Augmented Reality (AR) Visualization of SWAT+ Hydrological Data Using GPS-Based Mobile Interaction

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Introduction

Hydrologic Model

- Hydrologic models help simulate and predict water movement.
- Show how nature reacts to changes like climate, land use, or soil management.
- The results support decision-making for water and land policies.

Augmented Reality

- AR refers to the real-time integration of digital information into a user's environment.
- AR technology overlays content onto the real world.

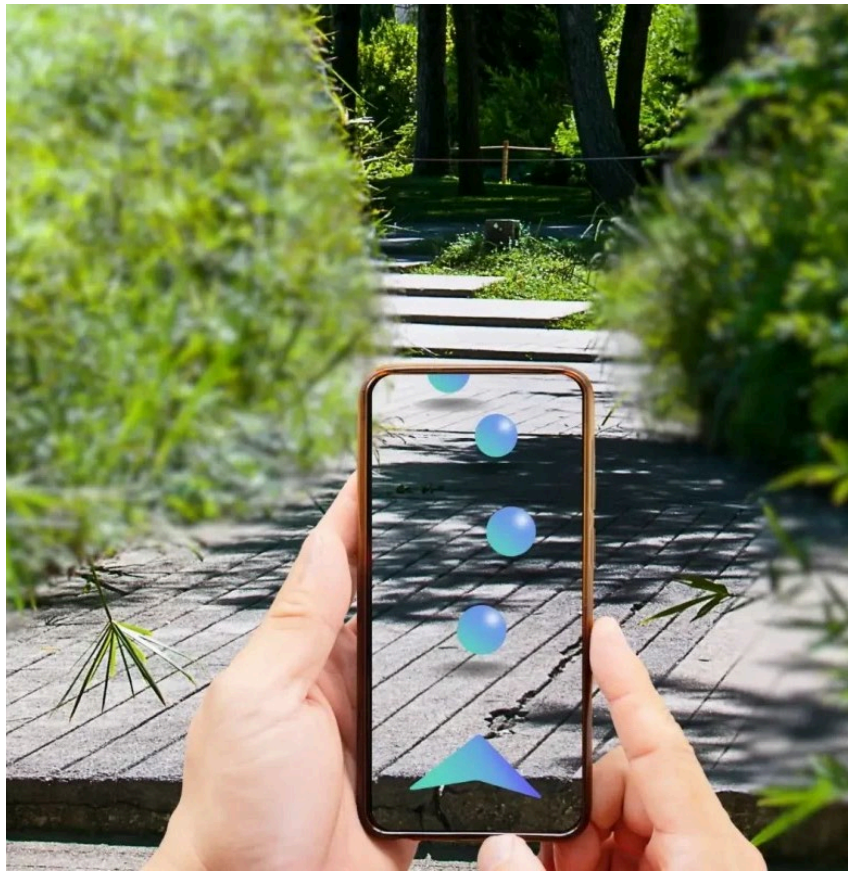
Background

SWAT+

- SWAT Model can simulate:
  - Soil Water Content
  - Surface Runoff
  - Water Yield
  - Nutrient Transport
- The output stored as static GIS maps or CSV tables

