Holding in Position”
- Pilot: “Continue to” runway aircraft-identifier

Cleared to Land -> Land -> Rollout

- ATC: aircraft-identifier “San Jose Tower”, runway-name “Cleared to Land” <optional order directions>
- Pilot repeats “Cleared to Land” runway-name aircraft-identifier

Contact Ground Dialog

- ATC: aircraft-identifier , Turn-Directions, “Contact Ground”; Pilot: repeats

Arrival Taxi Dialog: Pilot requests directions, ATC gives directions

Arrival Taxi

Use of Dialogs/Procedures

Utterance:

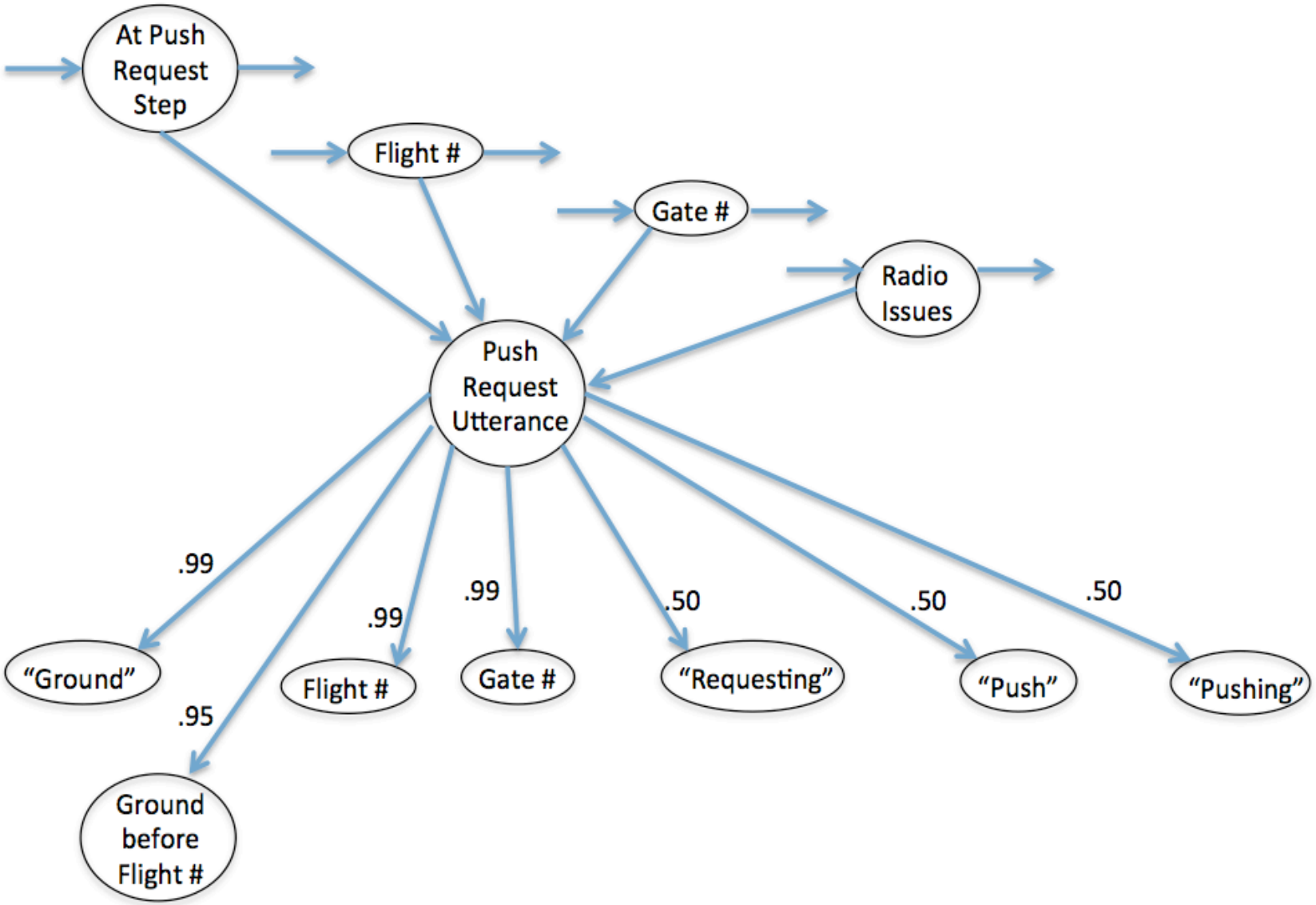
- Speaker? Channel?
- Process utterance with fractional grammars (small regular expr.)
- Extract flight/tail number (Associate with aircraft object)
- In middle of procedure/dialog?
- Expected dialog/utterance?
- Move to appropriate step in procedure (may skip forward)
- Extract pertinent information

