Small Language Model (SLM) for Device AI

Akraino Robotics Blueprint, Release 8 Enhancement

Device AI speech recognition challenges at the edge

- Device AI applications need to run ASR [1]
  - On very small form-factor devices (e.g. pico ITX)
  - With unreliable or no cloud connection
  - Under difficult conditions, including background noise, urgent or stressed voice input, and background talkers
  - Robotics servo motor and other mechanical noise increases difficulty

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[1] Automatic Speech Recognition

Precise Command Problem

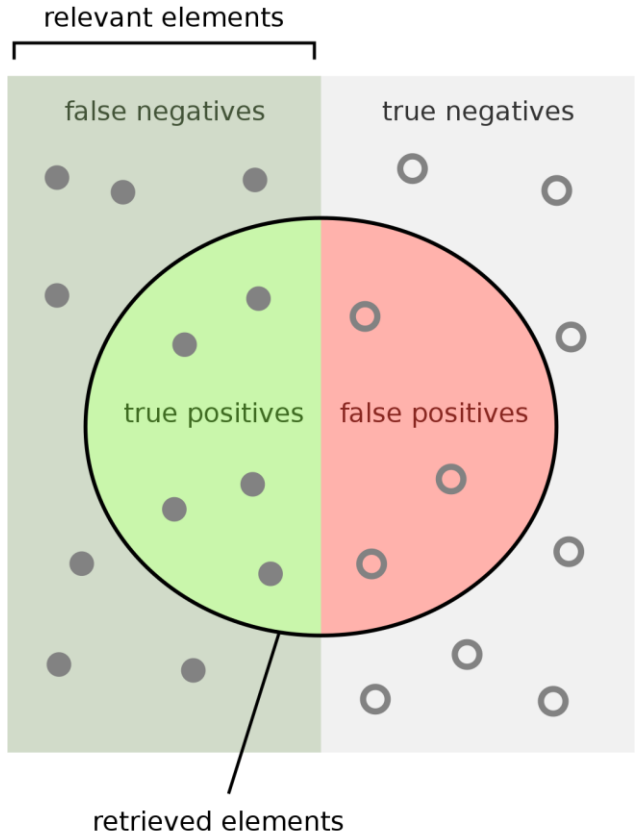
- Machine-readable APIs must be precise
- False positives must be carefully minimized
- Under difficult conditions, efficient open source ASRs such as Kaldi and Whisper produce "sound-alike“ errors, for example:

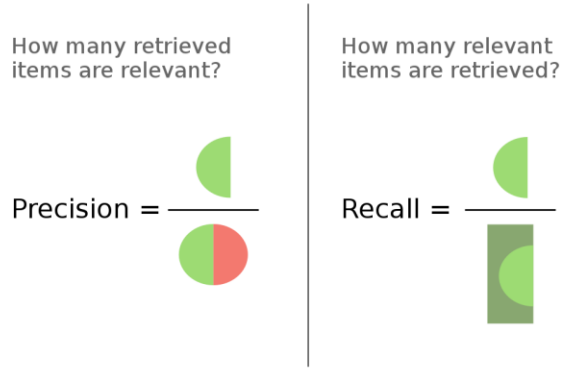
  “in the early days a king rolled the stake”

  which must be corrected to

  “in the early days a king ruled the state”

- Sound-alike errors are problematic for safety and emergency situations
  - Internet / cloud connection cannot be assumed. Phones may be useless
  - A first responder may use a portable hand-held device and give commands to a robotaxi such as "get off the road in that turn-out up ahead and shut down"





Use Cases

- Factory floor personnel need to give urgent commands
  - forklifts
  - hands-free equipment (e.g. food processing)

- First responders need to communicate with disabled or confused robotic vehicles
  - robotaxis
  - semi trucks

- Language Translation
  - sound-alike correction in text prior to translation
  - independent of ASR model

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Requirements

- Must correct sound-alike errors independently of ASR model without re-training, tuning, compression, or other reduction
- Very small form-factor, under 15 W
  - for example using two (2) Atom CPU cores
- Real-time – must run every 300 to 500 msec
- Backwards / forwards context of 3-4 words
  - unlike an LLM, wide context window, domain knowledge, and extensive web page training are not needed
- Compliant with emerging teleoperation standards
  - California included teleoperation as part of its regulation for driverless vehicles in 2018
  - NIST conference in 2020
  - WiFi or USB port interfaces typical

