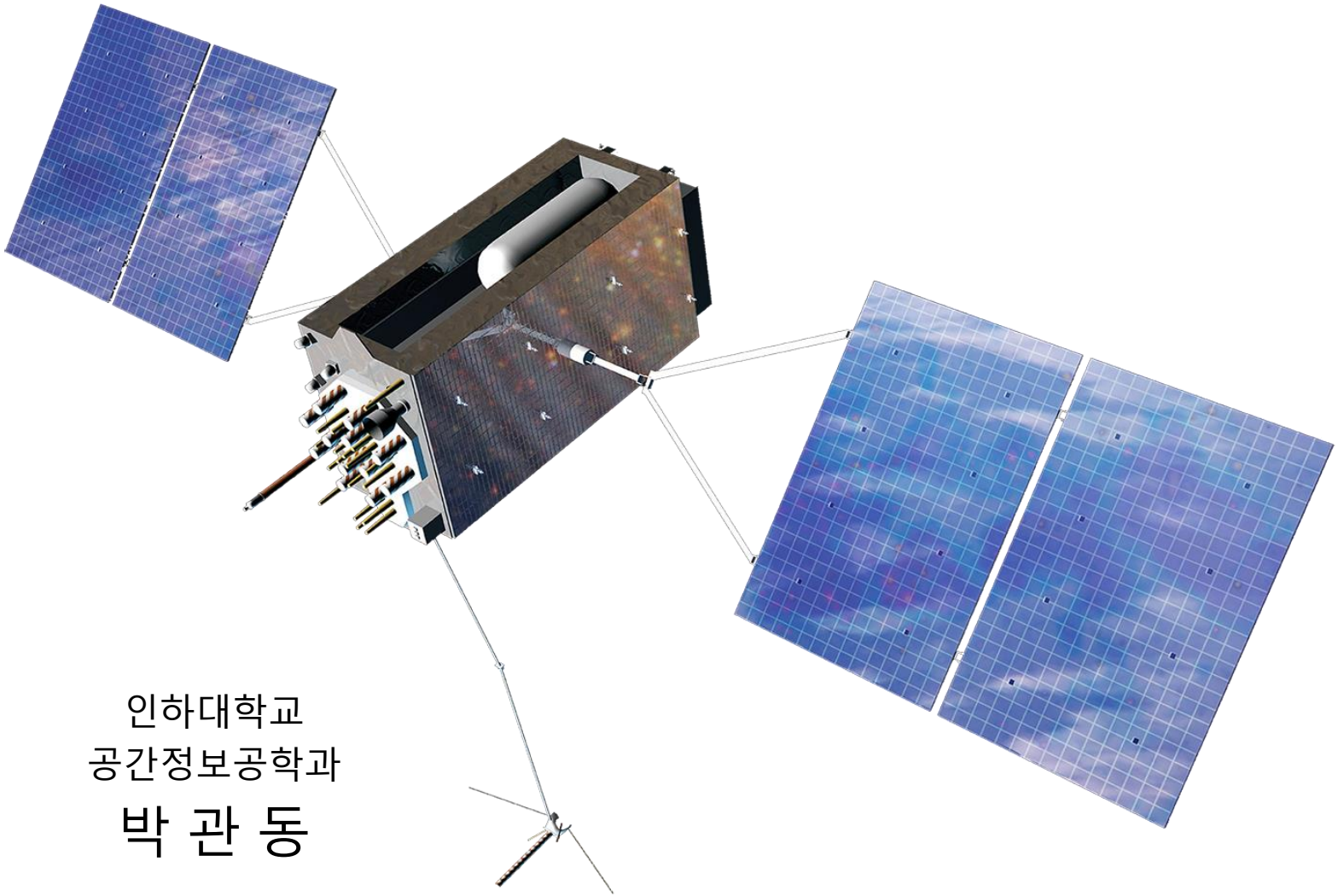
GPS 응용

코드의사거리(Code Pseudorange)기반

단독 측위(Point Positioning)



