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ROYAL MAXIM PALACE KEMPINSKI, CAIRO

Prediction of Surgical Success in Strabismus Surgery Using Artificial Intelligence

Presented by:
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Financial Disclosures:

"I have no actual or potential conflicts of interest to disclose in relation to this presentation"

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What is the definition of successful strabismus surgery?

- Acceptable postoperative range at a defined time 3-6 months:
  - Orthotropia
  - Horizontal deviations; ±10 prism diopters
  - Vertical deviations; ± 5 prism diopters
- Functional binocular vision & pt cosmetic satisfaction
- Absence of diplopia in primary gaze
- No reoperation

Definition of successful outcomes after surgery for each type of strabismus: a Delphi study

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BACKGROUND The Delphi process has been widely used to delineate guidelines for the treatment of disorders for which there is little or no evidence in the published literature. The purpose of this study was to use the Delphi process to identify areas of consensus and disagreement on the definition of success after surgery for each type of strabismus.

METHODS Two rounds of electronic questionnaires were sent to 28 members of the Strabismus Success Definition Delphi Study Group. For the first round, responses to 70 questions were captured as agree (= 1) and disagree (= 2). For round 2, a total of 89 questions were captured on a Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree). Consensus was determined a priori at 85%.

RESULTS In both the first and second rounds, inter-rater agreement of 85% consensus was reached for only 20% of questions. Intra-rater agreement per question was low, with κ values ranging from −0.11 to 0.62. Intra-rater agreement was also low among themes, ranging from poor to fair agreement: κ = 0.25 for motor, κ = 0.28 for sensory, and κ = 0.35 for follow-up.

CONCLUSIONS This study highlights consensus areas that could be considered by researchers in designing studies and identifies areas where lack of consensus indicates that further research is needed. (J AAPOS 2021;25:3.e1-5)

Clinical Benefits

- Personalized surgical dosing
- Reduced reoperation rates
- Better patient counseling
- Objective decision support

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Why Prediction is Difficult by traditional methods?

- Surgeon-dependent factors
- Historical bias
- Nonlinear muscle response
- Individual anatomical variability
- Neuroplasticity differences

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Traditional Prediction Methods

- **Surgeon’s experience**
- Surgical tables and nomograms
- Prism adaptation
- Historical outcome analysis

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Traditional Prediction Methods

- Surgeon experience
- **Surgical tables and nomograms**
- Prism adaptation
- Historical outcome analysis

TABLE 14-2. Surgery for Exotropia

Angle of Dev (Δ)	*Rec LROU (mm)*
15	4
20	5
25	6
30	7
40 or >	8

Angle of Dev (Δ)	*Rec LR (mm)*	*Res MR (mm)*
15	4	3
20	5	4
25	6	5
30	7	6
40	8	7
50	9	8
60	10	9
80	11	10

Angle of Dev (Δ)	*Res MROU (mm)*
15	3
20	4
25	5
30	6
40 or >	7

Dev, deviation; MR, medial rectus; LR, lateral rectus; OU, both eyes; Rec, recession; Res, resection; Δ, diopters.

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So,

Is artificial intelligence a replacement for humans, or its here only to fix our imperfections?

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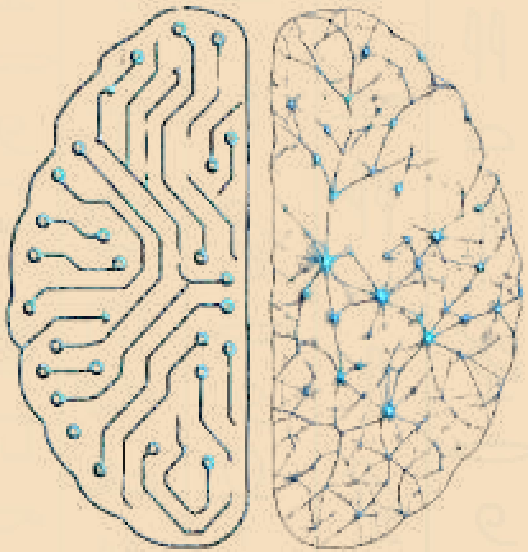
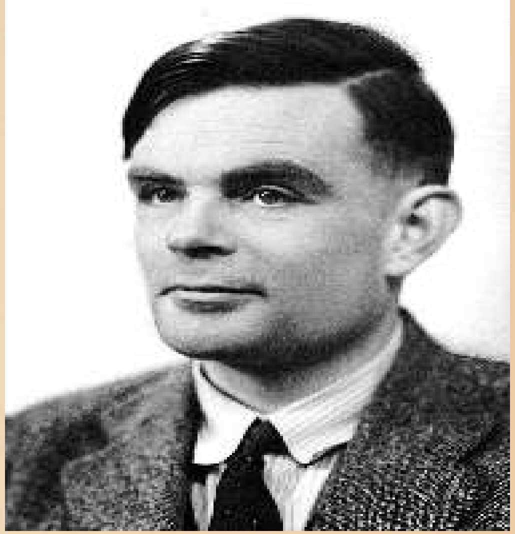


Artificial intelligence

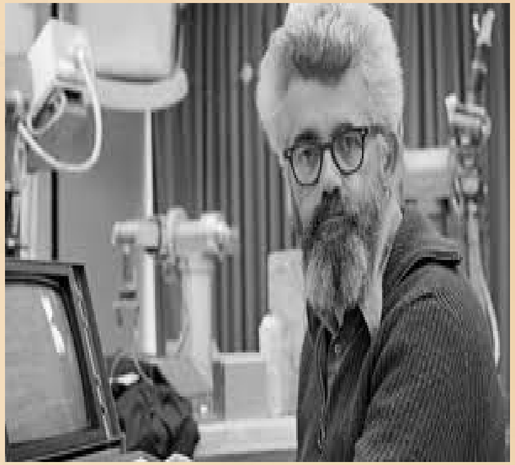
What Is Artificial Intelligence?