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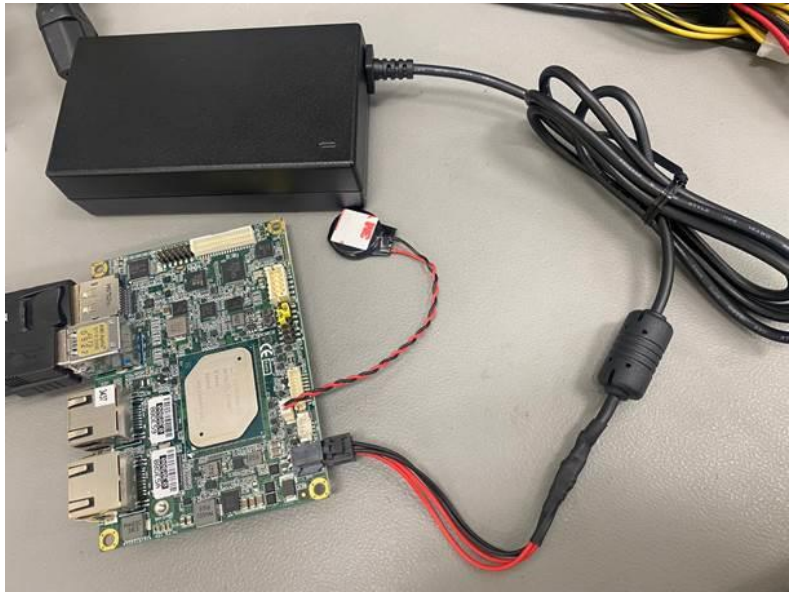
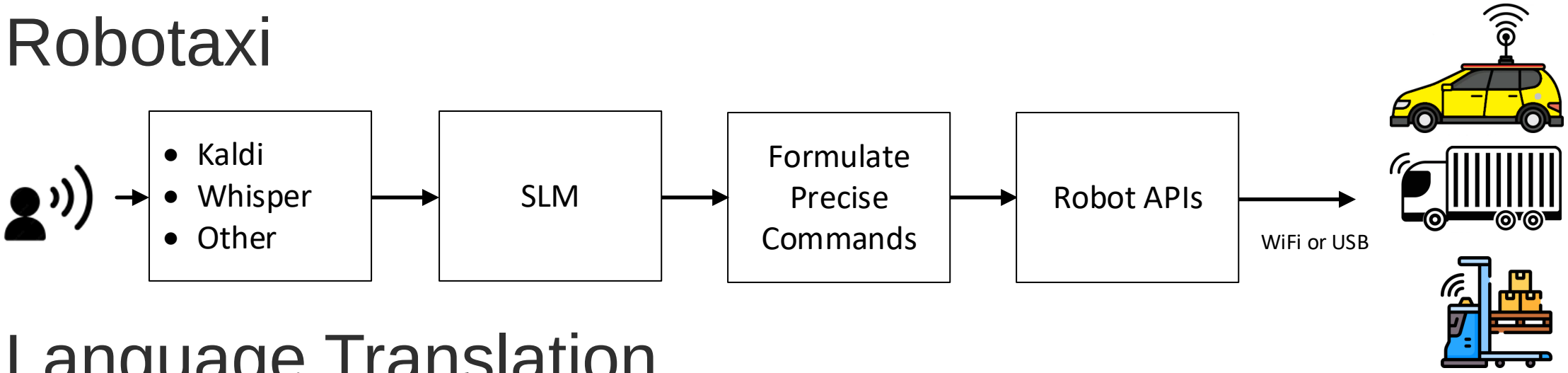


