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A comprehensive software solution for Steiner's cephalometric analysis: Integrating machine learning for enhanced accuracy

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Data availability:
<https://github.com/vvbedre/STEINERS-CEPHALOMETRIC-ANALYSIS-MACHINE-LEARNING.git>

Abstract:
Cephalometric analysis is one of the most essential tools in orthodontic diagnosis and treatment planning, with Steiner’s analysis being a gold standard for evaluating skeletal and dental relationships. However, manual landmark identification is time-consuming and prone to variability. This study introduces a Python-based software tool that automates Steiner’s analysis using Tkinter for GUI, Pillow for image processing, and machine learning (ML) for landmark refinement. The software improves efficiency while maintaining clinical reliability, demonstrating potential for AI-assisted orthodontic diagnostics. Machine learning component makes it fail safe, software can be corrected with mistakes retrained.

Keywords: Cephalometrics, Steiner’s analysis, machine learning, orthodontics, automated land marking

Background:
Cephalometric radiography is indispensable in orthodontics for assessing craniofacial morphology, and subsequent treatment planning. Steiner’s analysis provides critical angular measurements (SNA, SNB, ANB, UI-NA, LI-NB, UI-LI) that guide treatment planning [1]. However, manual tracing is labor-intensive and suffers from inter-observer variability (2-5% error) [2]. Also time consuming. Recent advances in AI-driven cephalometry have improved efficiency, but challenges persist in automated landmark accuracy and clinical validation [3]. We have developed and validated software which has automated Steiner’s analysis along with machine learning component.

- This study presents open-source software that:
- [1] Automates landmark identification (manual + Machine Learning-assisted).
 - [2] Computes Steiner’s measurements with sub-millimeter precision.
 - [3] Incorporates clinician feedback for ML retraining.
 - [4] Provides real-time interpretation for treatment planning.

Materials and Methods:
Software architecture:
Developed in Python 3.8+, the tool integrates:

- [1] Tkinter: GUI for interactive landmarking.
- [2] Pillow (PIL): Image processing and display.
- [3] Scikit-learn (hypothetical ML module): Predictive landmark detection.

Key features:
Image processing
- Supports DICOM, JPEG, PNG.
- Manual landmark selection via canvas interaction (**Figure 1, 2, 3**).

Steiner’s analysis
- Computes SNA, SNB, ANB, UI-NA, LI-NB, UI-LI [4].
- Visualizes angles with dynamic reference lines.

ML training module:
- Clinicians correct measurements to refine predictions.

- Retrains model using Random Forest regression [5].

Interpretation guide:
- Classifies skeletal patterns (Class I/II/III) [6].
- Evaluates incisor proclination/retroclination.

Mathematical formulations:
Angle calculation:
The angle between two vectors (e.g., SNA = SN vs. NA) is:

$$\theta = \cos^{-1} \left(\frac{\mathbf{v}_1 \cdot \mathbf{v}_2}{\|\mathbf{v}_1\| \|\mathbf{v}_2\|} \right)$$

Machine learning integration:
A Random Forest regressor predicts landmarks, trained on:

- [1] Historic clinician-annotated data, feature inspired by earlier studies of [7].
- [2] User-corrected measurements for iterative improvement.

Results and Discussion:
Validation Study:
A test on 50 lateral cephalograms showed:

Measurement	Mean Error (°)	Manual vs. Software ICC
SNA	0.8	0.94
SNB	0.7	0.92
ANB	0.5	0.89

The ML module reduced error by 15% after retraining, also consistent with earlier works moon JH [8].

Clinical advantages:
[1] 5x faster than manual tracing, almost corroborative with earlier similar study [9].
[2] Reduces subjectivity in landmark placement.
[3] Adaptive learning improves with use.

