A Fuzzy-Logic-Based Solution to Dynamic Target Interception and Landing with a Small Multirotor Aircraft

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Outline

Background

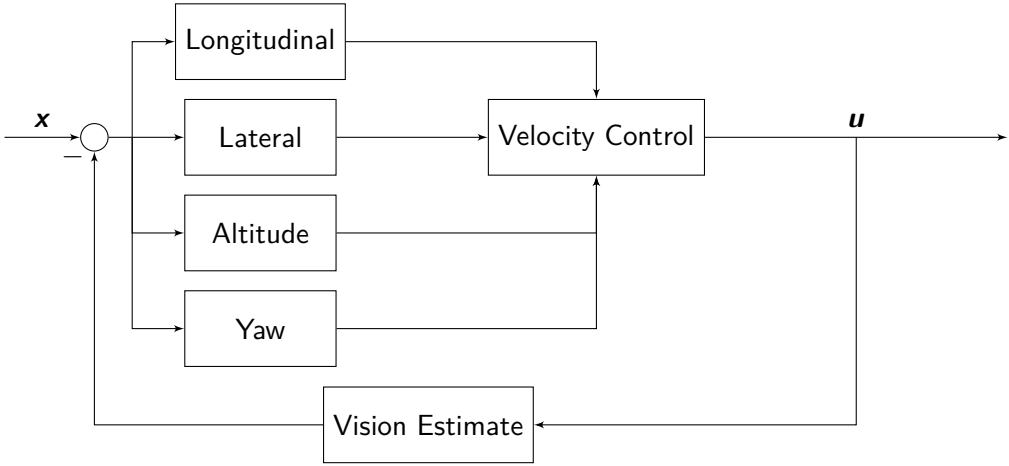
- Develop control strategy for robust, precision landing
  - Place focus on implementable control
  - Approach from hardware constraints
  - Controller will be on board the UAV
- Use vision-based sensors only for guidance
  - Independent of specialty sensors
- Target available hardware
- Caveats
  - Only consider planar motion for target

Flight Hardware

Motivation

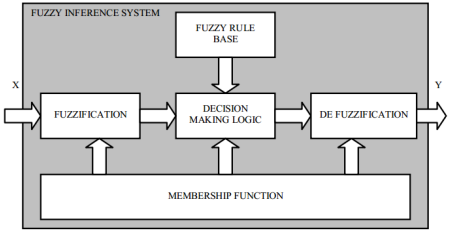
- Package delivery
- Mobile ground station deployment/recovery
- Possible on easily attainable hardware (repeatable)

Controller


Longitudinal
x
Lateral
Velocity Control
u
Altitude
Yaw
Vision Estimate

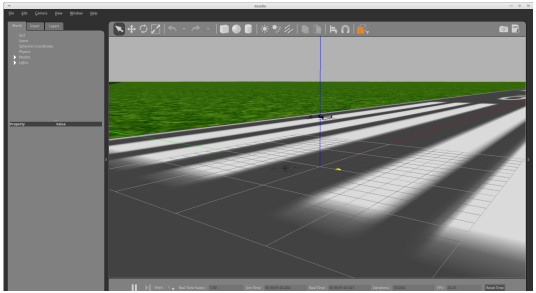
Control

- State vector
  - $\boldsymbol{x} = [x, y, z, \psi]^T$
- Control
  - Input: $\Delta \boldsymbol{x}$, $\dot{\Delta \boldsymbol{x}}$
  - Output: $\boldsymbol{u} = [\dot{x}, \dot{y}, \dot{z}, \dot{\psi}]^T$
- Fuzzy Logic Controller (FLC)
  - Robust to changes in plant
  - Computationally inexpensive
  - Tolerant of noisy data



Approach

- Simulate
  - Gazebo
  - High fidelity simulation
  - Hardware emulation
- Tune/Iterate
  - Evolutionary learning (WIP)
- Build
  - Hardware validation (WIP)



Tools

- Robot Operating System (ROS)
  - Multithreaded, distributed framework
  - Concurrent message passing
  - Publish/Subscribe model
- Gazebo
  - 3D dynamics simulator
  - Facile sensor simulation
- AprilTags
  - Visual fiducial system for robotics
  - Developed by Univ. of Michigan
  - Robust and lightweight (small data payloads)

