AR Educational Suite

For Primary Students' Geometry and Literacy





R26-IM-005

PROJECT SUPERVISION

Supervisor



Mr. Aruna Ishara Gamage

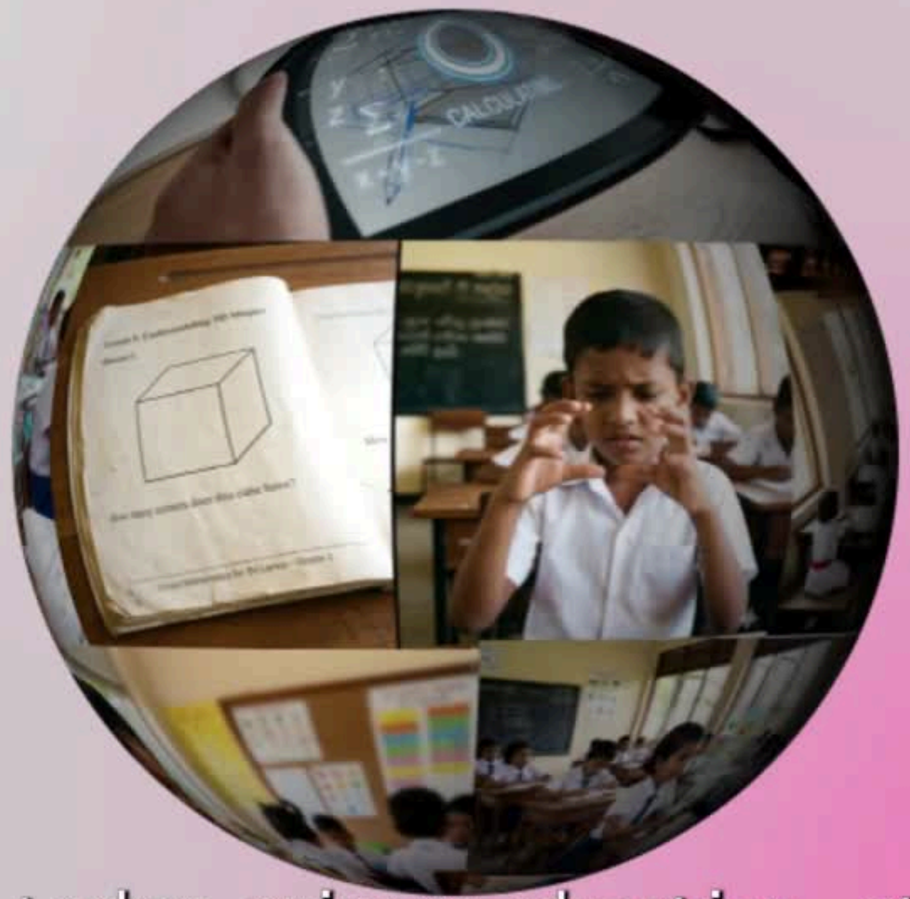
Senior Lecturer

Co - Supervisor



Mr. Nushkan Nisme

Assistant Lecturer



In Sri Lankan primary education, students face two critical hurdles.

Users, Stakeholders & Impact

Users

Students (Age 6-12)

Stakeholders

Teachers (Primary Grades)

Parents

Schools and Institutions



Impact

of the Research Problem

Students

- Difficulty understanding 3D concepts
- Poor handwriting development
- Weak vocabulary and pronunciation
- Low engagement in learning

Teachers

- Difficulty explaining abstract 3D concepts
- Limited tools for interactive teaching
- Hard to monitor individual student mistakes

Parents

- Difficulty supporting learning at home
- Lack of effective digital learning tools
- Concern about child's academic progress

Schools / Institutions

- Limited access to advanced learning technologies
- Lower student performance in STEM subjects
- Pressure to improve teaching effectivenes

Identified
Research Problem

How can a mobile-based AI and Augmented Reality (AR) system be designed to accurately convert student-drawn 2D sketches into validated 3D geometric models, verify geometric net correctness, and simultaneously support English letter stroke guidance and vocabulary learning in a single low-cost, real-time interactive educational environment optimized for primary school learners (ages 6–12)?



Existing Solutions & Their Limitations



Gaps Identified :

No real-time 2D sketch to valid 3D model conversion	No trajectory-based stroke order guidance in mobile learning
No visual explanation of spatial errors (only correct/incorrect feedback)	**No integrated system for writing, object recognition, and pronunciation**

Existing Solutions & Their Limitations

AR Geometry Learning Applications

Only visualize pre-built 3D models; no validation of student input

Handwriting / Letter Tracing Apps

Focus on final output; no real-time stroke order or trajectory analysis

Phonics & Pronunciation Apps

Teach pronunciation separately; no connection with writing or visual context

Sketch Recognition Systems

Convert sketches to models but do not validate geometric correctness

Air-Writing / Gesture Recognition Systems

Recognize gestures but lack educational feedback and learning integration

Proposed Solution

AI-Powered Mobile AR Educational Suite

C1 2D-to-3D Geometry Validation

- Sketch recognition and geometric feature extraction
- Conversion of student-drawn 2D sketches into 3D models
- Mathematical validation of geometric nets (foldability check)
- Real-time error detection in spatial structure

C2 Adaptive Scaffolding & Virtual Slicing

- Ghost overlay visualization for spatial comparison
- Real-time error highlighting using 3D overlapping models
- Virtual slicing for volume and fraction understanding (½, ⅓)
- Visual explanation of geometric mistakes (not just correctness)