“Computer systems that can perform tasks requiring human intelligence, like learning, reasoning, and decision-making”

AI is **designed to think and act like humans** in specific tasks



Alan Turing



John McCathry

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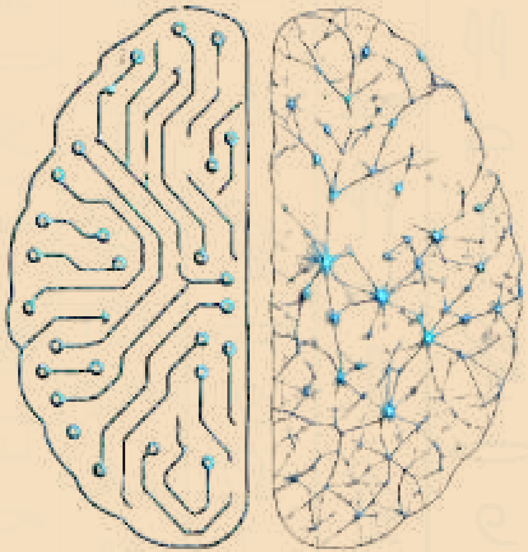

AI Models

AI Models:

Machine learning

Learns patterns from past surgical outcome (SVM, Random forest)

Deep learning

Neural networks analyze complex data (images, photos, videos)

Generative AI

Creates new data or simulations Supports decision-making and scenario modeling

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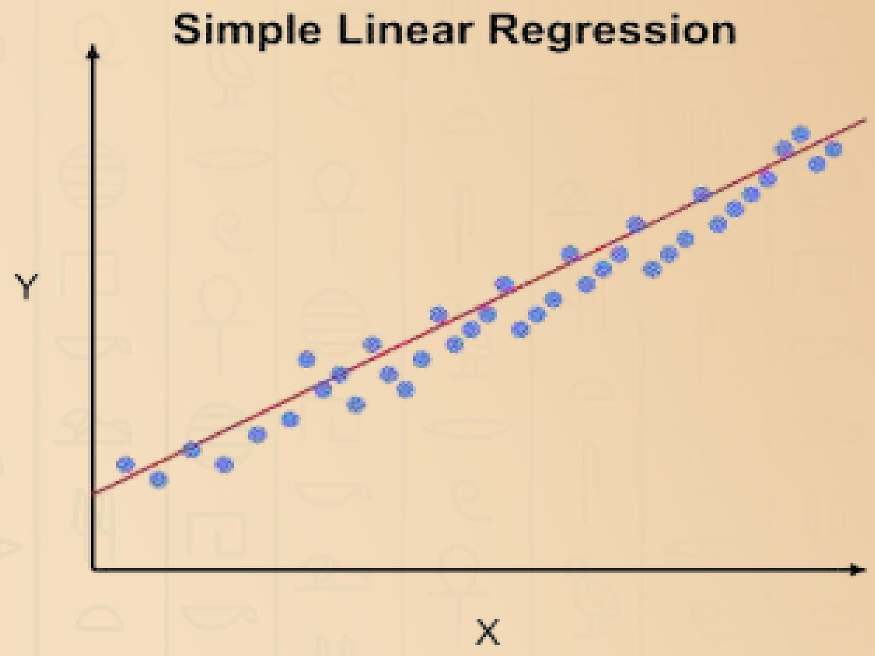
Types of AI Models

- Machine Learning:
  - **Linear Regression**
  - Support Vector Machines (SVM)
  - Random Forest
- Deep Learning:
  - Convolutional Neural Networks (CNN)
  - Multilayer Perceptron (MLP)



Predicts a value by drawing the best-fitting straight line through data points.

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Example： How to predict postoperative alignment according to patient age ?

Y= mx + b

X= age of the patient

M= slope : how age affects angle of strabismus

B= value of y when x is zero

Y= postoperative angle according to age

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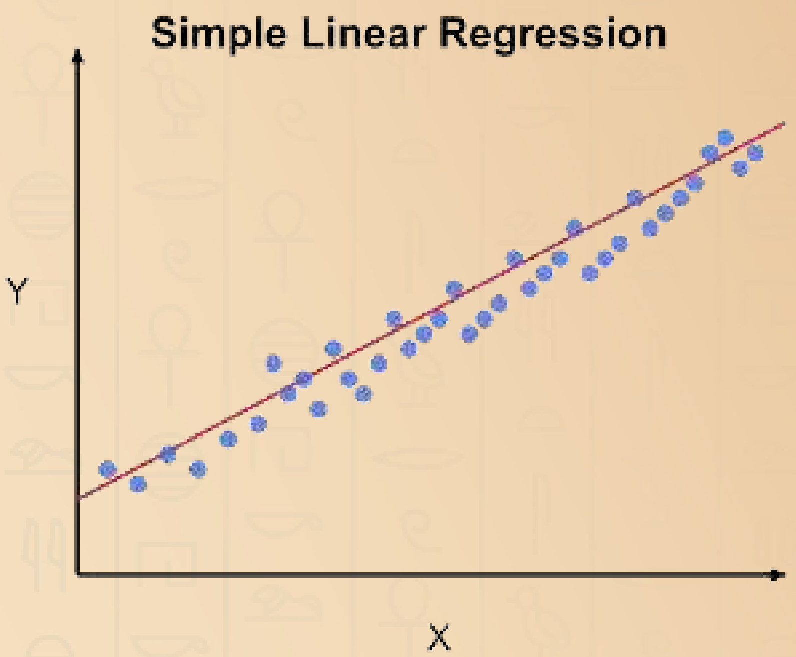

After applying the data to the equation. Now, we can predict the postoperative outcome based on age

DON'T reflect non linear or complex relationships

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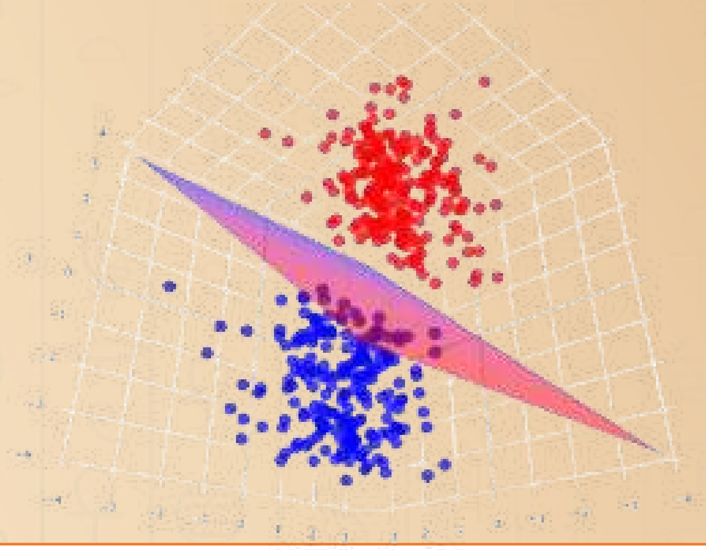
Types of AI Models



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- SVM uses key points (called support vectors) to separate two different classes
- In strabismus surgery, it can classify patients into good or poor postoperative outcomes
- SVM can handle complex and non-linear relationships
- It gives accurate predictions

