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Deep learning for Developmental Delay Screening in Children

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Introduction

- Cognoa App: ML algorithms screen for autism
  - Clinical validation: higher performance than standard screeners
    (See PAW healthcare talk)
  - Has been used by ~250,000 families
  - R&D into screeners for different conditions

- Outline:
  - Summarize our current algorithms
  - DL algorithms with audio + video in interactive stories
  - DL algorithms with cell phone phone videos uploaded by parents

Part 1: Introducing Cognoa

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The Cognoa autism screening App

Three sources for ML predictions of autism:

- Parental questionnaire
- Optional: short videos of child uploaded by parent
  - *Currently:* human analysts watch videos and answer questionnaire
- Optional: pediatrician questionnaire

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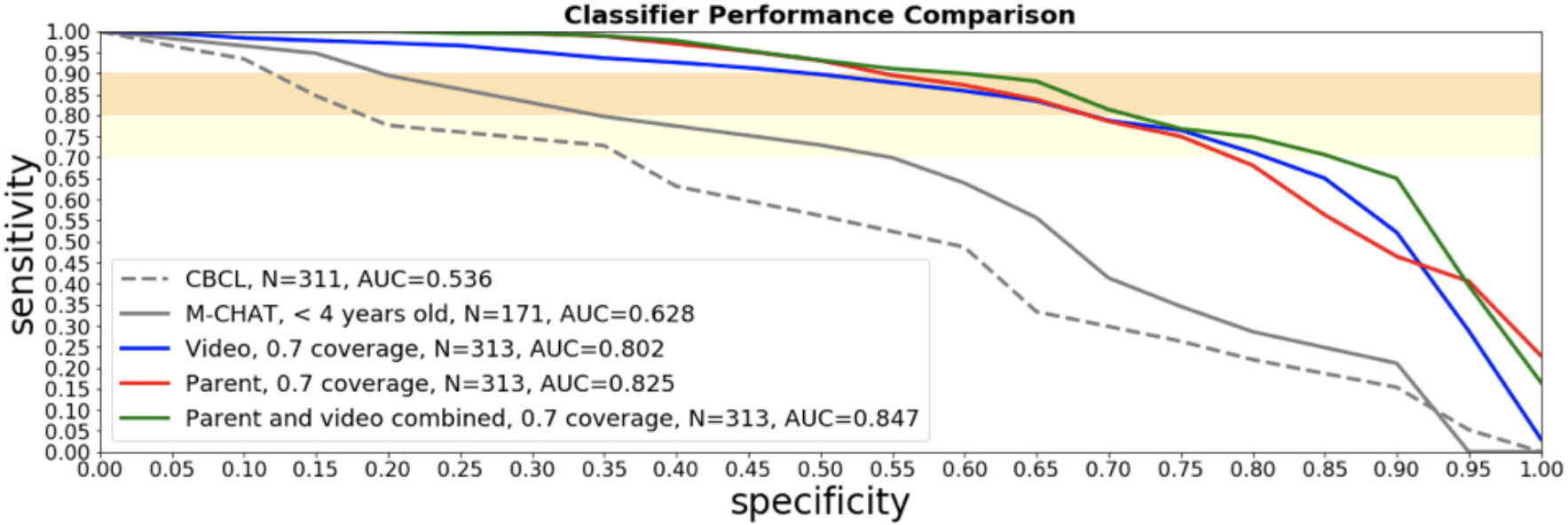
How well does our screener perform?

Clinical study of 313 high risk children ages 1.5 to 6

- Gray curves: commonly used, non-ML based autism screeners
- Colored curves: our algorithms

More details in PAW Healthcare talk



Part 2: R&D for deep learning based interactive instrument

Beyond screening tools: interaction with children

All algorithms so far: passive questionnaires and videos

Interacting directly with the child: increase sensitivity

- Information no other instrument can access
- Probe new conditions
- Therapies?