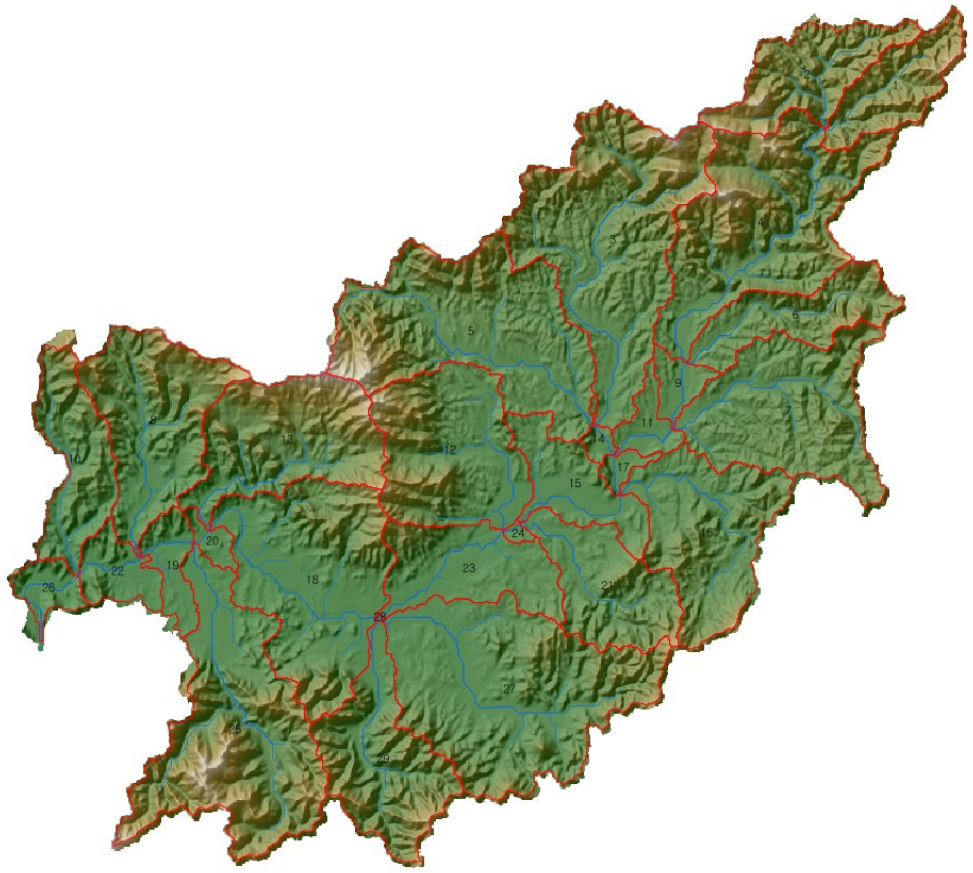
AR

- Display model results to the real-world using a mobile device
- Combining GPS tracking and SWAT+ outputs
  - Site-specific data visualization
  - Can increase knowledge and information, more ‘real’ experience
  - Helping stakeholders as a decision-making tools



Study Area

Map



Geumho River

- Largest tributary of Nakdong River (longest river in Korea)
- Flow through Daegu metropolitan area
- Agriculture for Gyeongsangbuk-do Province

Geumho River Basin

- 202,529.16 ha
- Subbasins: 29
- HRUs: 268

SWAT+

INPUT

Weather Data

- Rainfall (mm/day)
- Temperature (°C)
- Wind Speed (m/s)
- Solar Radiation (MJ/m²)
- RH (%)

Geospatial Data

- Watershed
  - DEM
- HRU
  - Soil Map
  - Land use Map

Streamflow Data

Water Discharge (m^3/s)

OUTPUT

- Runoff Simulation
- Water Quality Simulation
- HRU level:
  - Soil Water
  - Water Yield
  - Evapotranspiration
  - Precipitation

- Data Used: January 1st 2015 – January 1st 2025
- Warm up period: 2015 - 2016
- Calibration: 2017 - 2021
- Validation: 2022 - 2024

SWAT+

Sensitivity Analysis

Parameter	Definition	Absolute_t_stat	P_value
surlag.bsn	Surface runoff lag coefficient	12.26	2.38
k.sol	Saturated hydraulics conductivity	2.31	0.04
latq_co.hru	Lateral Flow Contribution Coefficient	2.23	0.05
canmx.hru	Maximum canopy storage	1.55	0.15
epco.hru	Plant uptake compensation factor	1.51	0.16
esco.hru	Soil evaporation compensation factor	1.16	0.27
cn2.hru	Curve Number for Moist Soil Conditions	0.57	0.58
awc.sol	Available water capacity of the soil layer	0.44	0.67
usle_p.hru	Support Practice Factor for Erosion	0.11	0.91

- **surlag.bsn** (surface runoff lag time):
  - strongly affects streamflow. Lower surlag values = more direct runoff response.
- **k.sol** (saturated hydraulic conductivity)
  - Influences infiltration and percolation.
- **latq_co.hru** (lateral flow coefficient)
  - Affects how much lateral flow contributes to streamflow.