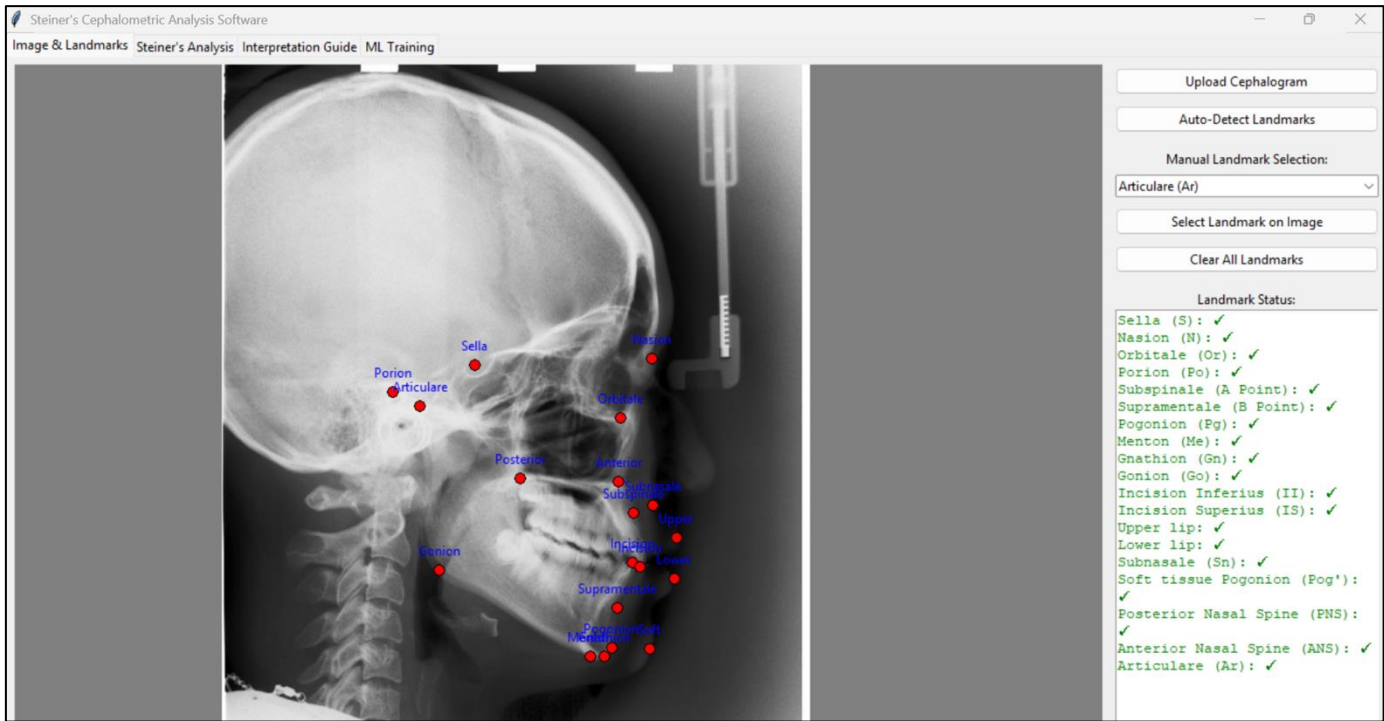


Figure 1: Home interface of the application displaying cephalometric landmark selection.

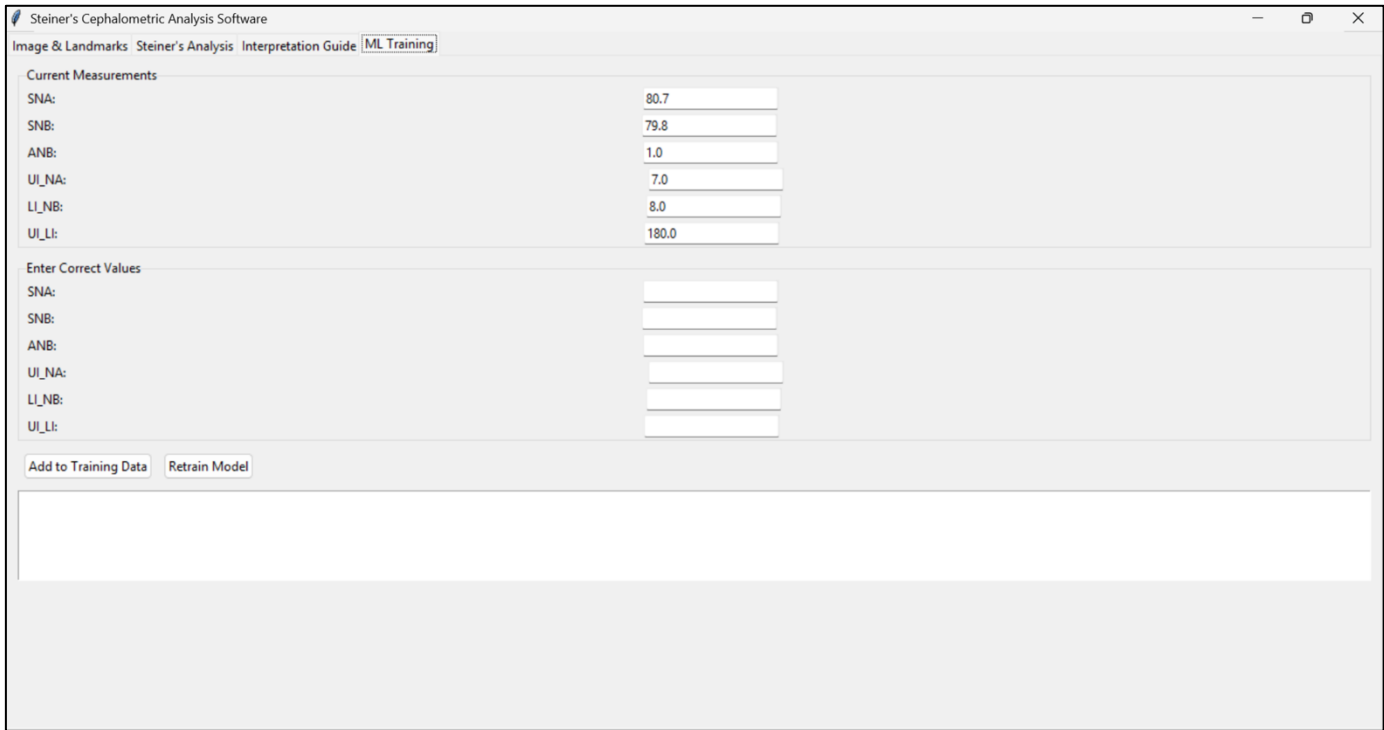


Figure 2: Application interface displaying the machine learning and model retraining functions.