Proposed Solution

AI-Powered Mobile AR Educational Suite

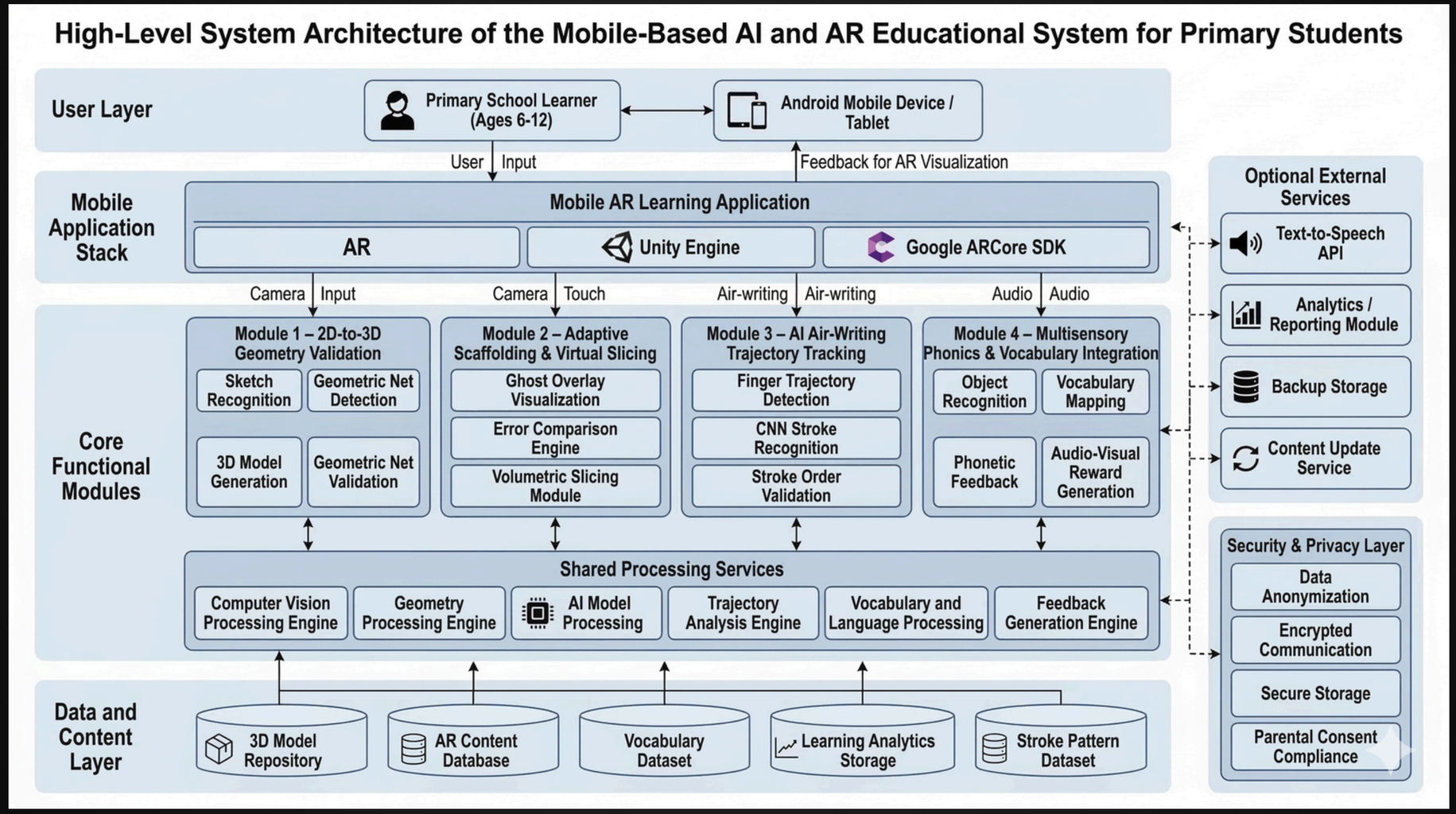
C3 AI Air-Writing Trajectory Tracking

- Finger trajectory detection using computer vision
- Stroke order and direction validation in real time
- CNN-based handwriting recognition
- Motion-based feedback for writing improvement

C4 Multisensory Phonics & Vocabulary Learning

- Object recognition linked with vocabulary learning
- Air-writing + word formation integration
- Speech-based pronunciation feedback
- Combined visual, motor, and auditory learning loop

System Architecture



Component 01 : 2D-to-3D Geometry Validation

IT22274298 | Himsara M.K.D.L



Contribution to Overall Project

- Develops the 2D-to-3D Geometry Validation Engine
- Transforms digital hand-drawn 2D sketches into mathematically validated 3D volumes in real-time
- Supports spatial understanding in geometry learning

Novelty

- Topological Validation Engine
- Uses an Adjacency Matrix and Euler's formula
- Combines sketch recognition with 3D model generation and validation in a single pipeline

Component 01 : 2D-to-3D Geometry Validation

Problem Definition

Primary school students struggle to understand how 2D geometric drawings relate to 3D objects. When students draw geometric nets or shapes, there is no system to verify whether their drawings can correctly form valid 3D structures. As a result, students develop misconceptions about spatial relationships and geometric properties.

- Incorrect sketches are not identified or corrected
- Lack of interactive tools to validate geometric constructions

Research Gap

- No real-time validation of student-generated sketches
- No mathematical verification of geometric net foldability
- Existing systems do not combine sketch recognition with geometry validation

Research Objective

Main Objective

To develop a system that converts student-drawn 2D geometric sketches into 3D models and validates their geometric correctness in real time within a mobile AR environment.

Sub-Objectives (SMART)

- Capture digital touch trajectories directly from the mobile UI canvas instead of physical paper.
- Extract geometric features using an optimized on-device CNN model.
- Develop a topological validation engine to mathematically verify the foldability of 2D nets.
- Procedurally generate custom 3D meshes in real-time from the validated digital sketch coordinates.
- Integrate ARCore to spatially anchor and animate the 2D-to-3D metamorphosis for interactive learning.