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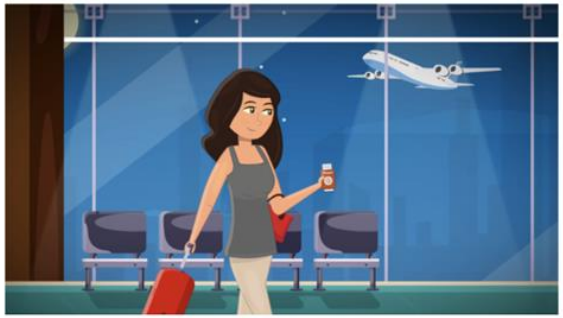
Tablet storytime

Child watches cartoon story on tablet at home

- Frequent pauses to ask child questions
- Record the *audio* and *video* streams from the tablet for analysis

"Hello, my name is Susan. Today I am going to tell you a really cool story. Are you ready for it? Tell me as loud as you can, are you ready?! Okay, let's listen to it now!"



One night, a young woman was walking through the airport...

"I hope you enjoyed the story!! Let's see if you remember what happened. Where did the story happen?"

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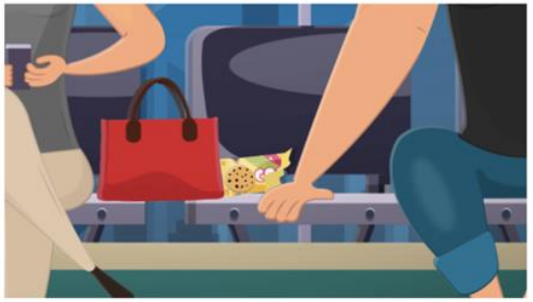
Storytime comprehension

Can child remember the story and repeat it?

"Alright. Now tell the story again to your mom or dad! You can do it!"



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Storytime creativity

Can child make up their own story?

"Here's a picture for you to tell your own story. Where are they and what are they doing?"

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POC trial

76 children 4 to 6 years old from general population

- 11 with speech/language impairments
- 60 normally developing

By-hand analysis:

- Can discriminate between kids with language problems and normal kids

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Deep learning algorithm potential

Progress tracker for normal children:

- Ability to focus, vocabulary & grammar sophistication, ...
- Comprehension, short term memory, creativity, ...

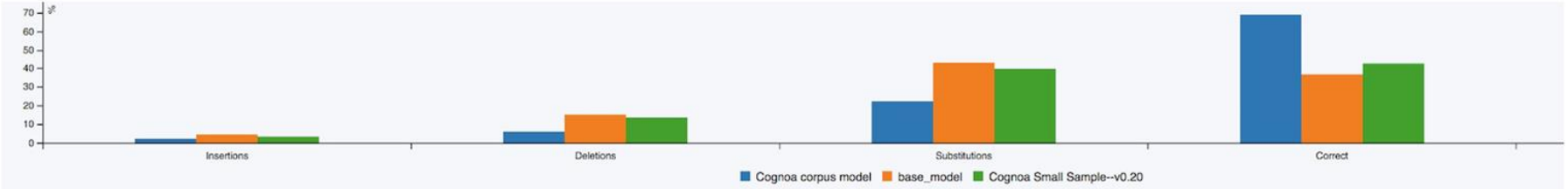
When more data for children with developmental problems available:

- Identify speech and language disabilities (prosody analysis)
- Autism and ADHD are challenging
    - But each have distinguishable features

Improved speech to text algorithm

Partner's STT algorithm: IDs ~35% of words, many mistakes

- Update corpus to child's vocabulary: performance ~2x



Cognoa corpus model ***With new corpus***

MEDIA FILE	SENTENCES	WORDS	INSERTIONS(%)	SUBSTITUTIONS(%)	DELETIONS(%)	CORRECT(%)	WORD
P1_01.wav	9.0	46.0	2.2	19.6	2.2	78.3	23.9
P1_03.wav	19.0	117.0	4.3	22.2	8.5	69.2	35.0
P1_02.wav	22.0	131.0	1.5	24.4	6.1	69.5	32.1
Totals	**50**	**294**	**2.38**	**22.45**	**6.12**	**69.05**	**31**

base_model ***Base model***

MEDIA FILE	SENTENCES	WORDS	INSERTIONS(%)	SUBSTITUTIONS(%)	DELETIONS(%)	CORRECT(%)	WORD
P1_01.wav	9.0	46.0	6.5	41.3	17.4	41.3	65.2
P1_03.wav	19.0	113.0	7.1	47.8	13.3	38.9	68.1
P1_02.wav	22.0	131.0	2.3	41.2	16.0	42.7	59.5
Totals	**50**	**290**	**4.83**	**43.45**	**15.17**	**36.55**	**63**