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목차

- 단독측위(Point Positioning, PP)의 정의
  - aka. standalone positioning
  - 기준국 혹은 보정정보 없이 하나의 수신기로 3차원 위치를 계산
- 관측방정식
- GPS 관련 파일 다루기
  - 데이터 형식과 구조
- 최소제곱 추정 (Least-Squares Estimation, LSE) 복습
- 3월내로 단독측위 알고리즘 구현
  - 30초 단위 24시간 데이터
  - 1초 단위 1시간 데이터

단독측위 관측방정식

- 코드의사거리(PR) 관측방정식

$$PR = \rho + c\,(\delta t_r - \delta t^s) + T + I + M + \delta_r + \delta^s + \varepsilon$$

  - ρ: Geometric(instantaneous or true) range; c: Speed of light
  - δt_r: Receiver clock offset; δt^s: Satellite clock offset
  - T: Tropospheric delay; I: Ionospheric delay; M: Multipath error
  - δ_r: Receiver hardware bias; δ^s: Satellite hardware bias
  - ε: Random noise

- 3월에는 코드의사거리 관측값만을 다룰 예정임
  - C/A or C1
  - 3월 이후, 아래와 같은 관측값과 관측방정식이 필요할 수 있음
    - 반송파위상과 그 관측방정식
    - 도플러와 평활화(smoothing)
    - 이중주파수와 무전리층(IF, Ionosphere-Fee) 조합

단독측위 관측방정식 ➲ 항법해

- Geometric range ρ
  - 궤도력 혹은 위성의 3차원 좌표 ⊂ 항법메시지
  - 미지수: 안테나 좌표는 최소제곱추정에서 산출함

- Clock offsets δt_r δt^s
  - 위성시계 오프셋 ⊂ 항법메시지
  - 미지수: 수신기시계 오프셋은 최소제곱추정에서 산출함

- Other errors **I T M** δ_r δ^s
  - Ionospheric and tropospheric errors ➲ 별도 강의에서 다룸
  - Multipath and hardware biases ➲ 당분간 무시함

- 단순화된 항법해를 위한 관측방정식 ➲ $PR = \rho + c\,\delta t_r + \varepsilon$

Handling of Measurements

- Measurements from observation RINEX files
  - Measurements = Observables = Observations (?)

- Conversion of observation RINEX files to QM format
  - QM: Quick Measurement

- Structure of QM file: four-column data
  - Column #1: [gs] GPS week second; tt(time-tag)
  - Column #2: [PRN] PRN ID
  - Column #3: [obsType] Observation Type
  - Column #4: [obs] Measurement

QM: PRN, obsType

- Constellations denoted by the first digit of 3-digit satellite ID
  - 100's GPS GPS
  - 200's BeiDou BDS
  - 300's GLONASS GLO
  - 400's Galileo GAL

- obsType denoted by 3-digit [ABC]
  - A: Satellite constellation (1, 2, 3, 4, 5, 6, …)
  - B: Signal type (1: carrier phases; 2: code pseudo-ranges, 3: Doppler, 4: SNR)
  - C: Frequency (1, 2, 5)

- obsType - GPS
  - 111, 112: L1/L2 – Carrier phase measurements
  - 120, 121, 122: C1/P1/P2 – Code pseudo-range measurements
  - 131, 132: D1/D2 – Doppler measurements
  - 141, 142: S1/S2 – SNR measurements

HW #1

- ReadQM
  - ReadQM.m
    - Input: QMfile
    - Output: arrQM, FinalPRNs, FinalTTs
      - arrQM: 4-column array in the same format as QMfile
      - FinalPRNs: List of PRN ID
      - FinalTTs: List of time-tag
- PlotQM
  - PlotQM.m
    - Input: arrQM, prn, obsType
    - Output: Figure
    - Conditions: gs (GPS Week Second) should be converted to hours
      - Hours of Day

궤도력 처리

- 궤도력(ephemeris) 정의 by Merriam-Webster
  - “ephemeris”: a tabular statement of the assigned places of a celestial body for regular intervals; plural: ephemerides