SWAT+

Calibration and Validation

- Auto Calibration using RSWAT

Parameter	Change	Min	Max	Object	Conditions
cn2.hru	Relative	35	95	All	All
canmx.hru	Replace	1	10	All	All
esco.hru	Replace	0	1	All	All
k.sol	Replace	0.0001	2000	All	All
awc.sol	Replace	0.5	1.5	All	All
surlag.bsn	Replace	0.05	24	All	All
epco.hru	Absolute	0	1	All	All
latq_co.hru	Absolute	0	1	All	All
usle_p.hru	Absolute	0	0.65	All	All

Calibration Metrics

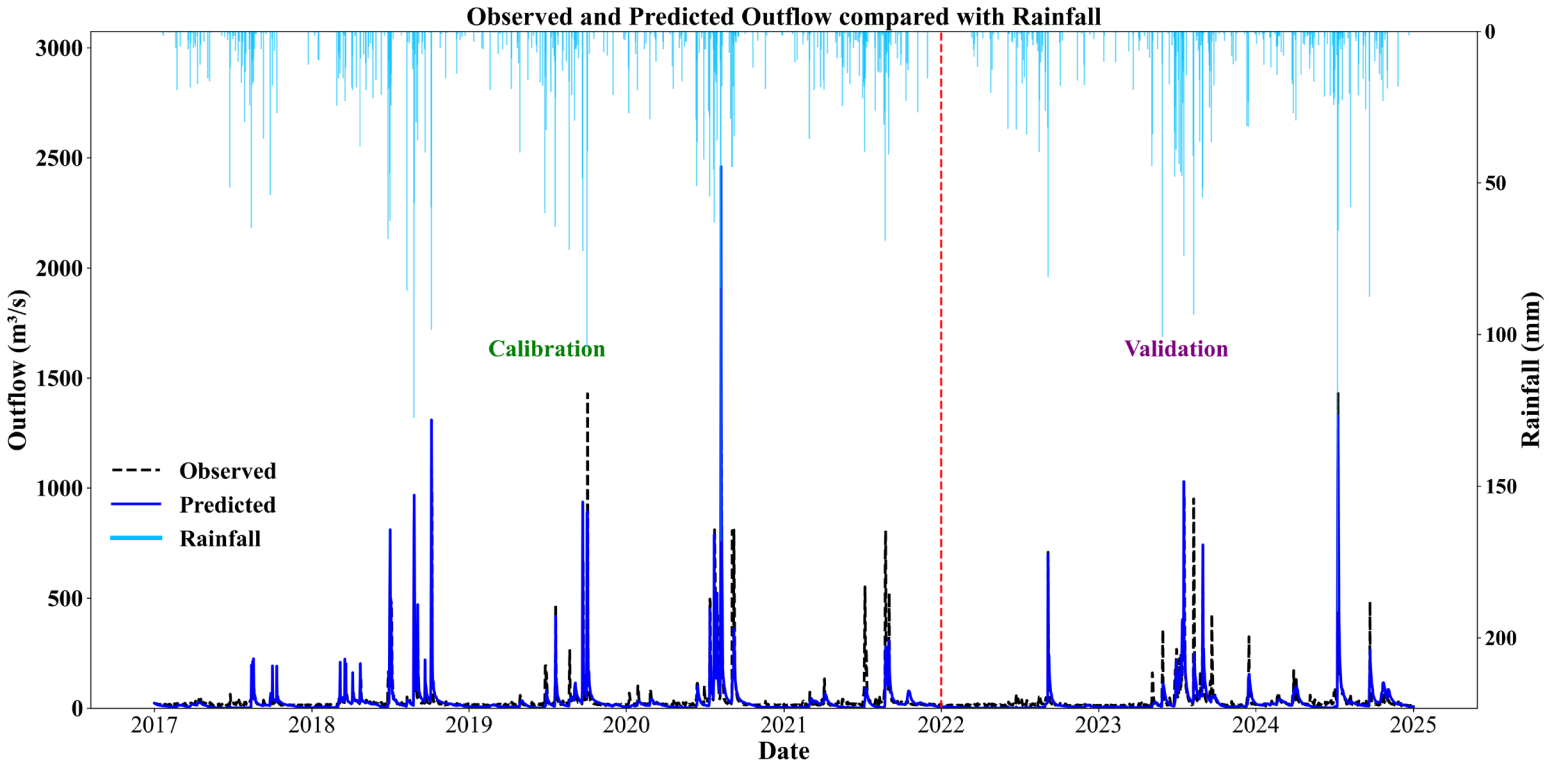
- NSE : 0.64
- R^2 : 0.66
- KGE : 0.76
- RMSE : 57.6
- aBIAS : 0.56