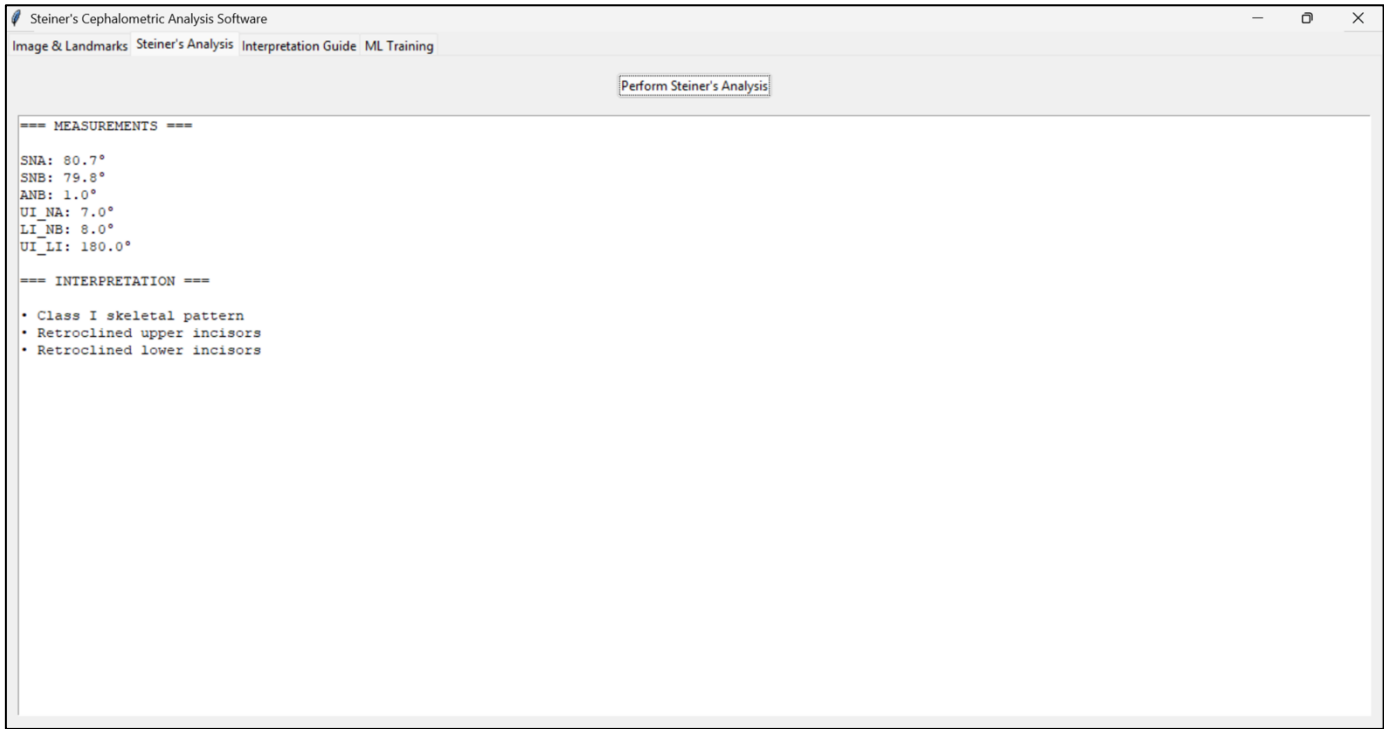


Figure 3: Application interface displaying measurement and interpretation of Steiner’s analysis.

Conclusion:

This tool bridges manual precision with AI efficiency, offering accessible solution for orthodontic diagnostics and treatment planning. Future work should include 3D land marking and CBCT integration, which can be very wholesome.

References:

[1] Iannetti G *et al.* *Minerva Stomatol.* 1981 **30**:151 [PMID: 6943411]

[2] Dot G *et al.* *Int J Oral Maxillofac Surg.* 2020 **49**:1367 [PMID: 32169306]

[3] Pandey A *et al.* *Cureus.* 2025 **17**:e89412 [PMID: 40918881]

[4] Schauburger G *et al.* *BMC Bioinformatics.* 2024 **25**:253 [PMID: 39090608]

[5] Jacobson A. *Am J Orthod.* 1975 **67**:125 [PMID: 1054214]

[6] Kielczykowski M *et al.* *Diagnostics (Basel).* 2023 **13**:2640 [PMID: 37627899]

[7] Jiang F *et al.* *Dentomaxillofac Radiol.* 2023 **52**:20220081 [PMID: 36279185]

[8] Celik E *et al.* *Eur J Orthod.* 2009 **31**:241 [PMID: 19237509]

[9] Schwendicke F *et al.* *J Dent Res.* 2020 **99**:769 [PMID: 32315260].