- 궤도력 종류
  - SP3 궤도력
    - Precise (정밀)
    - Rapid (신속)
    - Ultra-rapid (초신속)
  - 방송 궤도력 - (broadcast)
    - RINEX or 실시간 디코딩으로 확보

- 항법 RINEX 파일
  - 항법 RINEX 파일의 종류
    - Receiver-generated .vs. Internation GNSS Service (IGS)
    - suwn0320.15n .vs. brdc0320.15n
      - brdc for BRoaDCast
  - IGS에서 내려 받기 → 다음 슬라이드

IGS FTP

- International GNSS Service
  - http://igs.org or http://www.igs.org

- IGS has four Global Data Centers: GDC

Global Data Center

Institution	Abbreviation	Country
Institut Geographique National	IGN	France
Korean Astronomy and Space Science Institute	KASI	Korea
Crustal Dynamics Data Information System	CDDIS	USA
Scripps Institution of Oceanography	SIO	USA

- CDDIS
  - https://cddis.nasa.gov/archive/gnss/data/daily
  - Directory hierarchy: daily ➲ YYYY ➲ DOY ➲ YRo

항법 RINEX 파일 구조

PRN	Epoch					
ID	Year	Month	Day	Hour	Minute	Second

PRN + Epoch	SV clock bias (s)	SV clock drift (s/s)	SV clock drift rate (s/s^2)
IODE	C_{rs} (rad)	Δn (rad/s)	M_0 (rad)
C_{uc} (rad)	e (-)	C_{us} (rad)	$\sqrt{a}$ ($\sqrt{m}$)
t_{oe} (GPS Week Sec.)	C_{ic} (rad)	Ω_0 (rad)	C_{is} (rad)
i_0 (rad)	C_{rc} (rad)	ω (rad)	$\dot{\Omega}$ (rad/s)
$\dot{i}$ (rad/s)	Codes on L2 channel	GPS Week Number (-)	L2 P data flag
SV accuracy (m)	SV health	T_{GD} (s)	IODC
Tx time of message (GPS Week Sec.)	Fit interval (h)	spare	spare

항법 RINEX 파일 처리

- ReadEPH.p
  - Conversion of navigation RINEX to an array
  - Refer to a separate handout for the array structure
  - Usage: `eph = ReadEPH('brdc0320.15n')`
- PickEPH.p
  - Returns the nearest row number for the input time-tag
  - `ieph = PickEPH(eph, PRN, tt)`

#	ReadEPH: 190121 GPS	ReadEPH: 190124 BDS	ReadEPH: 190124 GAL	ReadEPH: 201214 QZSS
1	t_{oe}	t_{oe}	t_{oe}	t_{oe}
2	PRN	PRN	PRN	PRN
3	a	a	a	a
4	b	b	b	b
5	c	c	c	c
6	T_{GD}	T_{GD1} B1/B3	B_{GD} E5a/E1	T_{GD}
7		T_{GD2} B2/B3	B_{GD} E5b/E1	
8	IODE	IODE	IODE	IODE
9	IODC	IODC		IODC
10	$\sqrt{a}$	$\sqrt{a}$	$\sqrt{a}$	$\sqrt{a}$
11	e	e	e	e
12	i_0	i_0	i_0	i_0
13	ω	ω	ω	ω
14	Ω_0	Ω_0	Ω_0	Ω_0
15	M_0	M_0	M_0	M_0
16	$\dot{i}$	$\dot{i}$	$\dot{i}$	$\dot{i}$
17	$\dot{\Omega}$	$\dot{\Omega}$	$\dot{\Omega}$	$\dot{\Omega}$
18	Δn	Δn	Δn	Δn
19	SV Health	SV Health	SV Health	SV Health
20	C_{uc}	C_{uc}	C_{uc}	C_{uc}
21	C_{us}	C_{us}	C_{us}	C_{us}