Validation Metrics

- NSE : 0.59 → Satisfactory model performance. (Moriasi et. al, 2007)
- R^2 : 0.61
- KGE : 0.73
- RMSE : 53.3
- aBIAS : 0.14

SWAT+

Results Outflow



- **Rainfall**

- Outflow spikes closely follow rainfall events
- Outflow and rainfall show strong seasonal patterns

- **Outflow**

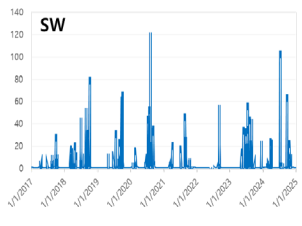
- Captures Seasonal and Multi-Year Trends
- Prediction captures many peak flow events
- Overestimate at High Peaks
- Underestimation in Dry Periods

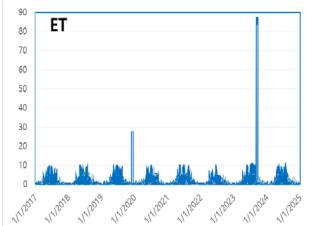
AR System Design

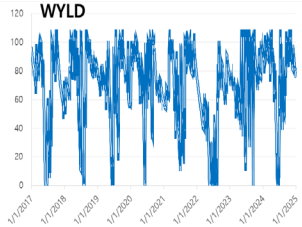
Objective goals

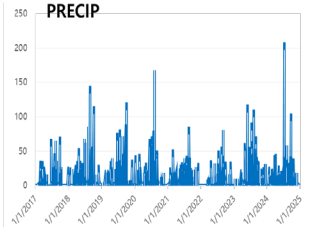
- Visualize SWAT+ outputs on-site based on AR and live GPS location

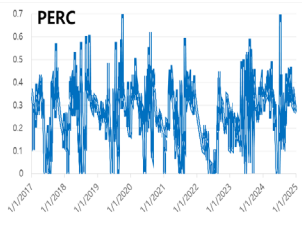
SWAT+ Outputs → **Convert Data** → **Unity + AR Foundation** → **Build AR application**