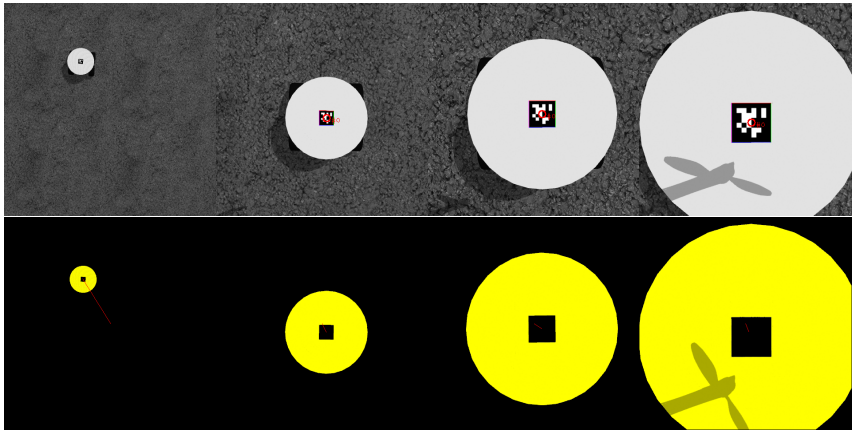
Homography

- Altitude estimation
  - Use GPS/Barometer until target is visible
  - Estimate altitude from known size of target
    - Circular Area (px) $\rightarrow$ Diameter (px) $\rightarrow \frac{d \cdot f}{m \cdot d_p} \rightarrow d_z$
  - Use AprilTag detection if available
    - Needed for target occlusion, frame saturation
- Position (2D) estimation
  - Centroid of target area
  - AprilTag if available
- Currently no fusion estimate implemented (WIP)

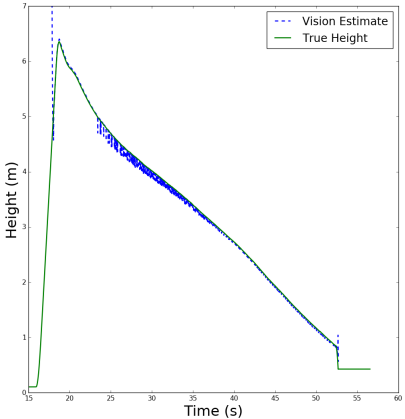
AprilTags

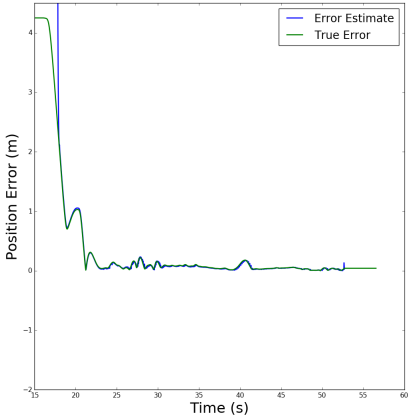
- Position
  - $x = 0$
  - $y = 0$
  - $z = 514$
- Orientation
  - $x = 0.925$
  - $y = -0.370$
  - $z = -0.024$
  - $w = 0.078$

Pose Estimation (1/2)

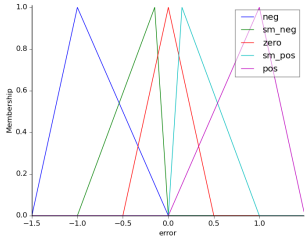


Pose Estimation (2/2)