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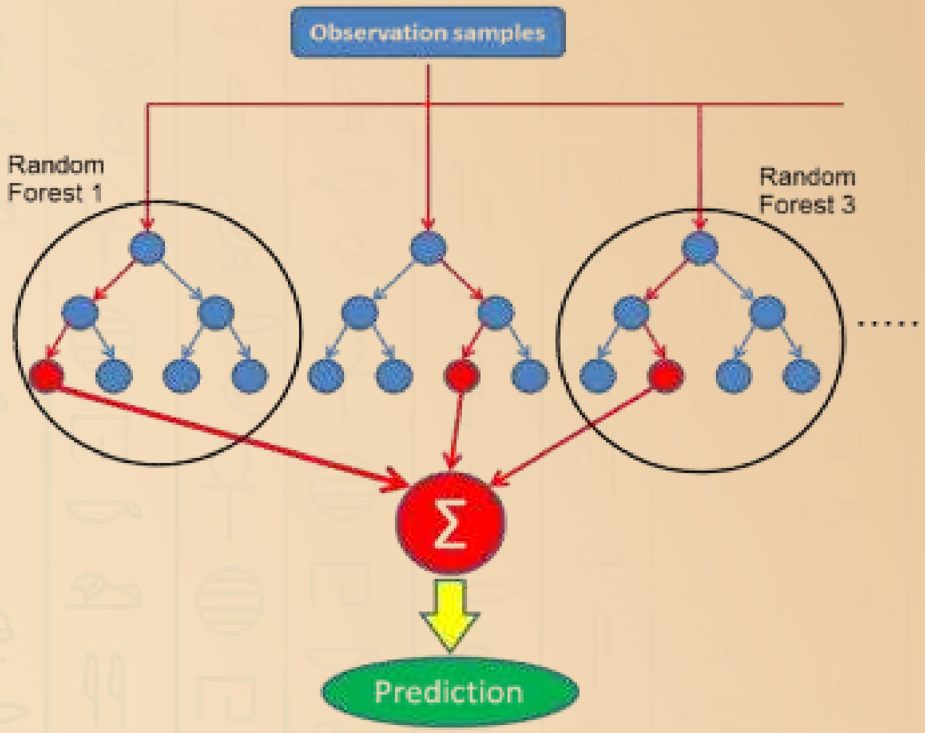

- Predicts postoperative alignment in children (2–10 years) using age, preoperative deviation, strabismus type and surgery type.
- Multiple decision trees are obtained from different random data sets.
- Final prediction = vote of all trees

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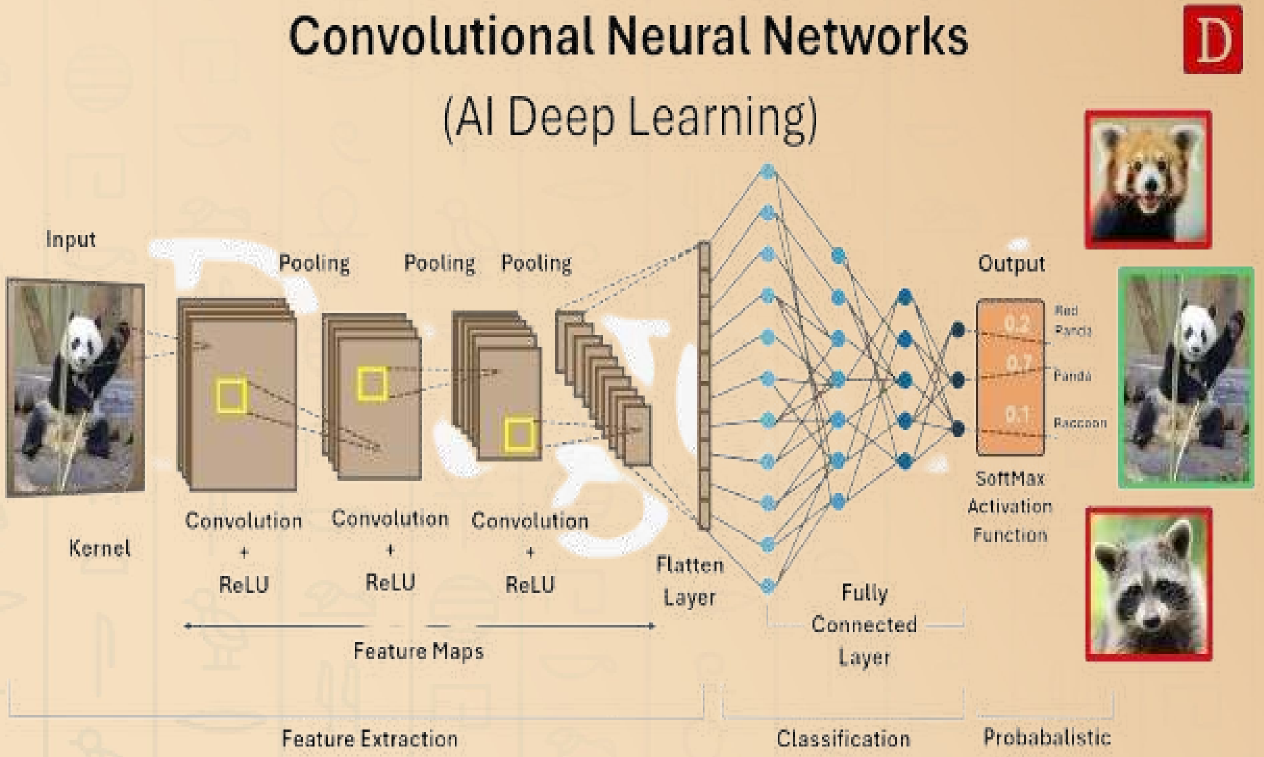

CNN:
Purpose: Analyze images and recognize patterns automatically.
How it works:
• Convolution layers: Detect small features (edges, shapes).
• Pooling layers: Reduce image size, keep important info.
• Fully connected layers: Combine features to classify the image.