HRU Output Data

- Arrange CSV format

- GPS System
- Time Series
- User Interface

- Target Output Result

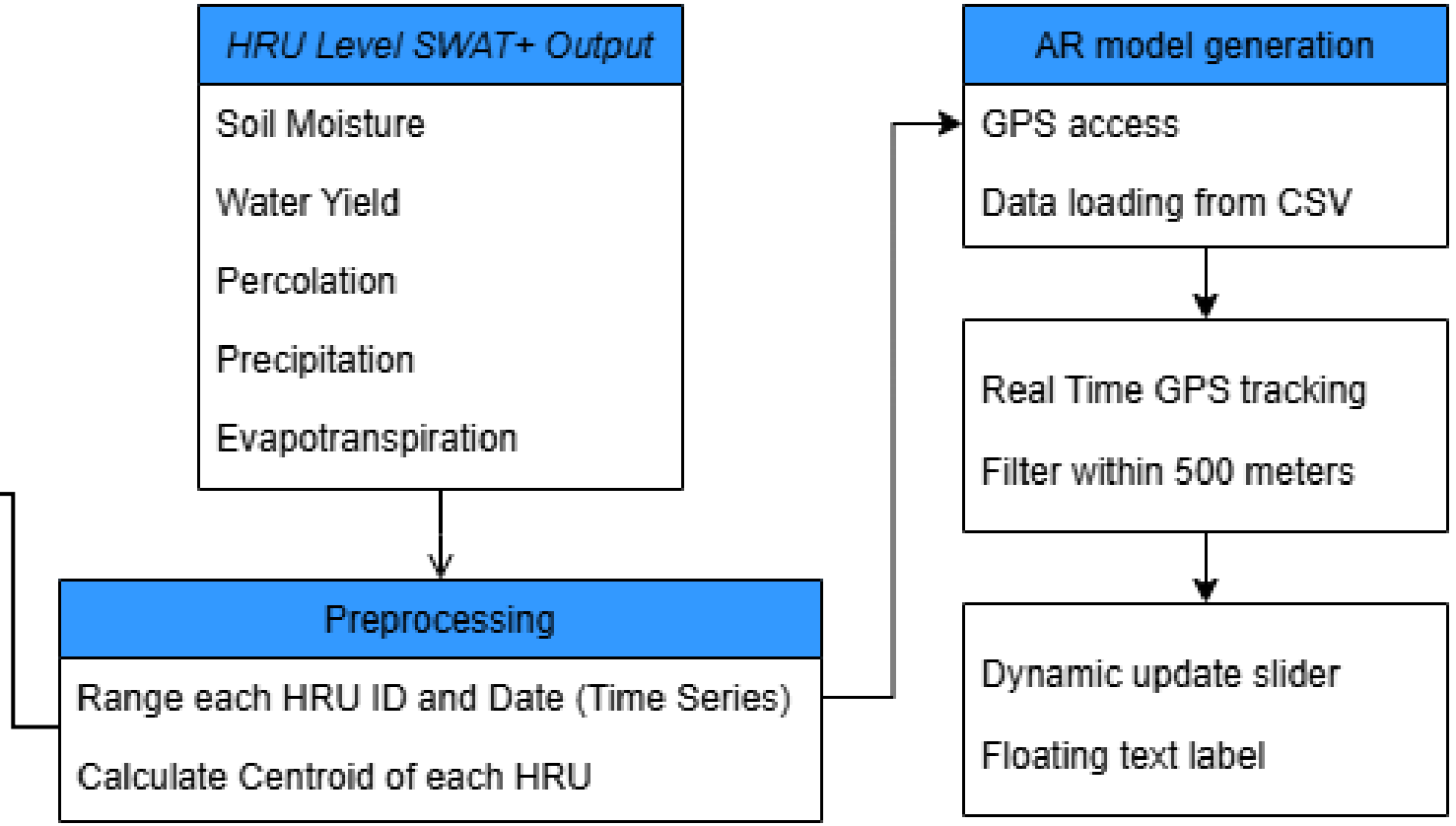
AR System Design

Flowchart

Flow work of building the AR system

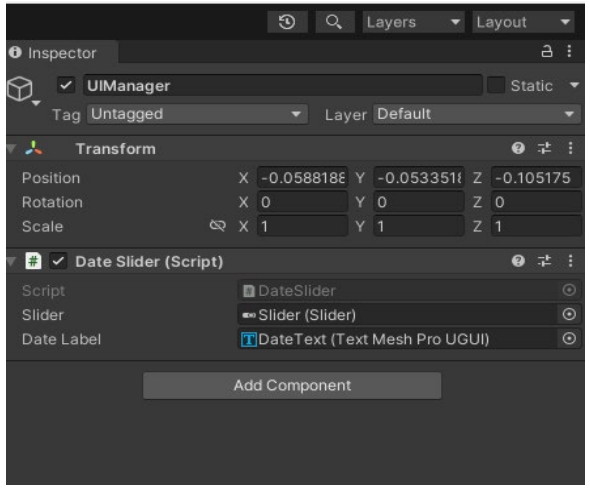
- SWAT+ outputs
- Data with GPS & date
- GPS finds nearest HRU (<500 m)
- User scrolls time with date slider
- AR app loads CSV
- Shows floating label