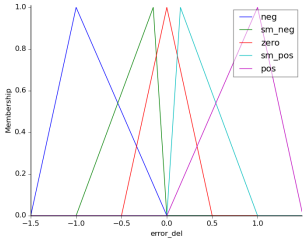




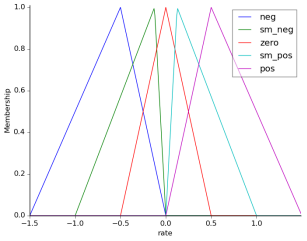
Membership Functions



Error input template



Error change input template



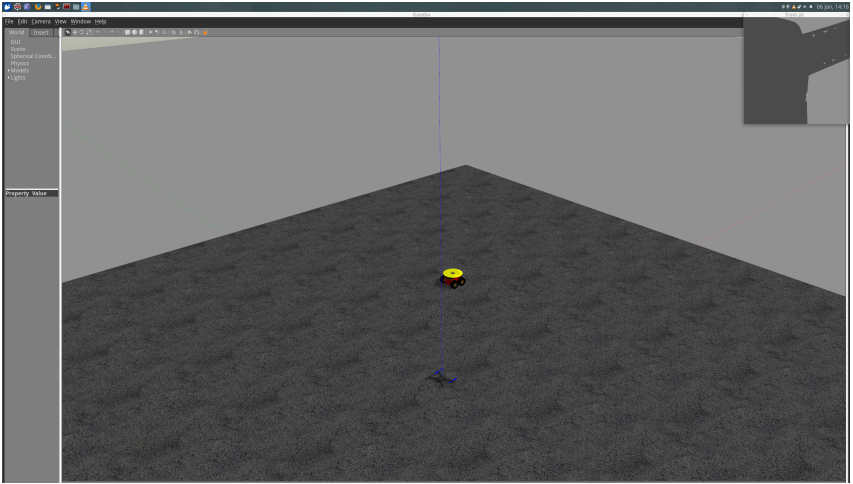
Velocity output template

Rule Base

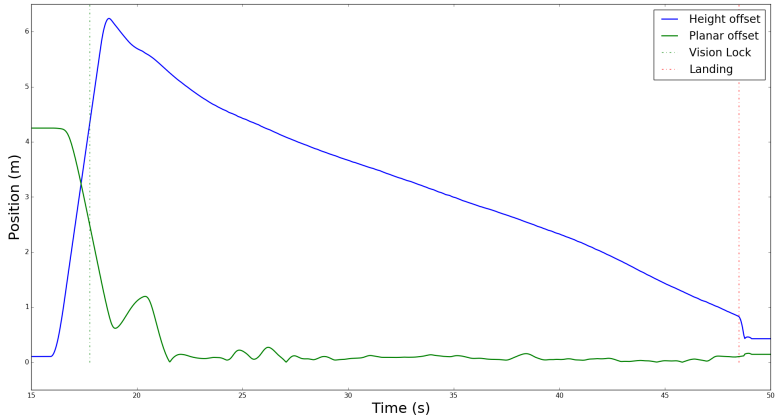
Fuzzy rule base

error rate \ error	N	SN	Z	SP	P
N	P	P	SP	SP	Z
SN	P	SP	SP	Z	SN
Z	SP	SP	Z	SN	SN
SP	SP	Z	SN	SN	N
P	Z	SN	SN	N	N