Component 01 : 2D-to-3D Geometry Validation

Key Technologies & Methodology

Sketch Recognition (Computer Vision)

- Detect geometric shapes from student-drawn sketches
- Extract edges, vertices, and structural features

Geometric Net Detection

- Identify valid geometric nets (cube, pyramid, prism)
- Analyze adjacency and face connections

2D-to-3D Model Generation

- Convert validated 2D sketches into 3D geometric models
- Use mesh construction and transformation algorithms

Geometric Validation Engine

- Perform foldability checks for nets
- Verify spatial correctness using geometric rules

AR Integration (Unity + ARCore)

- Render generated 3D models in real-world space
- Enable interactive visualization for students

Feature Extraction & Processing

- Extract key geometric parameters (edges, angles, faces)
- Normalize and preprocess sketch input

Validation & Evaluation

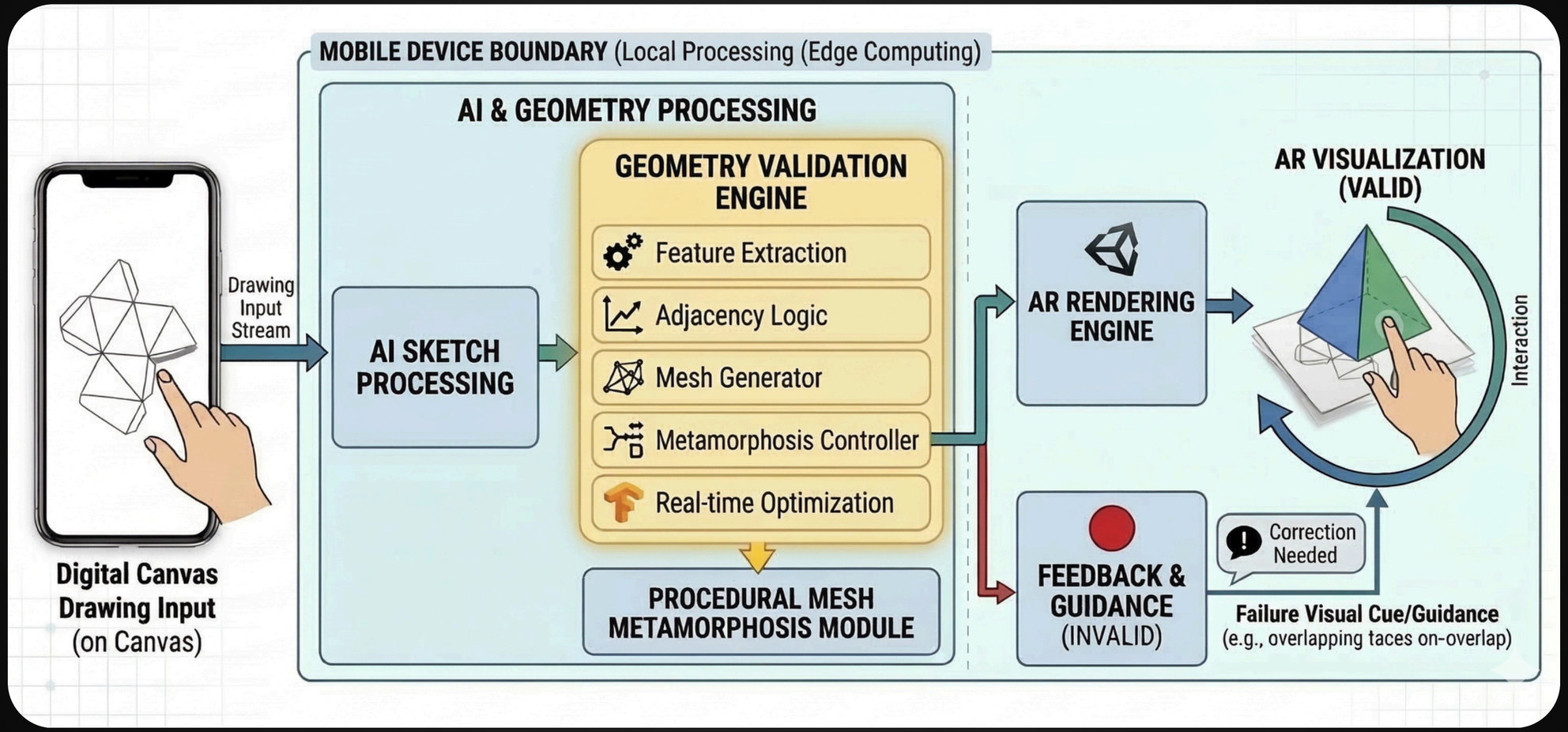
- Accuracy of sketch recognition and shape detection
- Validation success rate of geometric nets
- User testing with students to measure understanding improvement

Data & Ethics

- Student-generated sketch data used for processing
- No personal or sensitive data collected
- System designed for child-safe educational use

Component 01 : 2D-to-3D Geometry Validation

System Overview



Component 02 : Adaptive Scaffolding & Virtual Slicing

IT22179876 | De Costa M.M.P.



Contribution to Overall Project

- Provides visual explanation of errors instead of binary feedback
- Enhances understanding of 3D spatial relationships
- Supports geometry validation module with feedback layer
- Improves student learning through interactive AR guidance

Novelty

- Introduces ghost overlay visualization for real-time spatial comparison
- Provides visual error explanation instead of correct/incorrect feedback
- Integrates virtual slicing to reveal internal geometry and volume concepts
- Combines scaffolding + AR interaction in a single educational system

Component 02 : Adaptive Scaffolding & Virtual Slicing

Problem Definition

Primary school students often struggle to understand spatial errors in geometric constructions because existing learning systems provide only simple correct or incorrect feedback. Students cannot clearly identify where their mistakes occur or why their geometric structures are incorrect, leading to weak conceptual understanding.