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Future storytime plans

Immediate: keep improving speech to text algorithm

Build deep learning features from:

- Vocabulary and grammar analysis
- Prosody analysis of speech patterns (clues of impairments)
- **Video analysis**:
  - Where is child's attention?
  - Eye tracking: strong signals for autism

Part 3: Deep learning analysis of videos

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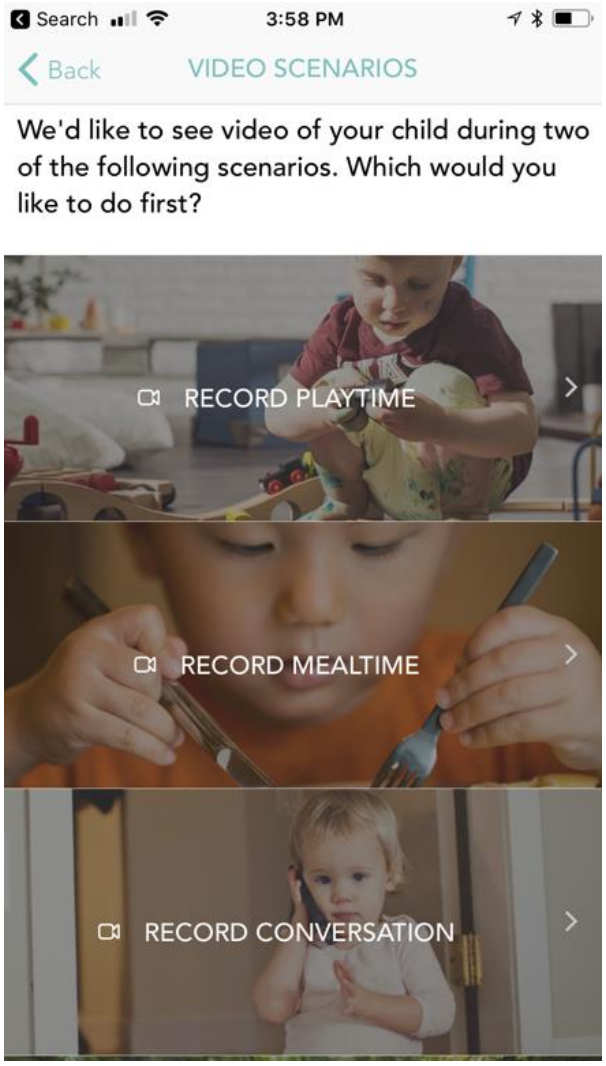
The cognoa video screening algorithm

Parents upload a two or three ~2 minute videos of child

Multiple analysts watch videos

- Analyst answers to questionnaire pass to ML algorithm

Key challenge: does not scale well



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How could deep learning help us?

Option 1: do tasks of video analysts

- Algorithm uses videos to answer questionnaire
- Preprocessing step to our autism prediction ML algorithm

Option 2: end-to-end identification of autism

- Algorithm uses videos to directly predict autism

Focus on the simpler option 1 in this talk

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Test on an example feature

Does the child make appropriate eye contact with others?

- Can we train deep learning algorithm to answer this?