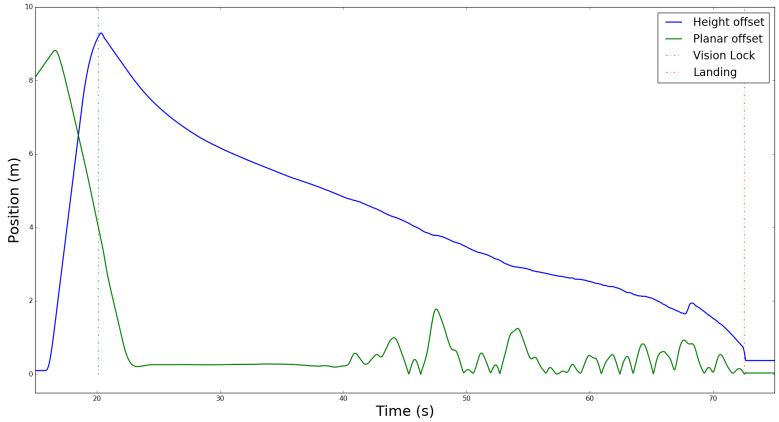
Simulation


File Edit Camera View Window Help
World
Insert
Property
Value

Static Target



Dynamic Target



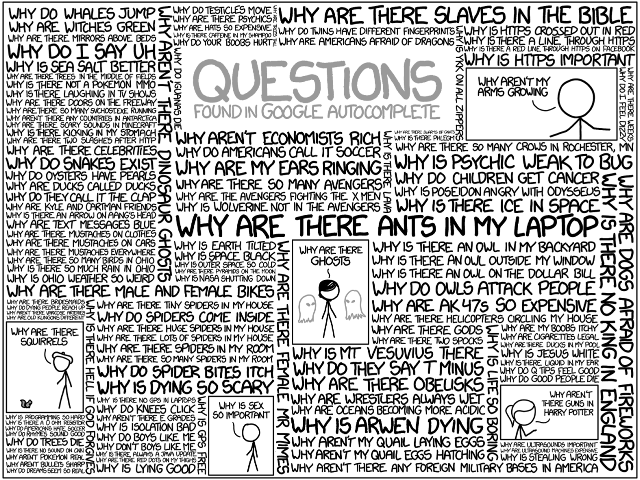
Conclusions

- Untuned FLC
- Noisy data
- Drastically different plants
- FLC is still able to handle it (albeit with some trouble)
- Tested PID controller - needed different set of gains for each case

Continuing work

- Vision estimate Kalman filter (barometer, naive estimate, AprilTag)
- Rigidly mount camera to frame
  - Current work assumes perfect gimbal
- Tune FLC (genetic algorithm)
- Test implementation on flight hardware

Questions?