- No visual explanation of spatial mistakes
- Students cannot compare correct vs incorrect structures
- Limited tools to understand internal geometry (volume, fractions)

Research Gap

Most existing AR learning systems focus on visualization rather than explanation. They do not provide adaptive visual guidance mechanisms that help students understand spatial errors through comparison or internal structure analysis.

- No adaptive visual scaffolding (ghost overlays)
- No real-time error comparison using 3D models
- No volumetric slicing to explain internal structures
- Lack of visual feedback beyond correct/incorrect responses

Research Objective

Main Objective

To develop an adaptive visual scaffolding system within a mobile AR environment that explains spatial errors using ghost overlays and virtual slicing visualizations.

Sub-Objectives (SMART)

- Design ghost overlay models to compare student-generated and correct 3D structures
- Develop an error comparison module using 3D overlapping visualization
- Implement a virtual slicing module to demonstrate volume fractions (½, ⅓)
- Integrate real-time visual feedback into the AR learning system
- Evaluate improvement in student spatial understanding

Component 02 : Adaptive Scaffolding & Virtual Slicing

Key Technologies & Methodology

Ghost Overlay Visualization

- Generate transparent reference 3D models
- Overlay correct model on student-generated model

Error Comparison Engine

- Compare geometry using spatial alignment
- Highlight mismatched areas in real time

Virtual Slicing Module

- Slice 3D models to show internal structures
- Demonstrate volume fractions (½, ⅓)

3D Model Alignment & Processing

- Align student and reference models in AR space
- Perform geometric comparison operations

AR Rendering (Unity + ARCore)

- Render overlays and slicing in real-world environment
- Enable real-time interaction and feedback

Feedback Generation System

- Provide visual cues (highlight, color, transparency)
- Guide user corrections interactively

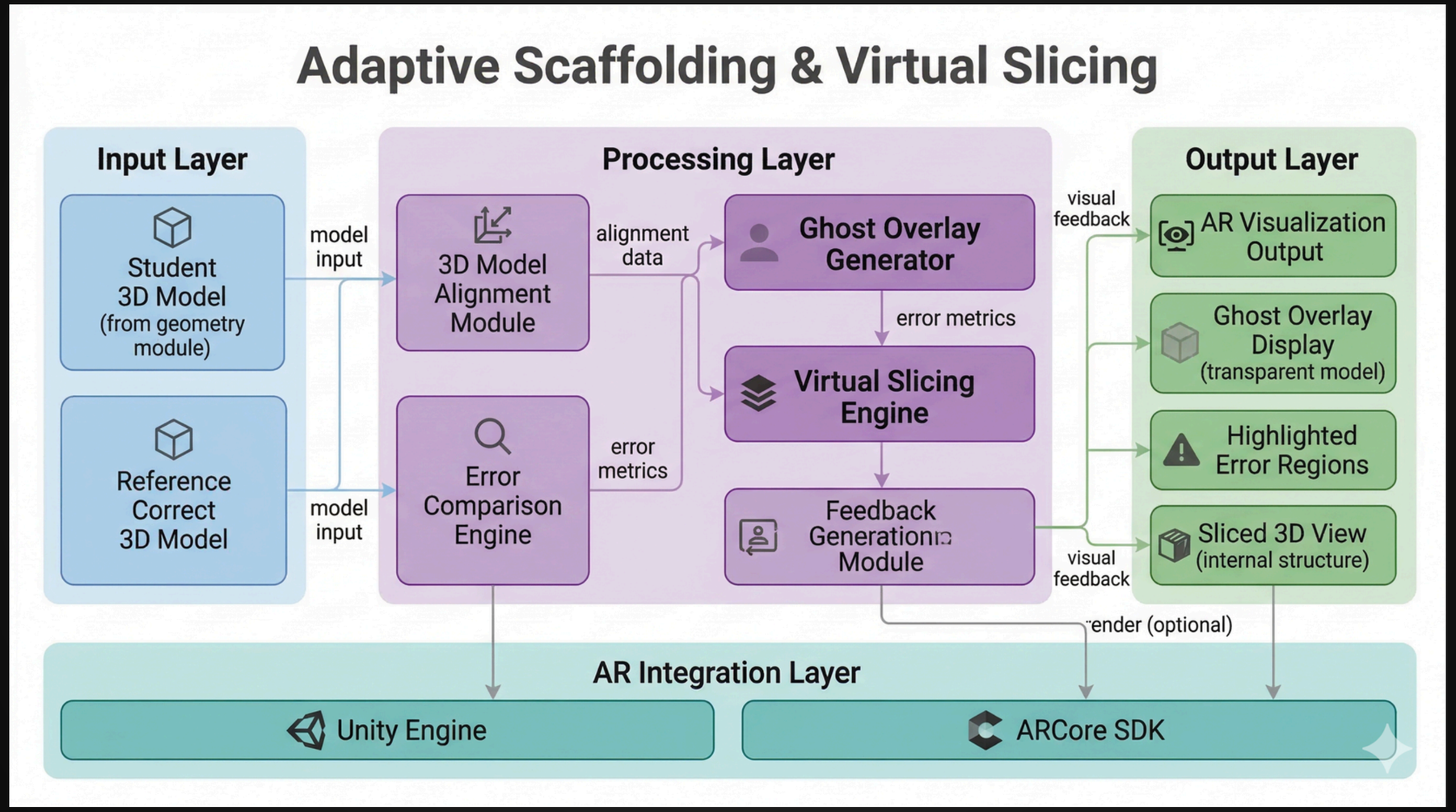
Validation & Evaluation

- Improvement in student spatial understanding
- Reduction in geometric errors after feedback
- Usability testing with primary school students
- User satisfaction and learning engagement analysis