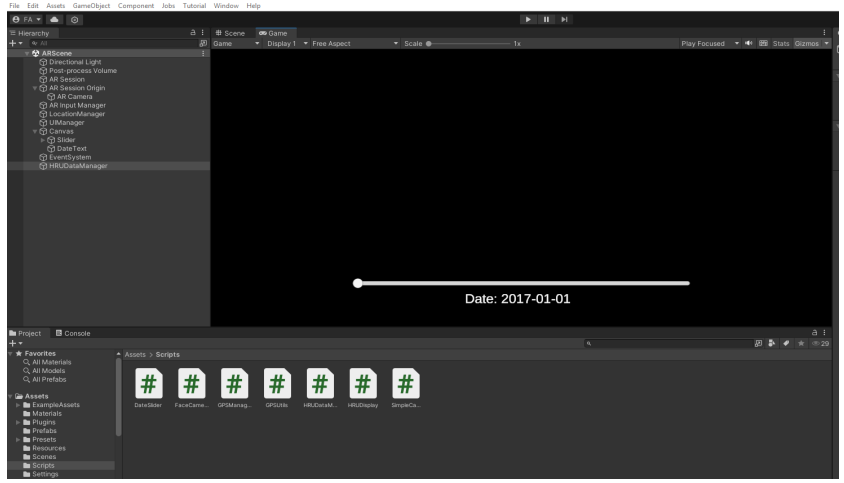
hruId	lat	lon	date	sw	wyld	perc	et	precip
1	36.211	129.176	1/1/2017	0.284	96.6	0.373	0.155	0
1	36.211	129.176	1/2/2017	0.275	95.8	0.369	0.155	0
1	36.211	129.176	1/3/2017	0.269	95	0.365	0.157	0
1	36.211	129.176	1/4/2017	0.265	94.2	0.361	0.116	0
1	36.211	129.176	1/5/2017	0.261	93.6	0.358	2.67E-02	0
1	36.211	129.176	1/6/2017	0.258	92.9	0.355	5.05E-02	0
1	36.211	129.176	1/7/2017	0.255	92.3	0.352	8.95E-02	0
1	36.211	129.176	1/8/2017	0.252	91.5	0.348	0.119	0
1	36.211	129.176	1/9/2017	0.249	90.8	0.345	0.104	0



AR System Design

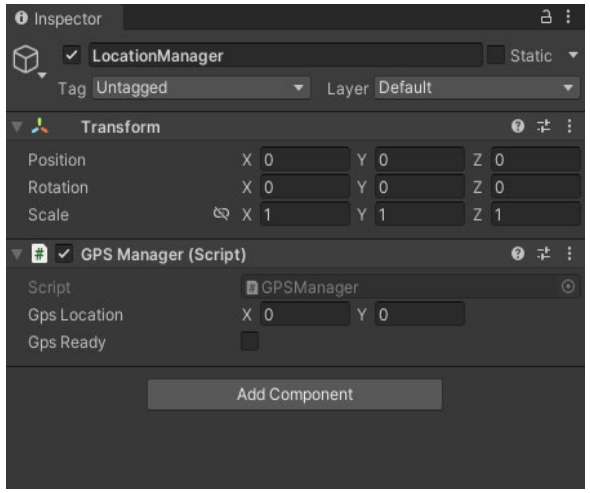
User interface(Slider)





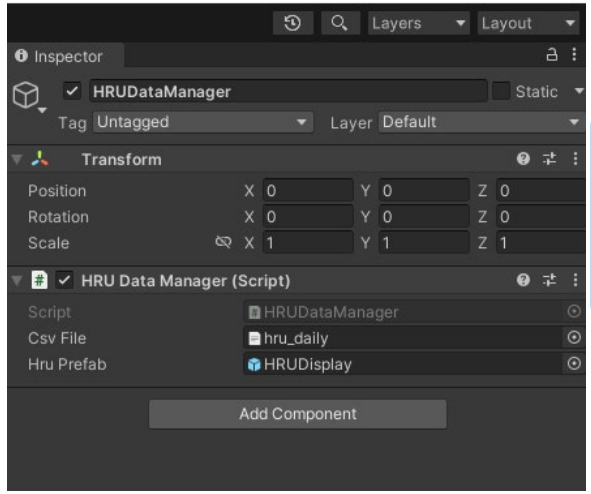
- Date Slider show on user interface
- To see the temporal changes of HRU data

GPS system



The GPS system detect user location based on device location and match to the data base