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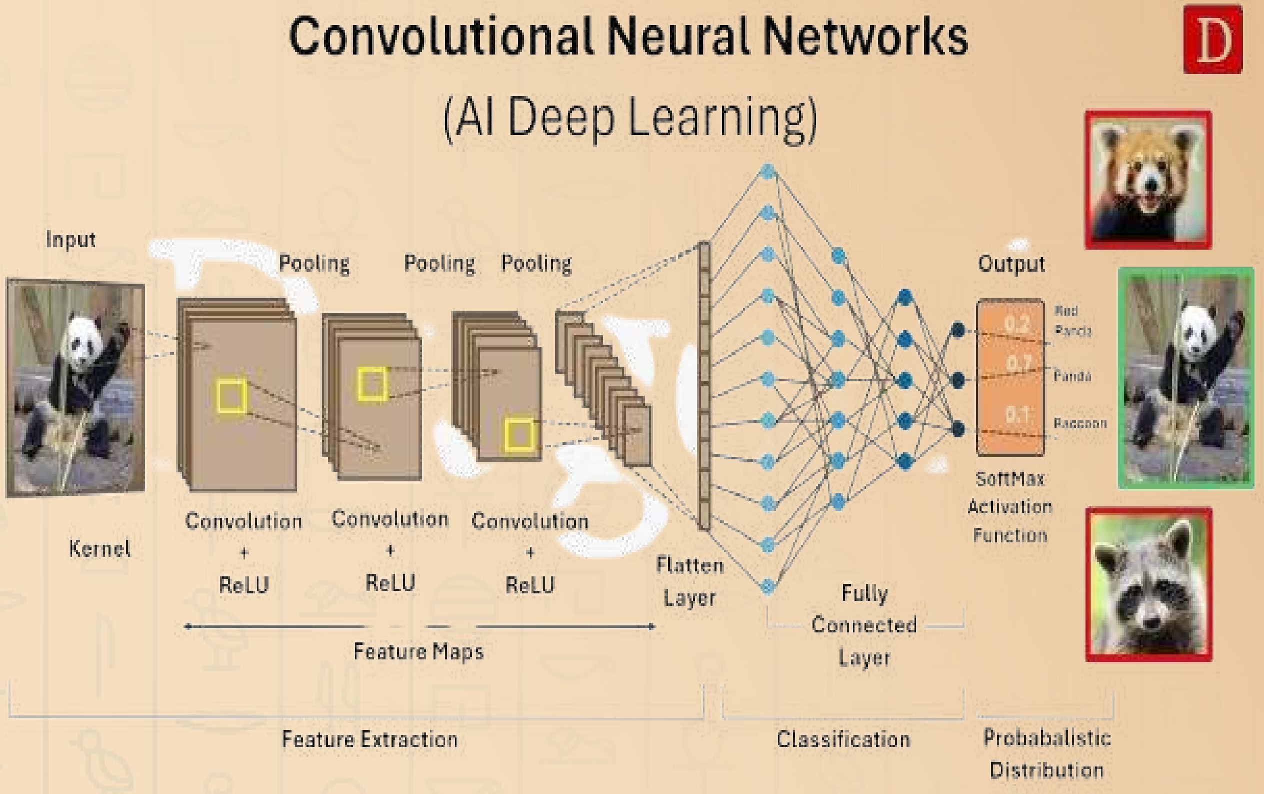

•CNN analyzes preoperative photos of children.
• Predicts postoperative alignment and appearance.

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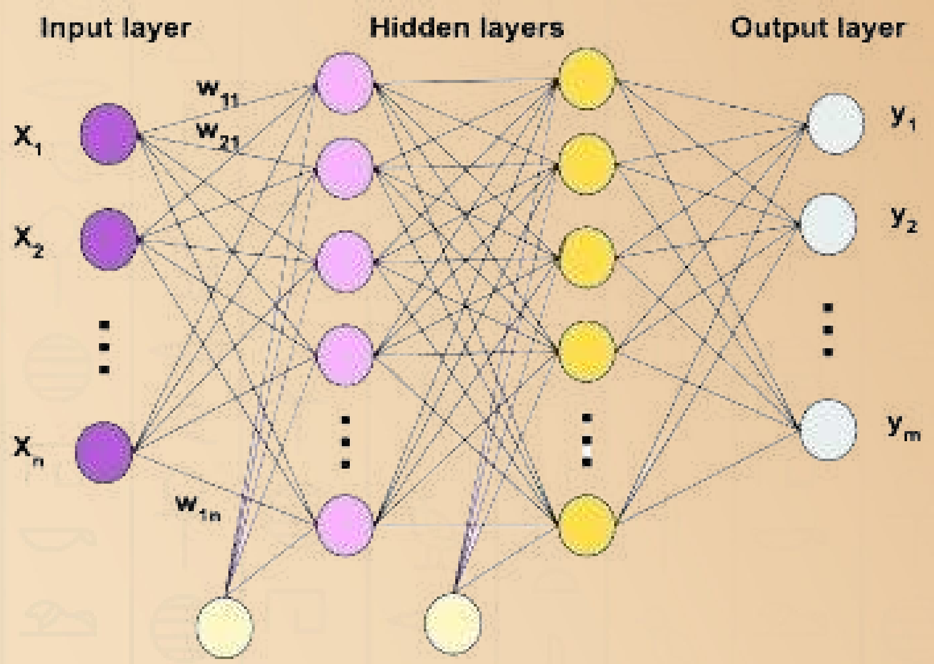

Purpose: Predict outcomes from complex data using multiple layers of neurons.
How it works?
• Input layer: Takes initial features (age, type of strabismus, preoperative deviation).
• Hidden layers: Find patterns and relationships between features.
• Output layer: Produces the prediction

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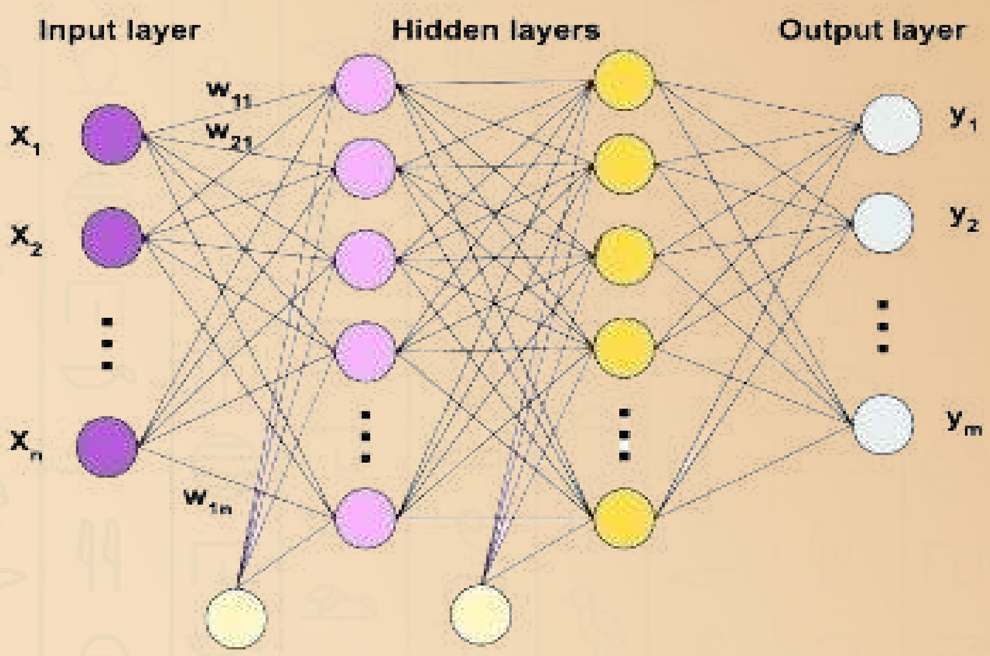
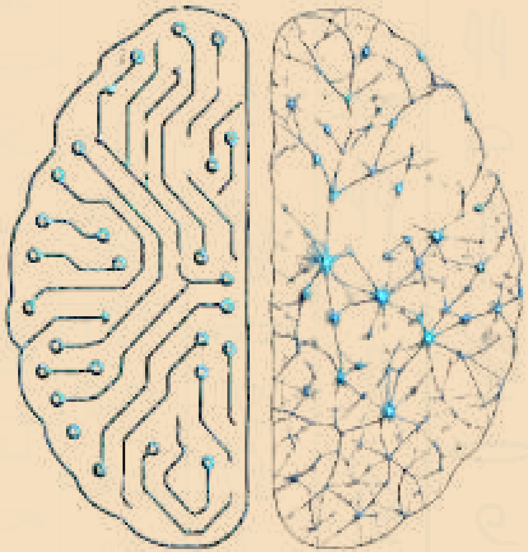


Example in Strabismus Surgery:
- MLP analyzes preoperative data
- Predicts postoperative and potential adjustments needed



How can it work?