Movement (Sensor)

- Associate with flight/tail number
- Expected step in procedure?
- Move to appropriate step in procedure

Update Prediction

Bayesian Networks



Demonstration Preview

San Jose Airport Ground Procedures

- Departing/Arriving,
- Landing/Taking-Off
- To/From SJC Gates and FBO
- Flight Numbers / Tail Numbers (Abbreviations)

Processing actual SJC ATC Transcripts

Perfect speech to text recognition, except dropped

Simulation is transcripts plus simple ground truth / sensor model (position, velocity, tail height (invariant) with error)

Correlated Sensor data / predicted

Prediction updated with sensor data

Output: Predicted trajectory/position drawn in Google maps

Phase I Prototype Demonstration

17 planes (6 clutter) /12 minutes

Arrivals/Departures

Flight Numbers / Tail Numbers

Gates / FBO

Real Dialog / Extraneous Dialog / Words

Prototype Display

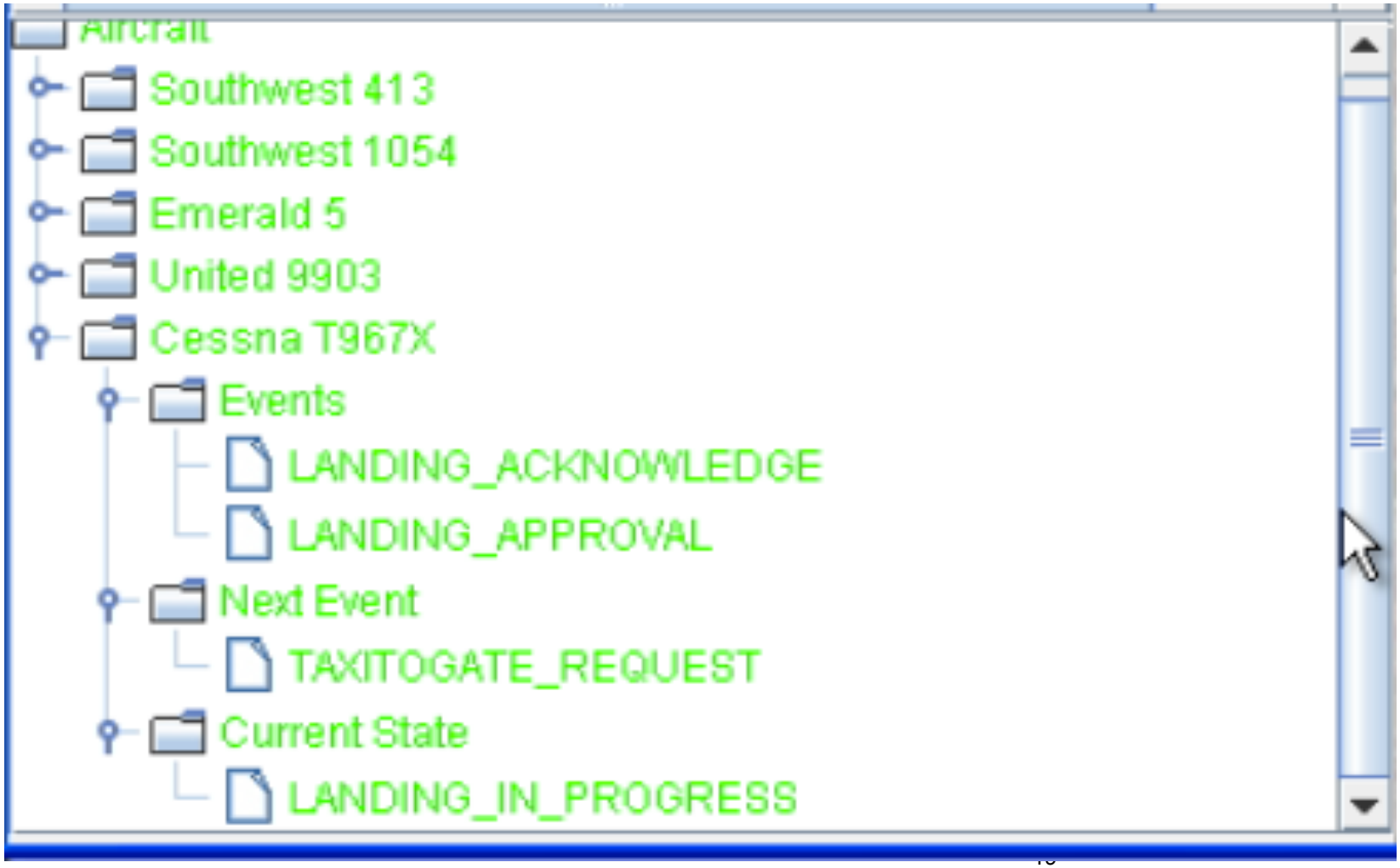
Display

Ground Truth (Icon)

Sensor (Red Dot)

Predicted (Green Triangle)

Procedure Steps Display



Dialog Issues

Clutter, Abbreviations, Ambiguous Routes

Pilot 02/28/2011 15:28:15 Ground, Southwest 1054, Gate 24 with Foxtrot, **requesting push**
ATC 02/28/2011 15:28:17 Southwest 1054, push your tail to the south
Pilot 02/28/2011 15:28:20 Push tail to the south, Southwest 1054
Pilot 02/28/2011 15:28:45 San Jose Ground, Southwest 1054, taxiing Foxtrot
ATC 02/28/2011 15:28:57 Southwest 1054, **Runway 30R taxi via Golf Yankee Alpha**
Pilot 02/28/2011 15:29:05 Golf Yankee Alpha 30R Southwest 1054
ATC 02/28/2011 15:29:12 **Nice job out there, sir. Thanks for the help**
Pilot 02/28/2011 15:29:15 **No, thank you**
...
Pilot 02/28/2011 15:29:55 San Jose Ground **Cessna Tango 967 X-Ray**, we're clear at 30 Left Juliet, we are going to Atlantic