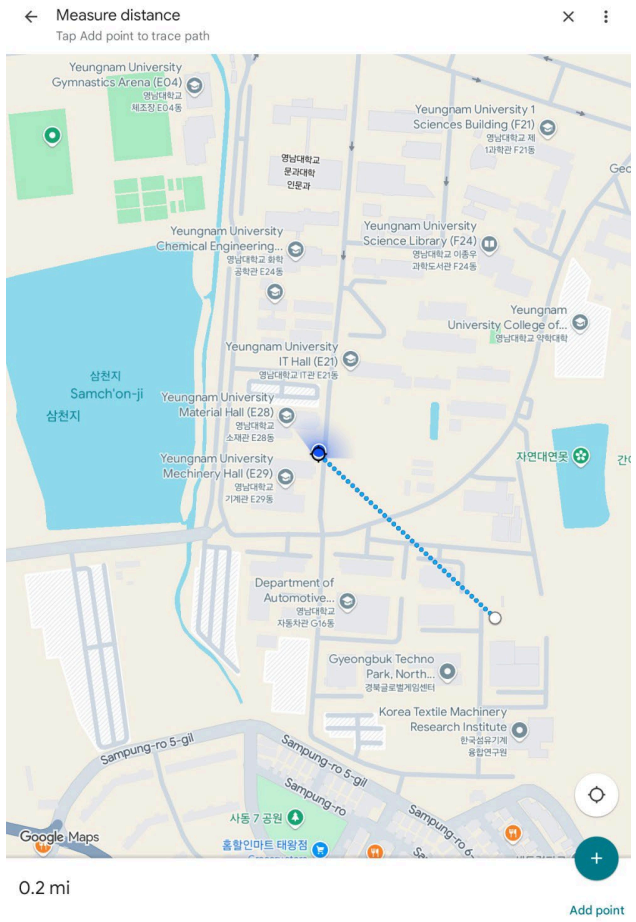
3D Object Generation



Print out the HRU information label on the screen
Floating label text

AR Visualization

AR Results



238	35.825	128.757	7/23/2017	1.12E-02	221	6.31E-02	1.36	0
238	35.825	128.757	7/24/2017	2.56E-03	231	6.11E-02	1.67	11.5
238	35.825	128.757	7/25/2017	6.00E-04	233	5.91E-02	1.09	3.5
238	35.825	128.757	7/26/2017	1.57E-04	230	5.71E-02	3.4	0
238	35.825	128.757	7/27/2017	5.62E-05	227	5.53E-02	2.12	0
238	35.825	128.757	7/28/2017	3.30E-05	226	5.35E-02	1.21	0
238	35.825	128.757	7/29/2017	2.01	253	5.17E-02	0.362	30
238	35.825	128.757	7/30/2017	0.454	251	5.01E-02	2.25	0.5
238	35.825	128.757	7/31/2017	0.103	264	4.84E-02	0.544	13.5
238	35.825	128.757	8/1/2017	2.32E-02	269	4.68E-02	2.85	7.5
238	35.825	128.757	8/2/2017	5.26E-03	266	4.53E-02	3.36	0
238	35.825	128.757	8/3/2017	1.21E-03	264	4.38E-02	1.85	0
238	35.825	128.757	8/4/2017	3.00E-04	262	4.24E-02	1.9	0

Input data base

- User location: 35.8268406 128.7546892
- 300-meter radius from HRU point

- Visualization of some HRU output parameters

AR Visualization

GPS :
35.8268406 128.7546892

- Demo video showing the application
- Sliding to different dates

Conclusion

- SWAT+ model was used to simulate daily hydrological dynamics across the study area.
- Augmented Reality (AR) was integrated to improve interpretation and communication of SWAT+ outputs.
- The application platform allows real-time, GPS-based interaction; users can view HRU data within a 500 m radius.
- A time-slider function enables exploration of daily data from 2017 to 2025, supporting educational and decision-making processes.
- The system provides an innovative and user-friendly approach to enhance spatial and temporal understanding of watershed behavior.

Challenges

- GPS precision in mobile devices
- Limited to areas where SWAT+ model data is available.

Future Work

- Expand AR support for more hydrological parameters
- Enhance AR interactivity and user interface
- Local stakeholders, farmers and students to use the app in participatory water resource planning

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감사합니다

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