Customer: Renesas
Project: Renesas Computer Vision and CNN
PROJECT MANAGEMENT OFFICE @
RT-RK Automotive LLC
08-11-2021
RT-RK - Renesas core team

Overview

- **Team size:** 30
  - with strong potential to grow (max ~5-10 per year)

- **Strengths:**
  - Versatile background (computer engineering / embedded / mathematics)
  - Strong expertise in Computer Vision and CNN IMP-X5+ optimizations
  - Growing expertise in Computer Vision and CNN Algorithm development

- **Relations with Renesas:**
  - Scaling partner – striving to be excellence center for Europe
  - RCar Consortium Members
  - Access to cutting edge boards and libraries
RCar Expertise

Technology Overview - current

- **IMP-X5+**:
  - CVe: MTMD parallelization
  - IMPc: configurable pre-processing-post pipeline (100 transformations)
  - PSC: pyramidal image scaling
  - Memory Pipeline: $DDR \leftrightarrow Scratchpad \leftrightarrow LWM$

- **CNN**:
  - **CNN FE**: improving configurability and usage of CNN Toolchain
  - **CNN FW**: from Caffe model to optimized forward propagation
  - **Custom Layer** - development: Fully Connected, Convolution 1x1, other on demand
  - **CNN Toolchain** – customer integration support
RCar Expertise
Technology Overview - current

• **VisionIP:**
  - Stereo Block Matching IP – usage and configuration
  - Optical Flow IP – usage and configuration
  - Classifier IP - usage and configuration

• **Image Processing:**
  - IMR – camera capture integration into pipeline
  - ISP – usage and configuration, customization, development of advanced pipelines
**RCar Testbed**

- **RENESAS RCar boards available:**
  - H3SK x 1
  - HAD SK x 1
  - RazorMotion x 1
  - V3M Eagle:
    - v1.0 x 1
    - v2.0 x 5
  - V3H SK v1.0 x 2
  - V3H Condor v1.0 x 2
  - V3H Condor v1.1 x 8
  - V3U x 1
  - V4H, V4U – Q1/2022
Team Overview
Project Portfolio
Expertise Growth
Renesas Optimizations

IMP-X5+ & CNN Training
Renesas IMP-X5+ & CNN

RT-RK Training Offer

• **Modules (separate):**
  - Basic training (CVe, IMPc, PSC, iDMA, TGDMAc) - 4 days x 2 hours
  - Advanced training (CNN) - 2 days x 2 hours

• **Form:** webinar or onsite

• **Target Groups:** Computer Vision embedded engineers

• **Goal:** gain understanding of IMP-X5+ and CNN IP architectures, advantages and limitations, with a solid basic and advanced practical hands-on
Basic RCar Training (IMP-X5+)

Agenda

- **Session B.1 - Introduction**
  - Team presentation
  - Renesas RCar overview and roadmap
  - IMP-X5+ architecture overview
  - Introduction to IMP-X5+ programming material

- **Session B.2 - Toolchain**
  - Toolchain overview and configuration
  - [OPTIONAL] e2Studio + IMP-PCTOOLS install

- **Session B.3 - CVe**
  - CVe overview (MTMD, CL execution, RECT/POINT, dataplanes, registers, intrinsics)
  - Hands on - CVe Programming material (simple/advanced)

- **Session B.4 - Memory handling**
  - Memory handling pipeline (scratchpad, LWM, GWM)
  - Core synchronization
  - iDMA (configuration, limits, example)
  - TGDMAC (configuration, limits, example)

- **Session B.5 - IMPc, PSC, advanced concepts**
  - IMP/PSC Core introduction and code usage
  - [OPTIONAL] Advanced optimization techniques
Advanced RCar Training (CNN)

Agenda

• **Session C.1 - CNN Overview**
  • Overview of CNN IP
  • Overview of CNN Framework deploy tool

• **Session C.2 - CNN Framework hands on**
  • Hands on session: go through the pipeline step-by-step
  • Tips and tricks: guidelines and constraints
Renesas RCar based project portfolio
Computer Vision expertise