Data & Ethics

- Uses system-generated geometric data only
- No personal or sensitive user data collected
- Ensures anonymized usage for evaluation
- Designed with child-safe and educational ethics

System Overview



Component 03 : AI-Air Writing Trajectory Traking

IT22081698 | Abhilash K.A.T.W



Contribution to Overall Project

- Adds the literacy tracking part of the full AR learning suite
- Captures live fingertip paths while students write letters in the air
- Checks stroke start, direction, and path before the reward step
- Sends correct-letter events to the phonics and 3D reward flow

Novelty

- Real-time stroke-direction awareness – Ensures strokes follow the correct direction.
- Tracks 3D air-writing trajectories – Captures full fingertip movement in 3D, using mobile phone camera.
- Checks start point stroke order – Verifies correct start and stroke sequence.

Component 03 : AI-Air Writing Trajectory Traking

Problem Definition

Primary school students often learn letter shapes without learning the correct stroke path. In busy classrooms, teachers cannot watch every child in classroom, so wrong writing habits can stay for a long time.

- Wrong stroke order is often not noticed early
- Most apps judge only the final letter shape
- Students get little step-by-step help while writing

Research Gap

Current literacy tools mainly use touch tracing or final-letter checking. Some research shows air-writing can work, but many solutions need extra sensors or do not give live AR guidance on normal phones.

- No real-time camera-based check of stroke order on standard mobile devices
- Limited instant visual correction for path and direction errors
- Weak link between air-writing guidance and the wider AR learning suite

Research Objective

Main Objective

To build a mobile AI + AR system that tracks 3D finger movement, recognizes English letter paths, and gives help so primary students can learn correct real-time stroke order and direction.

Sub-Objectives (SMART)

- Detect and normalize index-finger 3D coordinates from a live camera feed
- Build a trajectory buffer and motion features for 26 English letters
- Train a lightweight CNN and deploy it with TensorFlow Lite for offline use
- Compare live strokes with a standard path set and show AR correction at once

Component 03 : AI-Air Writing Trajectory Traking

Key Technologies & Methodology

Hand Landmark Detection

- MediaPipe Hands detects hand landmarks per frame in real time
- Index fingertip provides primary coordinate source

Stroke-Order Validation Engine

- Rule-based checks against canonical stroke database
- Validates start-point, stroke direction & waypoints

Trajectory Buffer & Feature Extraction

- Sliding temporal buffer accumulates fingertip coordinates
- Velocity vectors computed between consecutive frames
- Direction angles derived from velocity

AR Corrective Overlay (Unity + ARCore)

- Ghost path rendered at student's fingertip position in AR
- Directional arrows indicate correct next movement

CNN Trajectory Recognition Model

- 1D Convolutional Neural Network on coordinate sequences
- SoftMax output classifies all English letters

Tools & Platforms

- MediaPipe Hands - mobile-optimized hand tracking
- TensorFlow - CNN model training
- Unity 3D + ARCore - AR application framework
- Python · Android · Blender

Validation & Evaluation

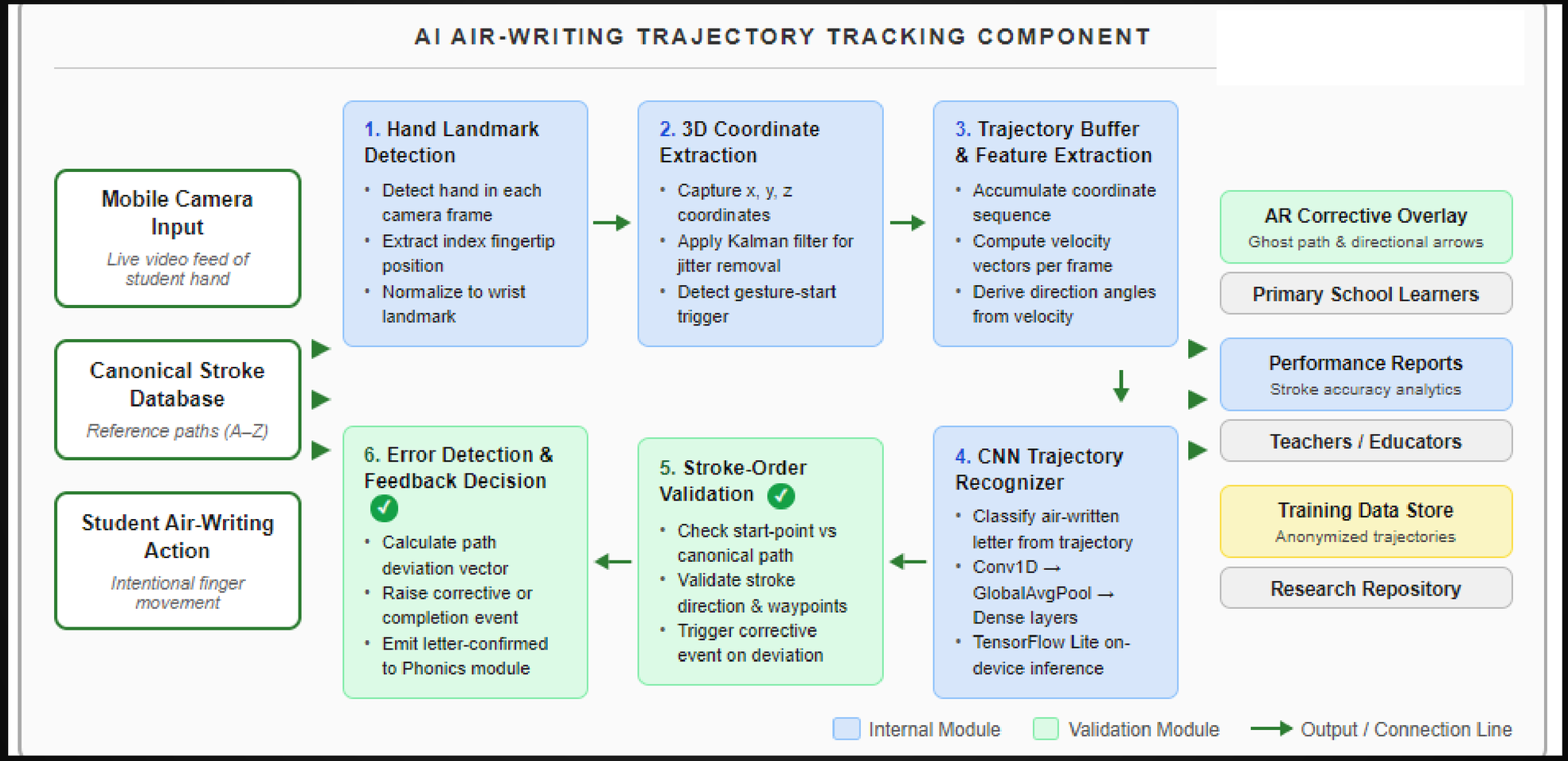
- Letter recognition accuracy via CNN test-set evaluation
- Stroke-direction detection rate using confusion matrix
- Real-time latency benchmarking on mid-range Android device
- Pre-test / post-test writing accuracy improvement with students
- User satisfaction assessed via System Usability Scale post-UAT