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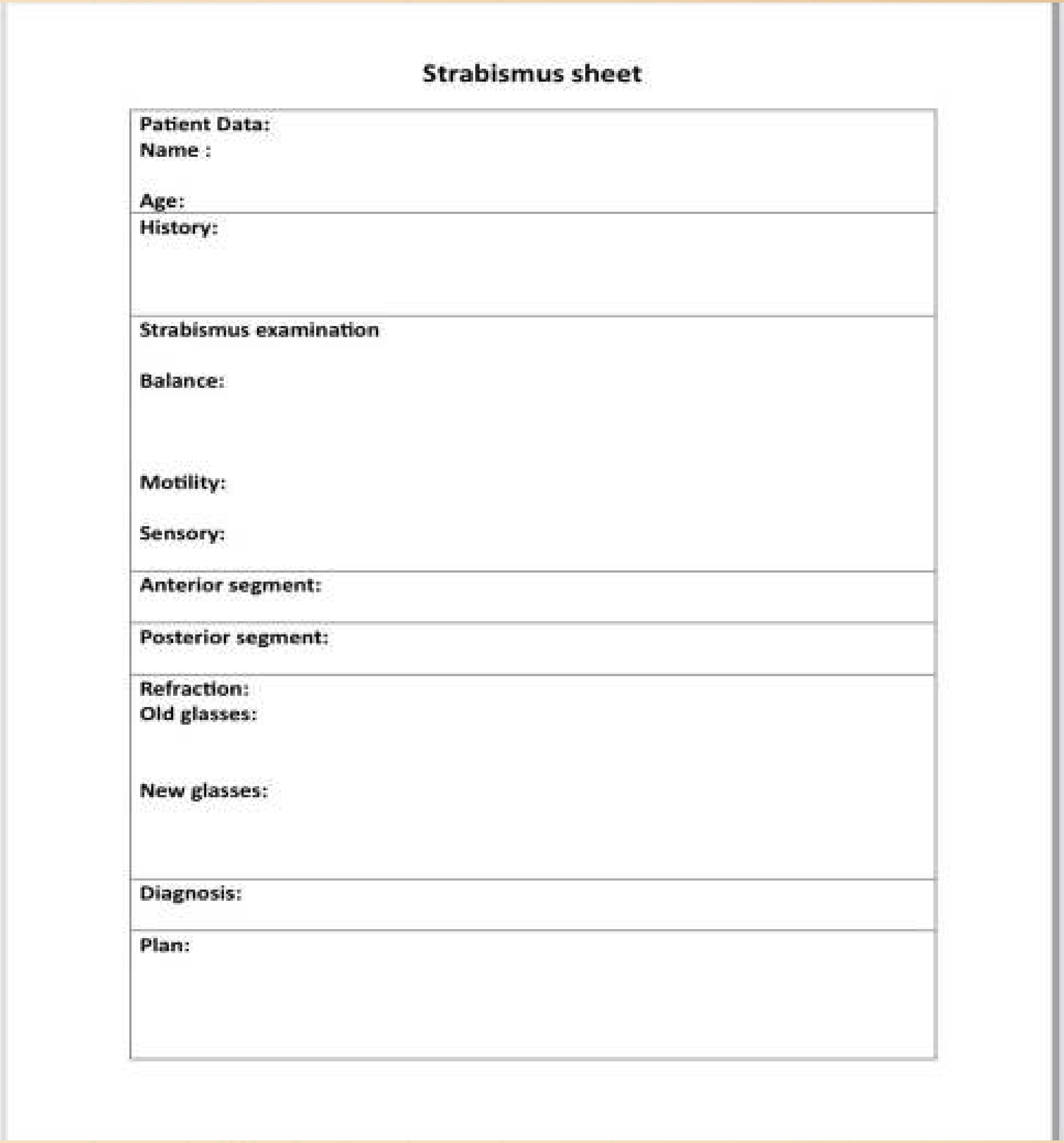
Data based AI



Strabismus sheet

Patient Data: **Name :** **Age:**
History:
Strabismus examination **Balance:**   **Motility:** **Sensory:**
Anterior segment:
Posterior segment:
Refraction: **Old glasses:**   **New glasses:**
Diagnosis:
Plan:

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Data based AI

- Demographics (age, sex)
- Type of strabismus
- Angle of deviation (distance/near)
- Visual acuity & amblyopia
- Refraction
- Binocular vision tests
- Surgical dose

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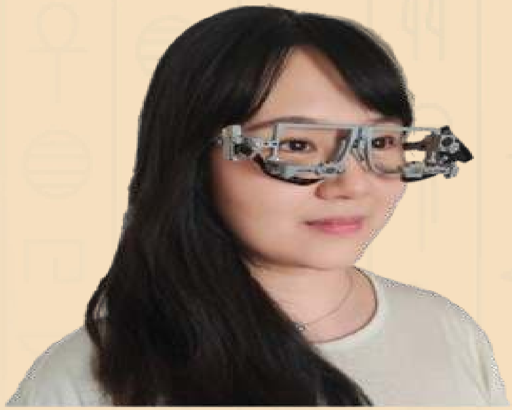
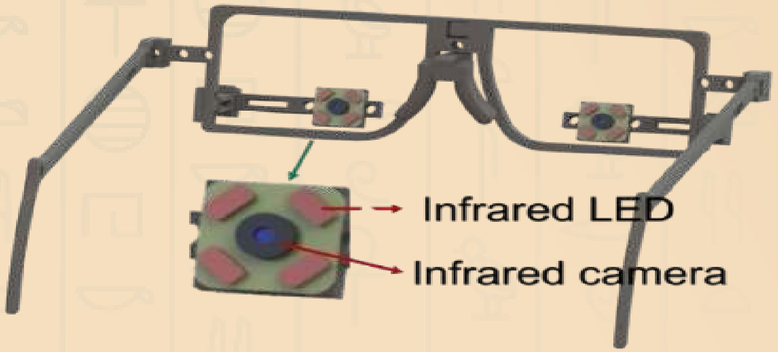
Imaging Based AI and strabismus angle assessment