<table>
<thead>
<tr>
<th>Client</th>
<th>Algorithm</th>
<th>KPI</th>
<th>Image size</th>
<th>Technology used</th>
<th>Notes</th>
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</thead>
<tbody>
<tr>
<td>Tier 1</td>
<td><strong>CMRS:</strong> HoG + Int. Image + Classification (5 stages)</td>
<td>60 fps (20 x gain)</td>
<td>1 MPix</td>
<td><strong>IMP-X5+:</strong> CVe IMPc iDMA (scratch) TGDMAc (LWM)</td>
<td>V3M Eagle v1.0</td>
</tr>
<tr>
<td>Tier 1</td>
<td><strong>Trailer detection:</strong> Sobel + Median + Voting+ Kalman</td>
<td>60 fps (15x gain)</td>
<td>1 MPix</td>
<td><strong>IMP-X5+</strong></td>
<td>V3M SK v2.0</td>
</tr>
<tr>
<td>Tier 1</td>
<td><strong>aKAZE:</strong> Scharr + Gauss + NLD</td>
<td>3x gain</td>
<td>0.6 MPix</td>
<td><strong>IMP-X5+</strong></td>
<td>V3M Eagle v2.0 Limited 3 week optimization</td>
</tr>
<tr>
<td>Tier 1</td>
<td><strong>Trailer 2:</strong> warp + NCC</td>
<td>60 fps (15x gain)</td>
<td>1 MPix</td>
<td><strong>IMP-X5+</strong></td>
<td>V3M Eagle v1.0</td>
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<tr>
<td>Tier 1</td>
<td><strong>3CAM:</strong> rectification+ feature extraction and matching</td>
<td>30 fps (10 x)</td>
<td>1 MPix</td>
<td><strong>IMP-X5+</strong></td>
<td>V3M Eagle v1.0</td>
</tr>
</tbody>
</table>
**Algorithm:**
- Histogram of Oriented Gradients + Integral Image + Classification (5 stages)

**DSP Optimizations:**
- **Overall:**
  - Algorithmic modifications and simplifications
  - Processor and Memory load analysis - adaptation to target cores (CVe, IMPc)
- **HoG:**
  - Parallelization on 2 CVe (64 threads)
  - Memory pipeline: use of 0$ cache, scratchpad and iDMA
  - LUT in scratchpad
- **Integral Image:**
  - Parallel use of IMPc and 2 CVe on parts of image
  - Memory pipeline: use of 0$ cache, scratchpad and iDMA
- **Classification (1\textsuperscript{st} stage):**
  - Parallelization on 2 CVe (64 threads)
  - ROI processing order analysis and load balancing on 2 CVe
  - Fully memory pipeline: scratchpad (iDMA) and LWM (TGDMAc)

**KPI:** \textit{Start}: 3 fps \textit{Final}: 60 fps
Trailer detection and angle calculation 1 & 2

- **Algorithm:**
  - V1.0: Polar Image Preprocess + Sobel + Median8/16 + Salient Gradient + Vote
  - V2.0: Template Matching

- **DSP Optimizations:**
  - **Overall:**
    - Processor and Memory load analysis - adaptation to target cores (CVe, IMPc)
  - **Polar Image Preprocess:**
    - Color space conversion: YUV422-to-GRAY8
    - Transformations: cropping, rectified2polar
  - **Sobel, Salient Gradient, Vote:**
    - Parallelization on 2 CVe (64 threads)
    - Memory pipeline: use of 0$ cache, scratchpad and iDMA
  - **Median:**
    - Parallelization on 4 IMPc
    - Memory pipeline: scratchpad (iDMA)

- **KPI:** *Start*: 5 fps *Final*: 60 fps
Algorithm:
- V2.0: Color conversion + Rectification + Feature Extraction & Matching