Data & Ethics

- Phase 1: users data traces to start model training
- Varied lighting and camera distance during collection
- Raw video is not stored, only anonymized coordinate data is saved
- Parent consent, secure storage, and ethics approval are required

Component 03 : AI-Air Writing Trajectory Traking

System Overview



Component 04: Multisensory Phonics Integration

IT22214102 | Wickramasingha N.N.



Contribution to Overall Component

- Supports the literacy learning part of the full AR Educational Suite
- Connects sketching, word learning, and pronunciation in one workflow
- Converts student-drawn 2D sketches into 3D representations
- Provides AR-based reward feedback to improve engagement
- Helps primary school learners learn vocabulary in an interactive way

Novelty

- Uses the student's own sketch as the basis for 3D generation
- Does not only display a ready-made 3D model
- Combines sketch recognition, word matching, and pronunciation validation
- Gives a completed 3D AR reward after successful learning steps
- Creates a multisensory learning loop

Component 04: Multisensory Phonics Integration

Problem Definition

- Children learn drawing, writing, and pronunciation separately
- Existing learning systems mostly focus on one activity at a time
- Limited real-time feedback in traditional learning methods
- Low engagement in passive learning environments
- Weak connection between English writing, and pronunciation

Research Gap

- No widely used system connects sketch, word, and pronunciation in one workflow
- Existing systems rarely transform the learner's own sketch into a 3D form
- AR tools mainly focus on visualization, not literacy validation
- Pronunciation tools and writing tools are mostly separate
- Limited mobile-based multisensory phonics systems for primary learners

Research Objective

Main Objective

- To design, develop, and evaluate a mobile-based multisensory phonics learning component using Unity and ARCore
- To recognize student-drawn sketches
- To transform sketches into 3D representations
- To validate word matching and pronunciation
- To provide AR-based reward feedback

Sub-Objectives (SMART)

- Develop a sketch recognition module
- Develop a 2D-to-3D transformation process
- Develop word and pronunciation validation
- Implement an AR-based reward mechanism
- feedback

Component 04: Multisensory Phonics Integration

Key Technologies & Methodology

Sketch Recognition (Computer Vision)

- Detect student-drawn object sketches
- Extract outlines and main shape features
- Identify the familiar object category

Pronunciation Validation

- Capture the learner's spoken word
- Recognize the spoken output
- Compare pronunciation with the expected word

2D-to-3D Transformation

- Convert the recognized 2D sketch into a 3D form
- Use shape filling, depth addition, and refinement
- Generate an initial 3D representation from the sketch

AR Integration (Unity + ARCore)

- Display the completed 3D object in AR
- Provide interactive reward-based feedback
- Improve learner engagement through visualization

Word Matching Validation

- Receive the air-written English word
- Compare it with the recognized object name
- Check whether the written word matches correctly

Supporting Tools

- OpenCV for sketch image processing
- TensorFlow for sketch recognition
- MediaPipe for hand input support
- Blender for 3D model refinement