Available videos with proper labels: 1500 negative, 1100 positive

- 80/20 train/test split

Experiment with different algorithms to predict eye contact

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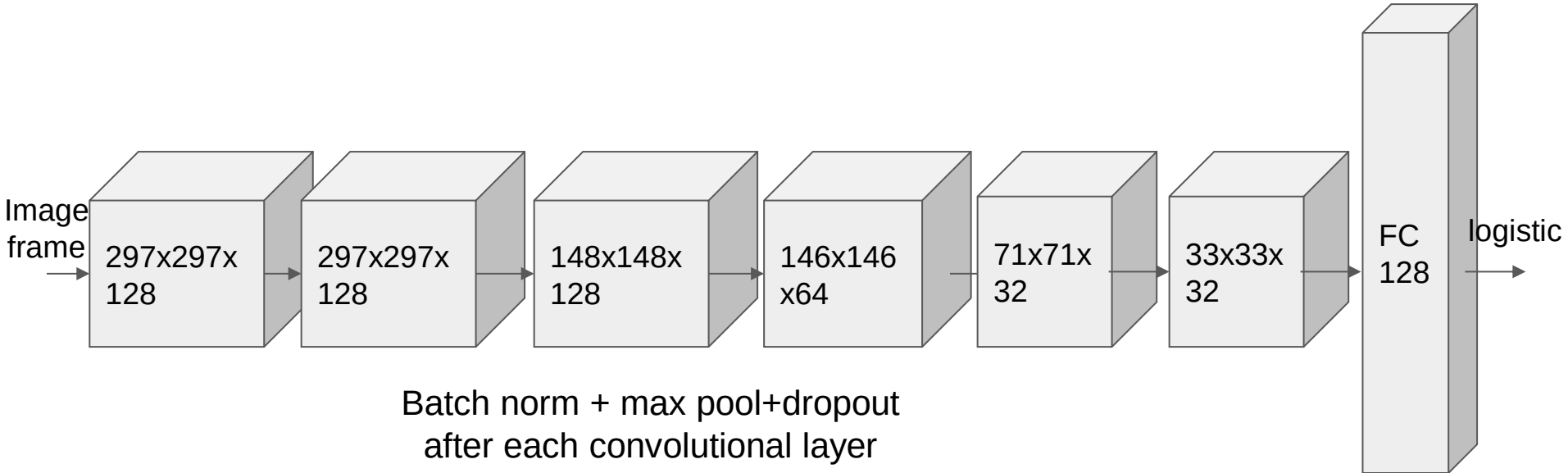
Method #1: 2D CNNs

Split each video into 75 frames

- Train CNN on individual frames



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Method #1: 2D CNNs

Split each video into 75 frames

- Train CNN on individual frames
- Average performance over each frame

Test set accuracy: ~72% in no eye-contact case, ~62% in eye-contact case

(Only using single frames in algorithm)

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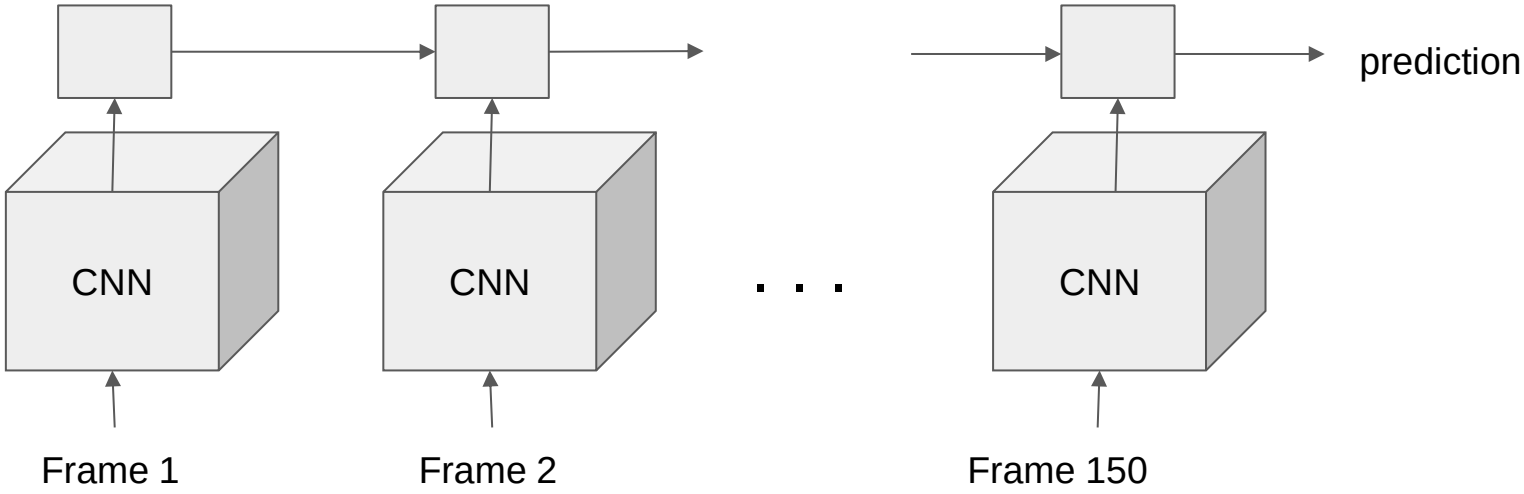
Method #2: CNN + LSTM