ATC 02/28/2011 15:29:58 **Cessna 67** Ground taxi to Atlantic via Juliet Victor
Pilot 02/28/2011 15:30:02 Juliet Victor to Atlantic, **Cessna 67 X-Ray**
Pilot 02/28/2011 15:30:05 Ground, Southwest 581, Gate 21, **pushing**
...
Pilot 02/28/2011 15:30:25 Ground, **good afternoon** Southwest 2989 Gate 20 **push with Foxtrot**
ATC 02/28/2011 15:30:30 Southwest 2989 San Jose Ground **push approved**
Pilot 02/28/2011 15:30:35 Ground, Southwest 581, ready to taxi from 21 with Foxtrot
ATC 02/28/2011 15:30:37 Southwest 581 **Runway Three-Zero-Left, taxi via Yankee**
Pilot 02/28/2011 15:30:40 Yankee 30 left, Southwest 581
ATC 02/28/2011 15:30:45 American 504, **Runway 12 Left** taxi via Kilo Yankee November
Pilot 02/28/2011 15:30:48 Kilo Yankee November 12 Left American 504

Future Work

Work with other contractors on architecture and integration requirements/opportunities/protocols

Requirements/Design/Implement in 3 versions

Next Phase IPIAS Capabilities

- 3-4 Airports of different types, ones that may be fielded at
- All ground procedures
- Use of all simulated sensor data with projected quality
- Utilize multiple speech recognized texts with certainties
  - Actual ATC dialog (both recorded and real-time)
- Correlation Uncertainty
- Integrated with Larger Architecture and testing Simulation
- Participate in ground tests with surrogate vehicle
- Ready to Transition to real UAV

Conclusions

Knowledge representation and reasoning techniques

- Fractional grammars
- Dialog Graphs
- Procedure Graphs
- Airport map

Were effective

- Classifying dialogs
- Extracting needed data
- Rejecting clutter

Successfully executed on actual ATC dialog

Being extended to multiple airports and actual radio ATC dialogs processed with automatic speech recognition