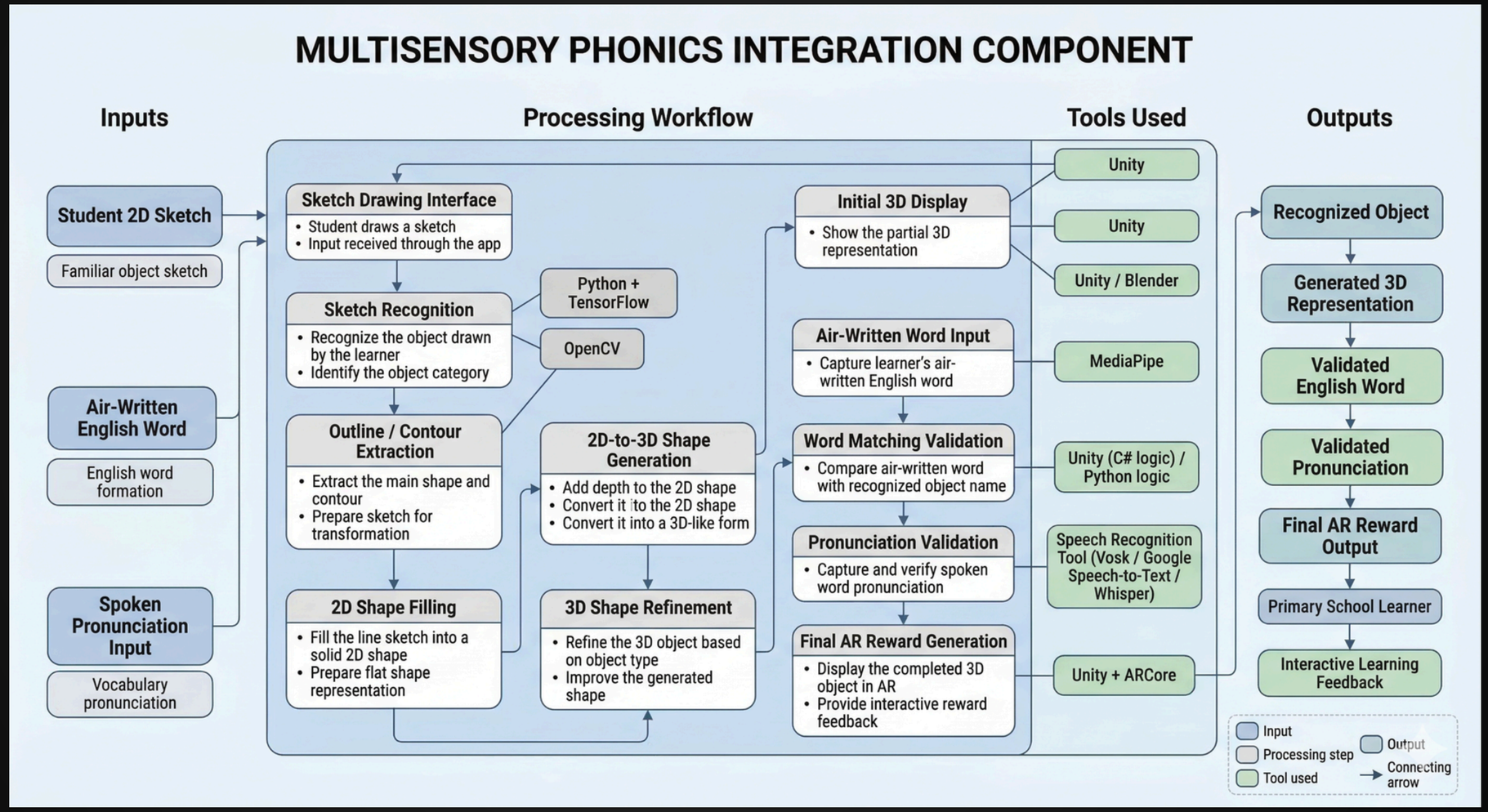
Validation & Evaluation

- Accuracy of sketch recognition
- Quality of 2D-to-3D transformation
- Accuracy of word matching
- Accuracy of pronunciation validation
- System response time for AR feedback
- User testing with learners for engagement and usability

Data & Ethics

- Student-generated sketch samples used for testing
- Object-word matching data used for validation
- Voice recordings used for pronunciation checking
- No unnecessary personal data collected
- Collected data anonymized for analysis
- System designed for safe educational use

System Overview



AR Educational Suite for For Primary Students' Geometry and Literacy - Commercialization

v1 Product Release

Released as a research prototype for testing and validation

Features

- Integration of all 4 components (Geometry + Literacy)
- Mobile AR application (Unity + ARCore)
- Basic AI modules for validation and feedback
- Proof-of-concept educational system

v1 Product Release

Planned as a full-scale commercial educational product

Features

- Full-featured mobile learning application
- Scalable cloud-based processing system
- Enhanced UI/UX for classroom and home learning
- Continuous updates and content expansion

Investment & Cost Recovery

- Development by student team using existing resources (low initial cost)
- Cost mainly for:
  - Mobile devices (tablets/smartphones)
  - Cloud services and backend infrastructure
  - Maintenance and updates
- Revenue through:
  - Subscription-based model for schools
  - Licensing for educational institutions
  - Premium features for parents (home learning)

Target Market & Value Proposition

- Target users:
  - Primary schools (local & international)
  - Parents of children (ages 6–12)
  - EdTech platforms
- Value:
  - Improves spatial understanding and literacy skills
  - Provides interactive and engaging learning experience
  - Combines multiple learning processes into one system
  - Scalable for global education markets