QUESTIONS
FOUND IN GOOGLE AUTOCOMPLETE
WHY DO WHALES JUMP
WHY ARE WITCHES GREEN
WHY ARE THERE MIRRORS ABOVE BEDS
WHY DO I SAY UH
WHY IS SEA SALT BETTER
WHY ARE THERE TREES IN THE MIDDLE OF FIELDS
WHY IS THERE NOT A POKEMON MMO
WHY IS THERE LAUGHING IN TV SHOWS
WHY ARE THERE DOORS ON THE FREEWAY
WHY ARE THERE SO MANY SVCHOST.EXE RUNNING
WHY AREN'T THERE ANY COUNTRIES IN ANTARCTICA
WHY ARE THERE SCARY SOUNDS IN MINECRAFT
WHY IS THERE KICKING IN MY STOMACH
WHY ARE THERE TWO SLASHES AFTER HTTP
WHY ARE THERE CELEBRITIES
WHY DO SNAKES EXIST
WHY DO OYSTERS HAVE PEARLS
WHY ARE DUCKS CALLED DUCKS
WHY DO THEY CALL IT THE CLAP
WHY ARE KYLE AND CARTMAN FRIENDS
WHY IS THERE AN ARROW ON AANG'S HEAD
WHY ARE TEXT MESSAGES BLUE
WHY ARE THERE MUSTACHES ON CLOTHES
WHY ARE THERE MUSTACHES ON CARS
WHY ARE THERE MUSTACHES EVERYWHERE
WHY ARE THERE SO MANY BIRDS IN OHIO
WHY IS THERE SO MUCH RAIN IN OHIO
WHY IS OHIO WEATHER SO WEIRD
WHY AREN'T THERE DINOSAUR GHOSTS
WHY DO IGUANAS DIE
WHY DO TESTICLES MOVE
WHY ARE THERE PSYCHICS
WHY ARE HATS SO EXPENSIVE
WHY IS THERE CAFFEINE IN MY SHAMPOO
WHY DO YOUR BOOBS HURT
WHY ARE THERE SLAVES IN THE BIBLE
WHY DO TWINS HAVE DIFFERENT FINGERPRINTS
WHY ARE AMERICANS AFRAID OF DRAGONS
WHY IS HTTPS CROSSED OUT IN RED
WHY IS THERE A LINE THROUGH HTTPS
WHY IS THERE A RED LINE THROUGH HTTPS ON FACEBOOK
WHY IS HTTPS IMPORTANT
WHY IS YKK ON ALL ZIPPERS
WHY AREN'T MY ARMS GROWING
WHY ARE THERE WEEKS
WHY DO I FEEL DIZZY
WHY AREN'T ECONOMISTS RICH
WHY DO AMERICANS CALL IT SOCCER
WHY ARE MY EARS RINGING
WHY ARE THERE SO MANY AVENGERS
WHY ARE THE AVENGERS FIGHTING THE X MEN
WHY IS WOLVERINE NOT IN THE AVENGERS
WHY IS THERE LAVA
WHY ARE THERE SWARMS OF GNATS
WHY IS THERE PHLEGM
WHY ARE THERE SO MANY CROWS IN ROCHESTER, MN
WHY IS PSYCHIC WEAK TO BUG
WHY DO CHILDREN GET CANCER
WHY IS POSEIDON ANGRY WITH ODYSSEUS
WHY IS THERE ICE IN SPACE
WHY ARE THERE ANTS IN MY LAPTOP
WHY IS EARTH TILTED
WHY IS SPACE BLACK
WHY IS OUTER SPACE SO COLD
WHY ARE THERE PYRAMIDS ON THE MOON
WHY IS NASA SHUTTING DOWN
WHY ARE THERE GHOSTS
WHY IS THERE AN OWL IN MY BACKYARD
WHY IS THERE AN OWL OUTSIDE MY WINDOW
WHY IS THERE AN OWL ON THE DOLLAR BILL
WHY DO OWLS ATTACK PEOPLE
WHY ARE AK 47s SO EXPENSIVE
WHY ARE THERE HELICOPTERS CIRCLING MY HOUSE
WHY ARE THERE GODS
WHY ARE THERE TWO SPOCKS
WHY IS THERE NO KING IN ENGLAND
WHY ARE DOGS AFRAID OF FIREWORKS
WHY ARE THERE MALE AND FEMALE BIKES
WHY ARE THERE BRIDESMAIDS
WHY DO DYING PEOPLE REACH UP
WHY AREN'T THERE VARICOSE ARTERIES
WHY ARE OLD KLINGONS DIFFERENT
WHY ARE THERE TINY SPIDERS IN MY HOUSE
WHY DO SPIDERS COME INSIDE
WHY ARE THERE HUGE SPIDERS IN MY HOUSE
WHY ARE THERE LOTS OF SPIDERS IN MY HOUSE
WHY ARE THERE SPIDERS IN MY ROOM
WHY ARE THERE SO MANY SPIDERS IN MY ROOM
WHY DO SPIDER BITES ITCH
WHY IS DYING SO SCARY
WHY IS THERE HELL IF GOD FORGIVES
WHY ARE THERE SQUIRRELS
WHY ARE THERE FEMALE MR MIMES
WHY IS MT VESUVIUS THERE
WHY DO THEY SAY T MINUS
WHY ARE THERE OBELISKS
WHY ARE WRESTLERS ALWAYS WET
WHY ARE OCEANS BECOMING MORE ACIDIC
WHY IS ARWEN DYING
WHY AREN'T MY QUAIL LAYING EGGS
WHY AREN'T MY QUAIL EGGS HATCHING
WHY AREN'T THERE ANY FOREIGN MILITARY BASES IN AMERICA
WHY IS LIFE SO BORING
WHY ARE MY BOOBS ITCHY
WHY ARE CIGARETTES LEGAL
WHY ARE THERE DUCKS IN MY POOL
WHY IS JESUS WHITE
WHY IS THERE LIQUID IN MY EAR
WHY DO Q TIPS FEEL GOOD
WHY DO GOOD PEOPLE DIE
WHY AREN'T THERE GUNS IN HARRY POTTER
WHY ARE ULTRASOUNDS IMPORTANT
WHY ARE ULTRASOUND MACHINES EXPENSIVE
WHY IS STEALING WRONG
WHY IS PROGRAMMING SO HARD
WHY IS THERE A 0 OHM RESISTOR
WHY DO AMERICANS HATE SOCCER
WHY DO RHYMES SOUND GOOD
WHY DO TREES DIE
WHY IS THERE NO SOUND ON CNN
WHY AREN'T POKEMON REAL
WHY AREN'T BULLETS SHARP
WHY DO DREAMS SEEM SO REAL
WHY IS THERE NO GPS IN LAPTOPS
WHY DO KNEES CLICK
WHY AREN'T THERE E GRADES
WHY IS ISOLATION BAD
WHY DO BOYS LIKE ME
WHY DON'T BOYS LIKE ME
WHY IS THERE ALWAYS A JAVA UPDATE
WHY ARE THERE RED DOTS ON MY THIGHS
WHY IS LYING GOOD
WHY IS GPS FREE
WHY IS SEX SO IMPORTANT