- Corneal light reflex photographs
- Cover test videos
- Eye tracking data
- CNNs automatically extract features

- CNNs localize pupil & corneal reflex
- Calculate deviation in prism diopters
- Mean error < 4 PD, Compared to experienced clinicians





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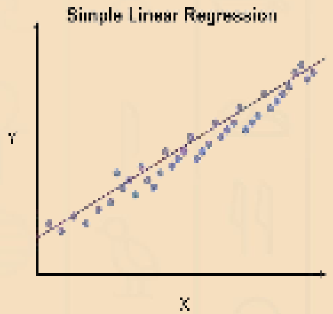
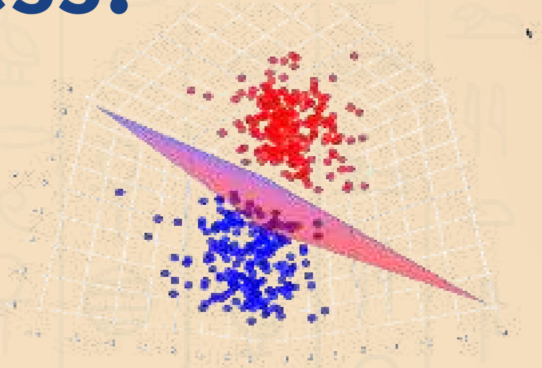
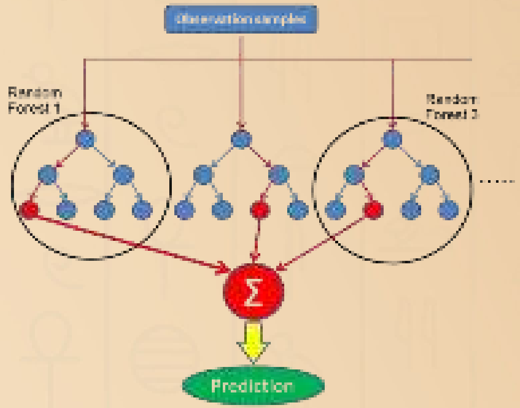
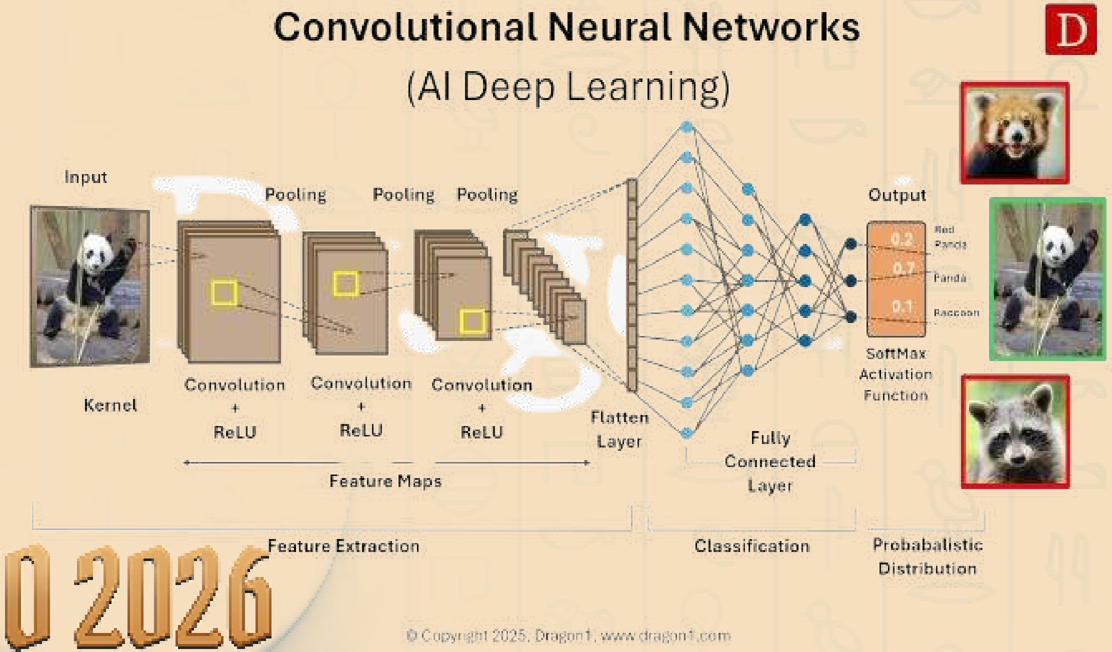
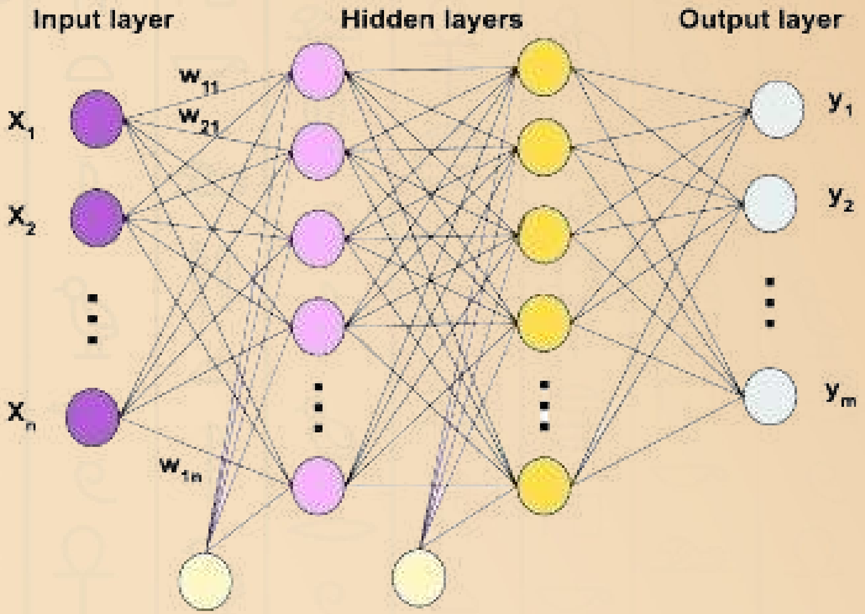
Prediction process:



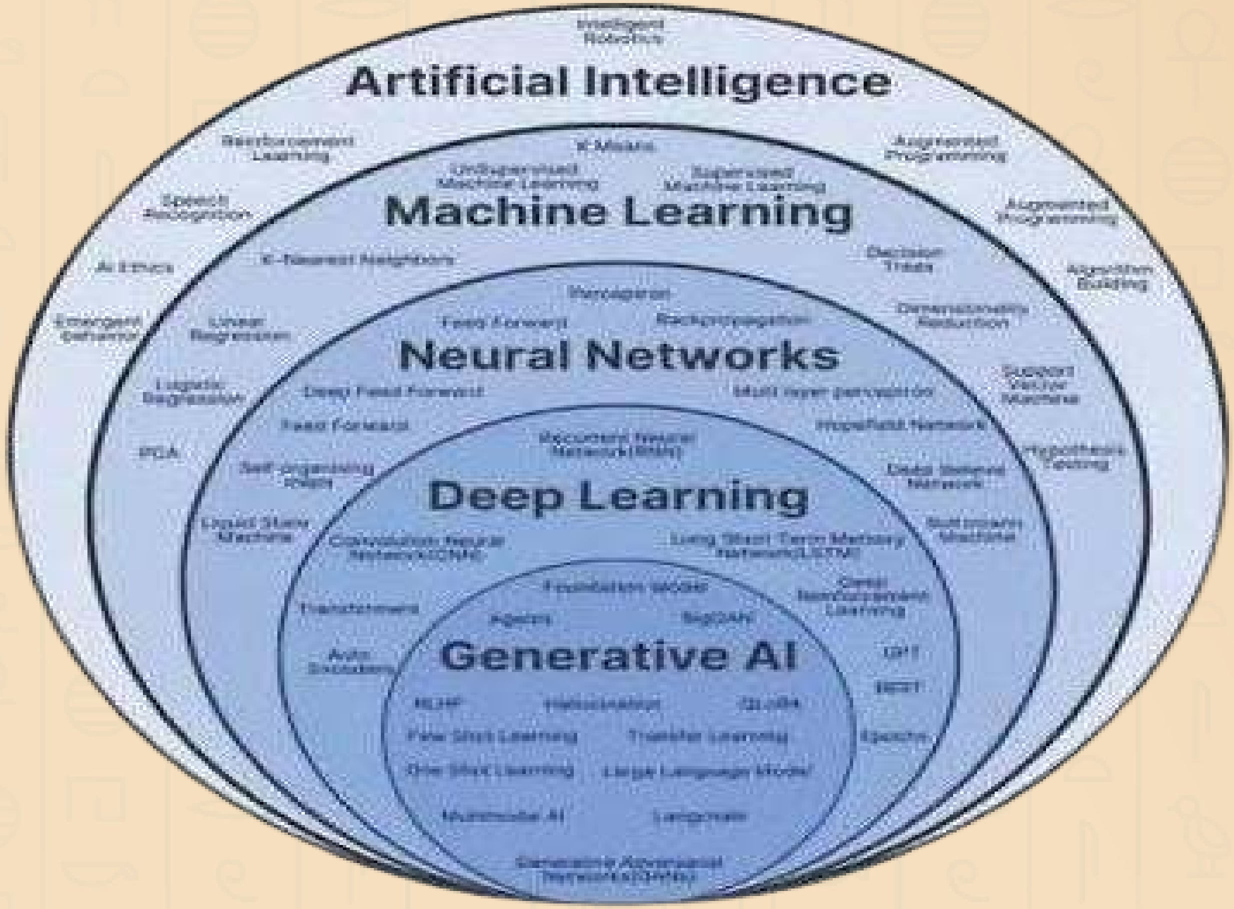








Prediction process:



Outcome Prediction Models

- Predict postoperative alignment
- Predict functional success
- Predict risk of under/overcorrection
- Predict need for reoperation

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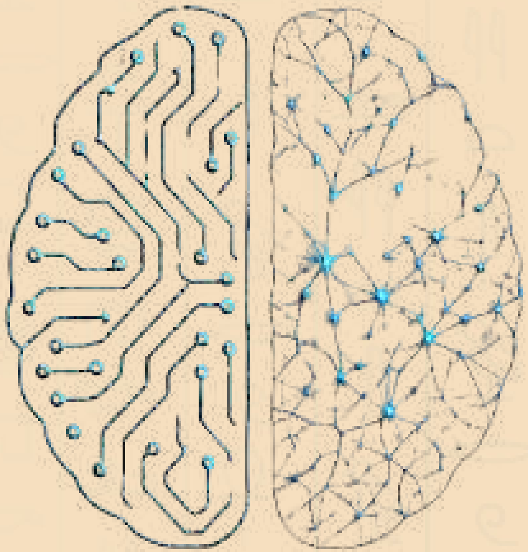

Recent studies?

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Key Study – Liu et al. 2019

- Intermittent exotropia
- **SVM model**
- Inputs: pre/post-op angles, fusion
- Accuracy: 82.1%
- Early post-op angle strongest predictor

Integrating artificial intelligence in strabismus management: current research landscape and future directions

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Abstract

Advancements in artificial intelligence (AI) are transforming strabismus management through improved screening, diagnosis, and surgical planning. Deep learning has notably enhanced diagnostic accuracy and optimized surgical outcomes. Despite these advancements, challenges such as the underrepresentation of diverse strabismus types and reliance on single-source data remain prevalent. Emphasizing the need for inclusive AI systems, future research should focus on expanding AI capabilities with large model technologies, integrating multimodal data to bridge existing gaps, and developing integrated management platforms to better accommodate diverse patient demographics and clinical scenarios.

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Key Study – Blau Most et al. 2025

- 1,079 pediatric surgeries
- **ML regression model**
- Success improved from 65.7% → 74.5%
- Important features: age, sex, dose

008 Strabismus surgery outcomes prediction using machine learning and multiple preoperative variables. Michal Blau Most, Daphna Mezad-Koursh, Chaim Stolovitch

Introduction: Current strabismus surgery planning typically relies on a single variable—the preoperative deviation angle—using traditional tables. However, preoperative measurements encompass multiple variables and additional data that could potentially improve the accuracy of strabismus surgeries.

Methods: A machine learning (ML) linear regression model was developed using a database of 1079 horizontal strabismus surgeries performed by a single surgeon using consistent surgical technique from 1990 to 2024. The model aimed to predict strabismus surgery outcomes based on multiple preoperative variables, including age, sex, refraction, corrected and uncorrected visual acuity for distance and near, as well as surgical data (amount of mm performed). Success was defined as $\leq 10^{\Delta}$ prediction error 6 weeks after the surgery, while failure was defined as $> 10^{\Delta}$.

Results: The ML model significantly increased the prediction success rate from 65.7% using traditional tables to 74.5% ($P = 0.029$). The variables that significantly influence the outcomes were: the amount of surgery (in mm) ($P < 0.001$), age ($P = 0.003$ for lateral rectus (LR) surgeries; $P = 0.045$ for medial rectus (MR) surgeries), sex ($P = 0.018$ for MR surgeries) and distance uncorrected visual acuity in both eyes ($P = 0.021$ for MR surgeries). Refraction was found to be insignificant ($P = 0.563$ for LR surgeries; $P = 0.591$ for MR surgeries).