Example: Donahue et al: https://arxiv.org/abs/1411.4389

Split video into 150 frames

- Each frame fed to 2D CNN
- Output to LSTM that crosses all frames



Method #3: 3D convolutional neural network

Naturally incorporates time dimension

Drawbacks:

- Models for transfer learning?
  - Probably have to project models into 3D
- Very slow to train

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Method #4: Two-stream networks

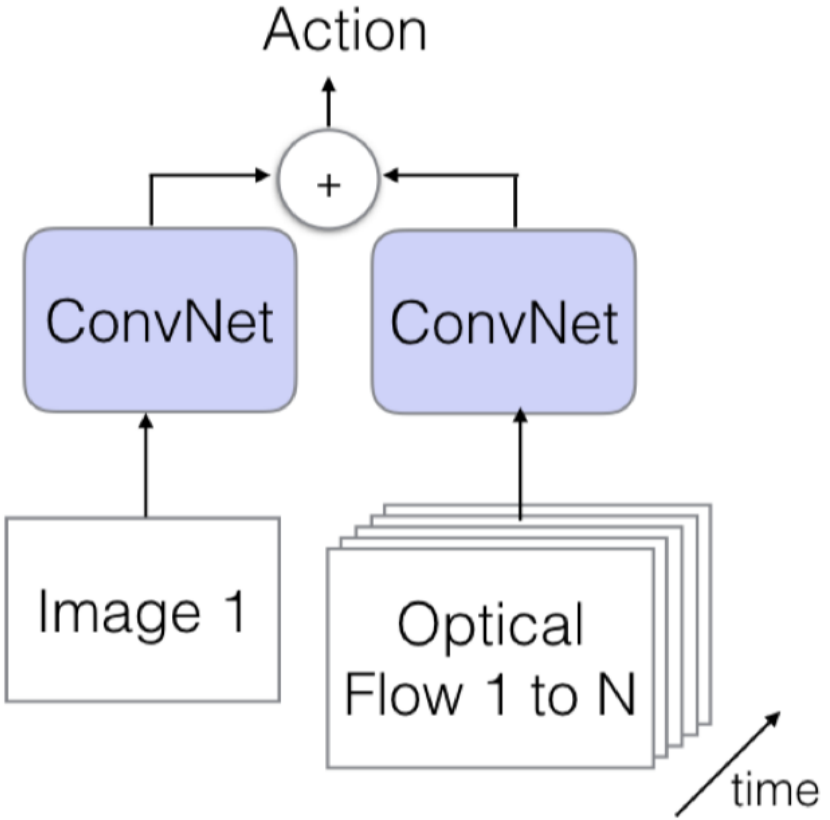
Snapshots of videos + optical flow

- J Carreira and A Zisserman: https://arxiv.org/pdf/1705.07750.pdf

Stream 1: CNN on snapshot

Stream 2: snapshot + optical flow → many images → CNN

Aggregate predictions from each stream



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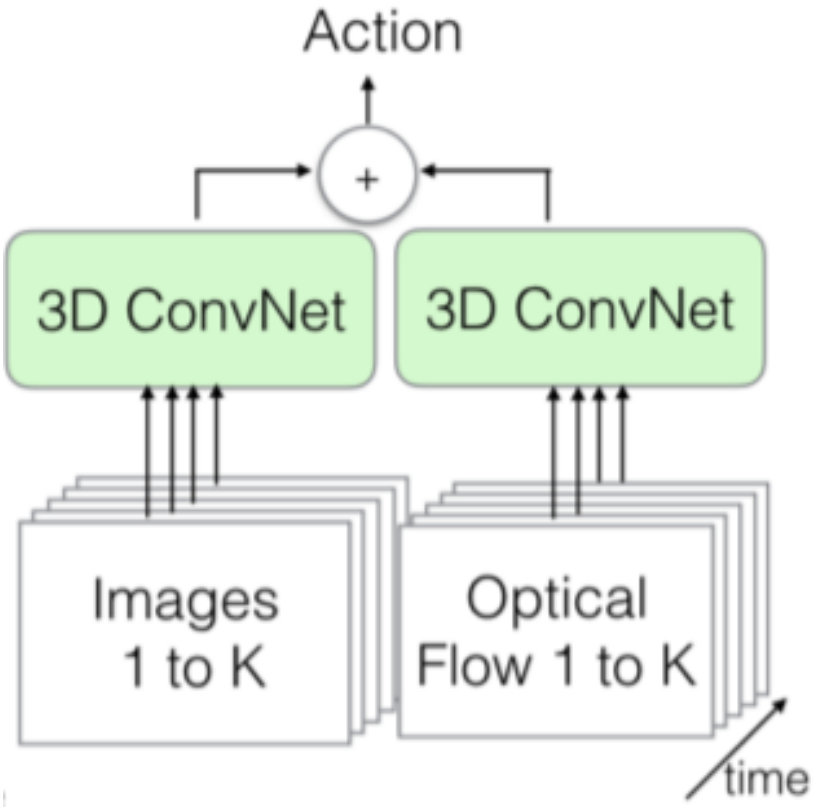
Method #5: Two-stream inflated 3D CNNs