P-Codes Part #1

- HW #2
  - ReadEPH.p
  - PickEPH.p
- HW #3
  - ReadSP3.p
  - Get2ENDsp3.p
- Conversions of date and time
  - jd2gwgs.p `function [gw, gs] = jd2gwgs(JD)`
  - date2jd.p `function [jd] = date2jd(yr4, month, day, hh, mm, ss)`
  - date2gwgs `function [gw, gs] = date2gwgs(yy, mo, dd, h, m, s)`

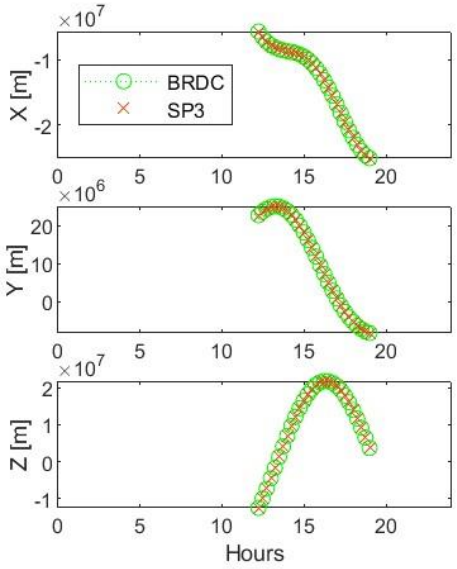
GetSatPos (x^s, y^s, z^s) 검증

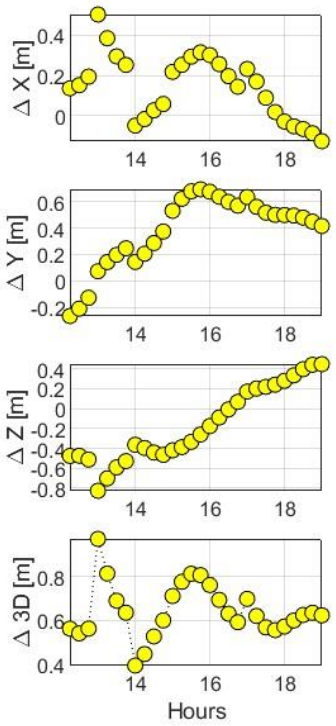
- Truth or reference provided by SP3 files
  - File format: igswwwwd.sp3 (eg, “igs18300.sp3”)
  - Sampled at 15-minute

- ReadSP3.p
  - Reads in a SP3 file into an array
  - `function [sp3_array] = ReadSP3(sp3_File)`
  - Necessary subroutines, or subsidiary functions
    - `function [gw, gs] = date2gwgs(yr, mon, day, hr, min, sec)`
    - `function [jd] = date2jd(yr, mon, day, hr, min, sec)`
    - `function [gw, gs] = jd2gwgs(JD)`
    - `function [s] = Get2ENDsp3(sp3_fid)`

HW #2

- CompEPH.m
  - To compare satellite ephemeris from navigation RINEX and SP3 files
  - CompEPH.m
    - Input: arrQM, sp3, eph, prn
    - Output: Figure






```
119    64800 -22054563.890  -5431403.651  13961657.056 (BRDC)
             -22054563.860  -5431404.150  13961656.778 (SP3)
                    -0.030         0.499         0.278 (3D) 0.6m

119    65700 -23133593.610  -6449672.766  11658317.920 (BRDC)
             -23133593.557  -6449673.261  11658317.587 (SP3)
                    -0.053         0.495         0.333 (3D) 0.6m

119    66600 -24039474.501  -7255807.996   9157347.184 (BRDC)
             -24039474.434  -7255808.475   9157346.789 (SP3)
                    -0.067         0.479         0.395 (3D) 0.6m

119    67500 -24735314.368  -7865218.644   6501690.077 (BRDC)
             -24735314.280  -7865219.093   6501689.638 (SP3)
                    -0.088         0.449         0.439 (3D) 0.6m

119    68400 -25189315.155  -8300350.235   3736556.783 (BRDC)
             -25189315.028  -8300350.651   3736556.337 (SP3)
                    -0.127         0.416         0.446 (3D) 0.6m
```