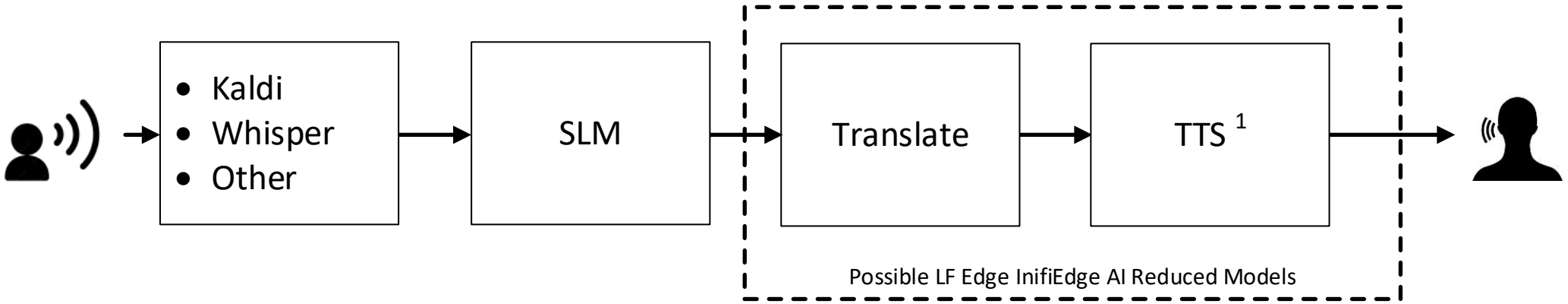
Teleoperation and Autonomous Vehicles Overview		
	Key Information	**Other Information**
What is teleoperation?	• Remote operation of a machine at a distance • Requires wireless link to machine • First concepts in 1870s; wire-guided torpedoes	• Similar to remote control • Or wired link if machine is nearby • Nikola Tesla-1898: Radio-controlled boat
3 levels of AV teleoperation	• Remote monitoring of AVs • Remote assistance to AVs • Remote driving of AVs	• Monitoring of AV fleet driving • Driving assist for a short time • Driving for a substantial time
Why is it needed?	• As human backup to driverless vehicles • To manage and learn from edge cases • To gain early AV deploy with acceptable safely	• To be part of most AV regulations • Transfer edge cases to known cases • Only for specific AV use-cases
Teleoperation regulation status	• California approval granted in February 2018 • California operational use started in April 2018 • Countries: Canada, Finland, Japan, Netherlands • Shanghai and other Chinese cities	• Driverless AVs require teleoperation • AZ, FL, MI, OH, TX too; More will follow • Sweden, UK; More will follow • Teleoperation expected in China
Teleoperation use-cases	• Sidewalk AVs: Most common usage • Trucks: AV on highway; last mile teleoperation • Robotaxis: Regulation and edge case • Others: Forklifts, excavators, yard trucks, combine • Shared electric scooters	• Examples: Kiwibot, Postmates • Examples: Einride, Hub-to-hub AVs • Zoox has remote operation patent • Testing, trials, some deployment • To return to base & charging stations
Teleoperation startups	• Designated Driver: Assisted & remote driving • DriveU: Assisted & remote driving teleoperation • Ottopia: Assisted & remote-driving teleoperation • Phantom Auto: Focus on remote driving use-cases	• Teleoperation for Texas A&M shuttle • Member: Israeli teleoperation consortium • Partners: BMW, Denso, EasyMile, others • Forklifts, yard trucks and similar clients
Make or buy teleoperation?	• Top AV software platform: own teleoperation • Many companies will buy teleoperation software	• Likely integrated with AV software driver • From multiple teleoperation startups
Teleoperation standards	• Teleoperation standards likely to happen • Best chance is high level standards	• AV software driver variety is big barrier • At functional or operational level
Teleoperation Forum	• First conference on teleoperation (virtual) • NIST Vehicle Teleoperation Forum | NIST	• November 13, 2020 by NIST • 40 speakers; 8+ hours of video sessions
Teleoperation Consortium	• TC is a non-profit business organization • 30+ companies, universities, organizations	• Founded December 2020 • Website: Teleoperation Consortium
NIST=National Institute of Standards and Technology		
Source: Egil Juliussen, May 2021		

Technology Overview – Dataflow

› Robotaxi



› Language Translation



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[2] Text-to-Speech

Technology Overview – Training and Inference

- Conventional CPUs
  - Arm, x86
  - no CPUs, no HBM
- Conventional memory, 8 GB min
- Training
  - frequency domain representations of 10,000 text words – becomes an image recognition problem
    - non-linear memory space, self-organizing, sound-alikes are near each other
    - extremely fast
    - no gradient descent or other high complexity algorithms
- Inference
  - content addressable memory – series of spans and local searches

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Status and Next Steps

- Working now
  - Kaldi ASR running on one Atom core in real-time
  - pico ITX board (Atom x5-E3940)
  - 20,000 word vocabulary
- SLM under development
  - live demo next step
  - pico ITX board
  - planning for Akraino Fall Summit