DSP Optimizations:
- Overall:
  - Processor and Memory load analysis - adaptation to target cores (CVe, IMPc)
- Image Preprocess:
  - Color space conversion: YUV422-to-GRAY8, YUV422-to-RGB, RGB-to-GRAY8
- Rectification:
  - Parallelization on 2 CVe (64 threads)
  - Full memory pipeline: 0$ cache, scratchpad (iDMA) and LWM (TGDMAc)
  - LUT in scratchpad
- Feature Extraction & Matching (delivery pending)

KPI: Start: 17 fps Final: 56 fps
Algorithm:

- Scharr + Gauss + NLD

DSP Optimizations:

- Overall:
  - Algorithmic modifications and simplifications
  - Processor and Memory load analysis - adaptation to target cores (CVe, IMPc)

- Scharr + Gauss + NLD:
  - Parallelization on 2 CVe (64 threads)
  - Fully memory pipeline: scratchpad (iDMA) and LWM (TGDMAc)

KPI: **Start**: 900 ms **Final**: 300 ms
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<tbody>
<tr>
<td></td>
<td>AlexNet + Stereo Block Matching</td>
<td>16 fps + 45 fps</td>
<td>0.6 MPix</td>
<td>CNN + STV IP</td>
<td>Network porting and retraining + Fully Connected</td>
</tr>
<tr>
<td>SphereFace-20</td>
<td>(face recognition)</td>
<td>NA</td>
<td>1.3 MPix</td>
<td>CNN + IMP-X5+</td>
<td>Optimization ongoing + custom layer design in progress</td>
</tr>
<tr>
<td>MobileNet-SSD</td>
<td>(object detection)</td>
<td>NA</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>SqueezeNet/VGG16/ResNet</td>
<td>(scene recognition)</td>
<td>NA</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Renesas CNN Toolchain</td>
<td>Development</td>
<td>NA</td>
<td>NA</td>
<td>CNN</td>
<td>Contribution since 2018</td>
</tr>
<tr>
<td>Lidar Pixel Segmentation</td>
<td>and Classification</td>
<td>60 fps</td>
<td>NA</td>
<td>CNN + CVe</td>
<td>Contribution since 2017</td>
</tr>
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AlexNet + Stereo Block Matching

- **Algorithm:**
  - AlexNet: 5 x (convolution + reLU + MAXpool) + 3 x Fully Connected
  - Stereo Block Matching: disparity = 80, block = 15

- **DSP Optimizations:**
  - AlexNet @ CNN IP
    - modifications and simplifications to match architecture + retraining (80% accuracy)
  - Fully Connected (FC) @ CVe:
    - Implementation from the scratch + Full Optimization (64 threads + memory pipeline) + Integration
    - Configurable size: 256x2x2 -> 4096x1x1 -> 1000x1x1
  - Stereo Block Matching @STV IP
    - Evaluation of STV IP simulator and benchmarking

- **KPI:** *Final*: AlexNet w/ FC 16 fps + STV 45 fps
• Algorithm:
  • SphereFace-20 (face recognition)
  • MobileNet-SSD (object detection)
  • SqueezeNet/VGG16/ResNet (scene recognition)
  • LSTM (keyword spotting/speech recognition)

• DSP Optimization Goals (N.B. project at the beginning):
  • Custom Layer Optimization + Integration @ CVe @CNN
    • Implementation from the scratch + Full Optimization (64 threads + memory pipeline)
  • CNN IP benchmarking

• KPI: **Final**: TBD
Goal: development of Renesas CNN Toolchain steps 0 and 1

• **CNN FE:**
  - Automation of the rest of CNN Toolchain pipeline
  - Enabling user configuration through individual files

• **CNN FW:**
  - Import/Export support for Caffe/ONNX
  - Optimization of intermediate representation (graph-2-HW mapping)
  - Support New HW acceleration feature (V4H, V3U, V4U)

• **Support**
  - CNN Toolchain - customer integration support
Team Overview
Project Portfolio
Expertise Growth
Expertise growth
Future Roadmap

• **OS:**
  - Yocto kernel modules/drivers
  - FreeRTOS / QNX / GreenHills
  - (Adaptive) AUTOSAR

• **Security & Safety:**
  - ISO26262 SW development
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