Conclusion/Relevance: Utilizing ML technology and incorporating additional preoperative variables can facilitate better prediction of strabismus surgery outcomes. This study represents an initial step toward improving strabismus surgery outcomes and developing an ML-based strabismus calculator that can provide surgeons with operative recommendations based on multiple variables.

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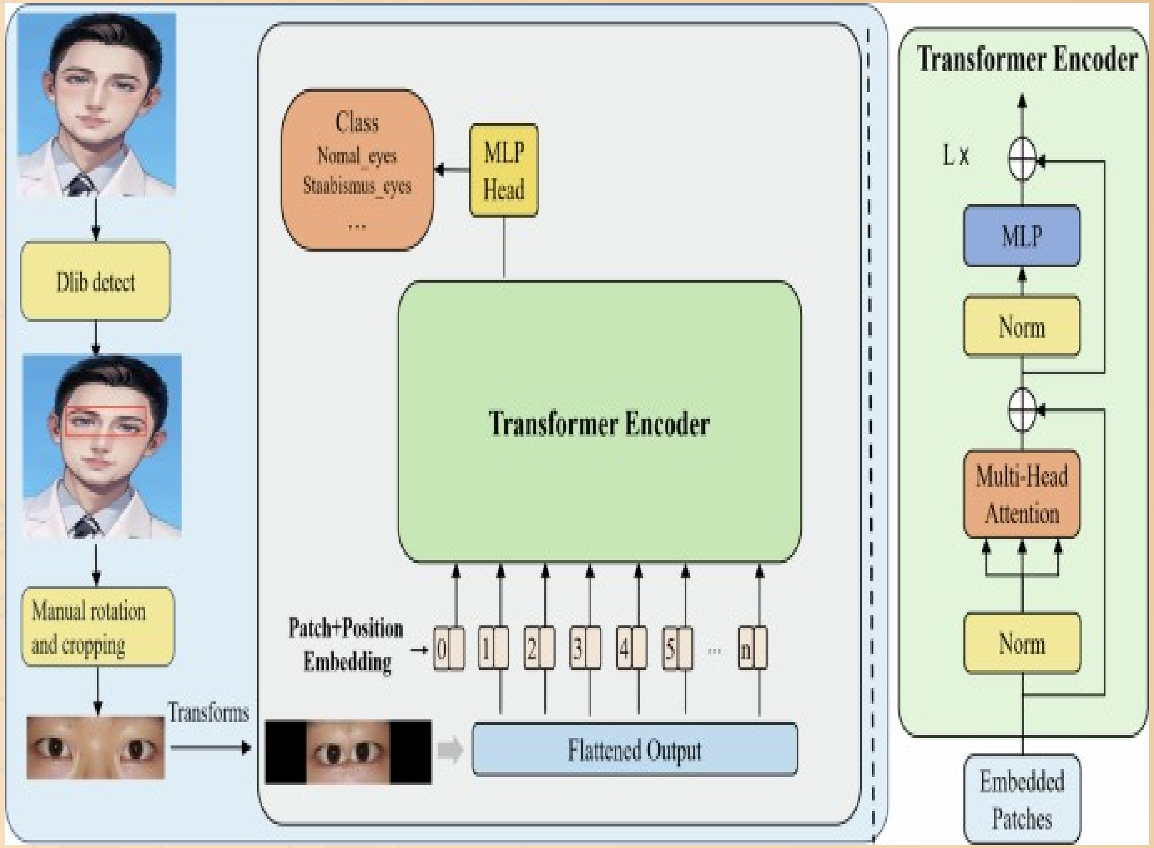
AI Surgical Planning Platforms

- **Zhongshan AI platform**
- Automated screening + angle estimation
- Smartphone-based deployment



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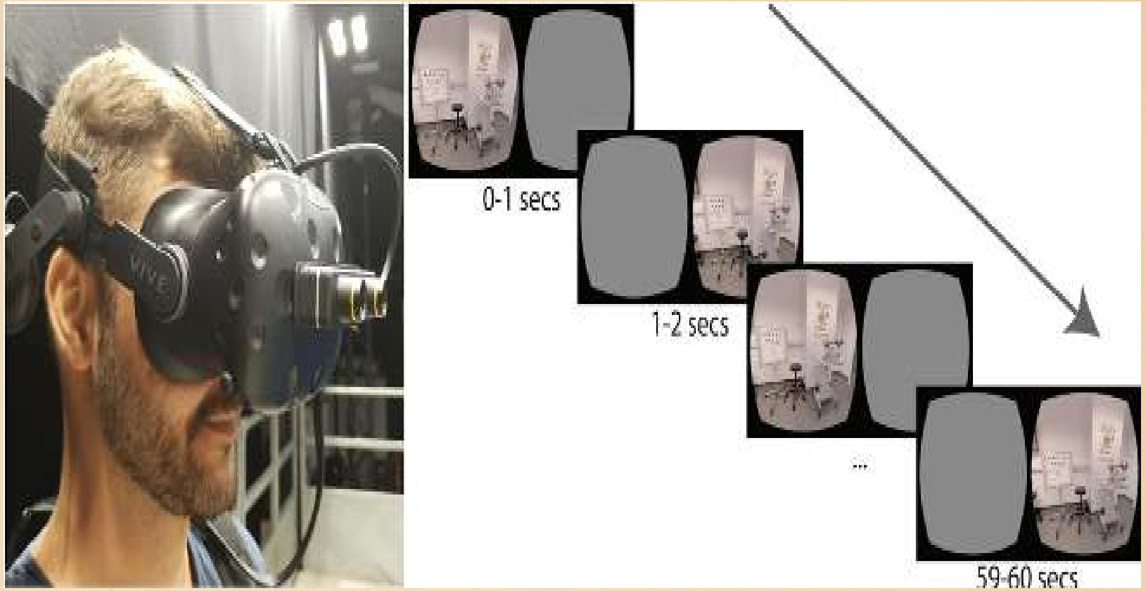

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AI Surgical Planning Platforms

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Future Directions

- Multimodal AI (images + EHR)
- Real-time surgical calculators
- Integration into EMR
- Prospective validation

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Institutions Leading Research

- Johns Hopkins University
- Moorfields Eye Hospital / UCL
- Zhongshan Ophthalmic Center
- Ulm University
- Harvard / MEEI

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Current Limitations

- Mostly retrospective data
- Single-center datasets
- Limited multimodal integration
- Lack of prospective trials
- Ethical considerations and data privacy

Take-Home Messages

- AI improves prediction of strabismus outcomes
- ML already outperforms traditional tables
- Imaging-based AI enhances precision
- Clinical adoption is approaching
- Supports—not replaces—surgeons

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Thank
you!