Promote 2D CNN to 3D

- Extrapolate from 2D CNN for transfer learning
- One stream: snapshots of real images
- Other stream: optical flow to improve those snapshots

Aggregate predictions from each stream



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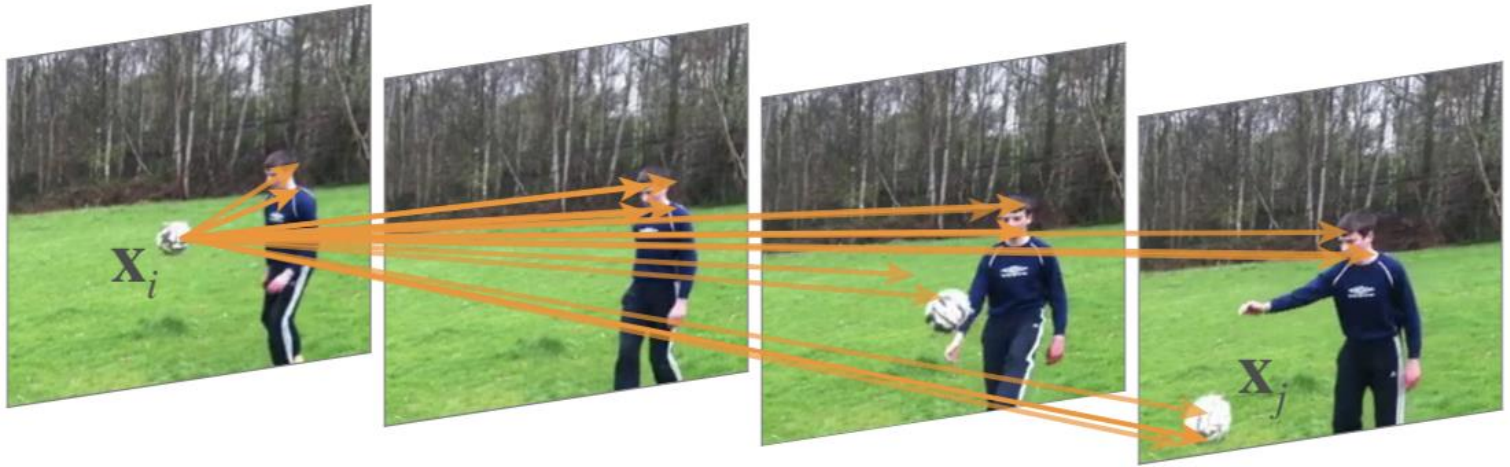
Possible Method #6: Non-local neural network layers

Calculations between every combination of points in video spacetime

- Great for long-range dependencies
- Insert as a layer to any CNN
- Surprisingly fast



From X Wang et al: https://arxiv.org/pdf/1711.07971.pdf

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The future

Cognoa ML algorithms already identify autism better than conventional screening tools

- But many new challenges lie ahead

Our R&D with deep learning has potential to build

- Revolutionary screeners
- Progress tracking tools
- Hopefully (therapies)

Bonus slides

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Why autism?

- Autism rates rising
  - 1.7% as of 2014, but maybe higher today
  - Some studies: higher rates in children of tech and academic workers

- Delayed diagnosis: treatments miss critical time when child's brain is developing
  - Autism can be diagnosed at 1.5 years, but …
  - Average wait time for diagnosis: 1.5 years
  - Average diagnosis age: 4.2 years