Customer Profile

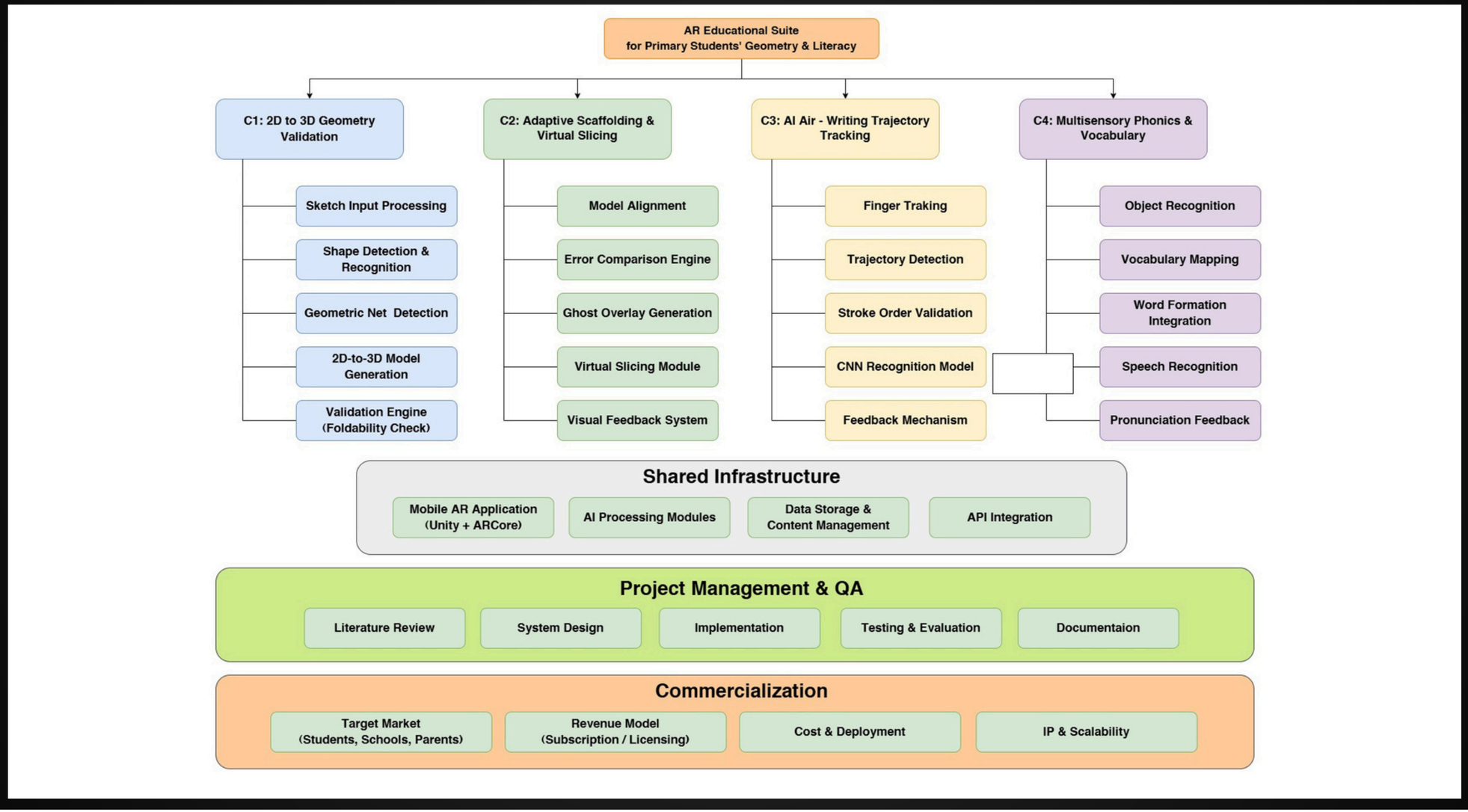
- Students (6–12 years) using mobile devices
- Teachers needing interactive teaching tools
- Parents supporting home learning
- Schools adopting digital education solutions

Intellectual Property Rights

- Novel system design integrating:
  - AR-based geometry validation
  - AI-based trajectory tracking
  - Multisensory learning integration
  - Adaptive visual scaffolding
- Potential protection:
  - Software copyright
  - Algorithm design and system architecture
- Possibility for:
  - Patent (combined AR + AI educational framework)
  - Licensing to educational platforms

AR Educational Suite for For Primary Students' Geometry and Literacy

Work Breakdown Structure (WBS)



AR Educational Suite for For Primary Students' Geometry and Literacy

Grantt Chart

	March	April	May	June	July	August	September	October	November	December
Proposal Submission										
Proposal Presentation										
Checklist Submission										
Progress Presentation 1										
Progress Presentation 2										
Final Report Submission										
Website Submission										
Final Checklist Submission										
Final Presentation & Viva										
Website Evaluation & Logbook Submission										
Research Paper Submission										
Research PaperPublication Evidence Submission										

References

- [1] W. Wang, et al., "Sketch2Model: Sketch-based 3D modeling using view-aware reconstruction," in Proceedings of the IEEE Virtual Reality Conference (VR), 2011.
- [2] R. Z. et al., "Deep Sketch Recognition: A Survey of Deep Learning Approaches," in Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition (CVPR) Workshops, 2018.
- [3] Z. Han, et al., "DeepSketch2Face: A Deep Learning Based Sketching System for 3D Face Modeling," ACM Transactions on Graphics, vol. 36, no. 4, pp. 126-136, 2017.
- [4] P. Xu, Q. Huang, and H. Wang, “Sketch-Based 3D Shape Retrieval Using Convolutional Neural Networks,” in Proc. IEEE Conf. Computer Vision and Pattern Recognition Workshops (CVPRW), Boston, MA, USA, 2015, pp. 187–194.
- [5] C. Amma, M. Georgi, and T. Schultz, “Air-Writing: Hands-Free Mobile Text Input by Spotting and Continuous Recognition of 3D-Space Handwriting with Inertial Sensors,” in Proc. ACM Int. Conf. Multimodal Interaction (ICMI), Santa Monica, CA, USA, 2012, pp. 52–59.
- [6] M. G. a. T. S. C. Amma, "Airwriting: Hands-free mobile text input by spotting and continuous recognition of 3D-space handwriting with inertial sensors," in ACM Int. Conf. on Multimodal Interaction (ICMI), 2012.
- [7] S. G. K. K. a. J. K. S. Molchanov, "Hand gesture recognition with 3D convolutional neural networks," in IEEE Conf. on Computer Vision and Pattern Recognition Workshops (CVPRW), 2015.

Thank You

We Welcome

Your Questions & Feedback