

# Super-Resolution on RISC-V

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# Outline

- RISC-V - Introduction
- Locally booted OS on RISC-V
- Requirements for Super-Resolution on RISC-V
- Photo-Realistic Single Image Super-Resolution Using Generative Adversarial Network



# RISC-V

- RISC-V – Open ISA based on RISC principles
- RISC-V ISA can be used freely (anyone can design, manufacture and sell RISC-V chips and software)
- Designed to be used in high-end computing as well as embedded systems
- Open RISC-V implementations are available
  - <https://riscv.org/riscv-cores/>
- RISC-V started at UC Berkeley in 2010 and is supported by industry, academia and volunteers

# Locally Booted OS on RISC-V

- We started from Fedora-RISCV kernel image with NBD-backed root FS:
  - [https://github.com/rwmjones/fedora-riscv-kernel/tree/sifive\\_u540](https://github.com/rwmjones/fedora-riscv-kernel/tree/sifive_u540)
- Building kernel is simple but booting relies on the NBD root filesystem
- Booting from a local root filesystem requires several steps including changes in the Makefile (fedora-riscv-kernel)
  - The SD card is required to have the first partition written with the bbl (Berkeley Boot Loader)
  - Second partition needs to have the kernel image (see above)
  - Third partition has rootfs (download Fedora RISC-V disk image from: <https://fedorapeople.org/groups/risc-v/disk-images/stage4-disk.img.xz>)



# Makefile Changes

- Fedora-RISC-V kernel script Makefile changes:

1) `ROOTFS = UUID=e06a1845-3577-4e35-92a9-015b3042b3f2` → `ROOTFS = / dev / <root fs partition>`

2) `CMDLINE="root=$(ROOTFS) netroot=nb:$(NBD) rootfstype=ext4 rw rootdelay=5 ip=dhcp rootwait console=ttyS10"`  
→ `CMDLINE="root=$(ROOTFS) rootfstype=ext4 rw rootdelay=5 ip=dhcp rootwait console=ttyS10"`

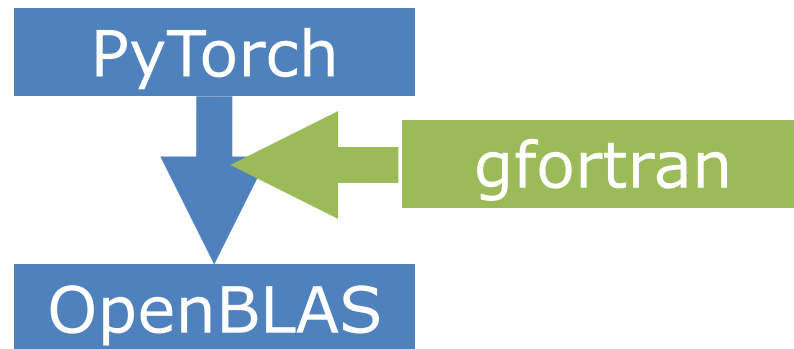
3) `dracut -m "nbd network base" @$-t $$$(uname -r) --no-kernel --force -v`  
→ `dracut @$-t $$$(uname -r) --no-kernel --force -v`

- Currently dnf package manager not working when booted from the SD card

# Which Machine Learning Framework?

- Many to choose from ...
- Tensorflow
  - Relies on Bazel to compile
  - Bazel relies on JDK which is not fully available on RISC-V
- Torch
  - Lots of Python dependencies
  - Requires luaJIT which is not yet fully available on RISC-V
- Theano – lack of GAN examples
- Keras, Caffe

- We chose Pytorch!
  - Few dependencies





# OpenBLAS on RISC-V

- OpenBLAS is a linear algebra library with optimized routines
- RISC-V is not yet supported
- We compiled generic C and fortran routines, instead of architecture specific
  - Current RISC-V hardware does not support vector instructions
- Significant performance gains:
  - Switching to OpenBLAS improved the performance of the full GAN inference by a factor of more than 20x
  - From minutes to ~16s



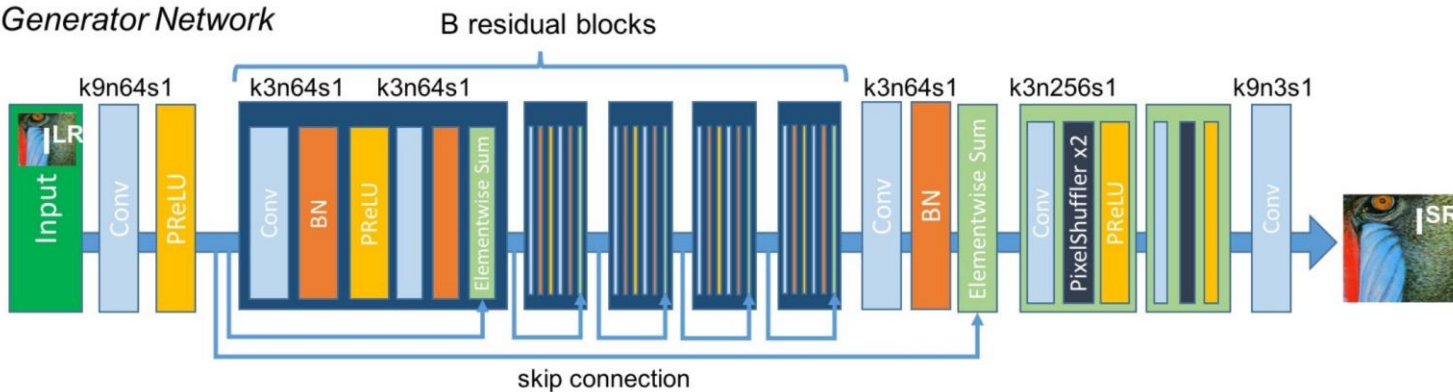
# Super-Resolution on Risc-V

- “Photo-Realistic Single Image Super-Resolution Using a Generative Adversarial Network”, Christian Ledig et al., May 2017, Arxiv.org
- Based on GAN approach for super-resolution
  - Train generative model with the goal of fooling a differentiable discriminator, trained to distinguish super-resolved images from real images
  - generator can learn to create solutions that are highly similar to real images and difficult to classify by discriminator
  - HR images are only available during the training. LR images are obtained from HR, by applying Gaussian filter followed by downsampling
- Utilize deep residual network with skip connection

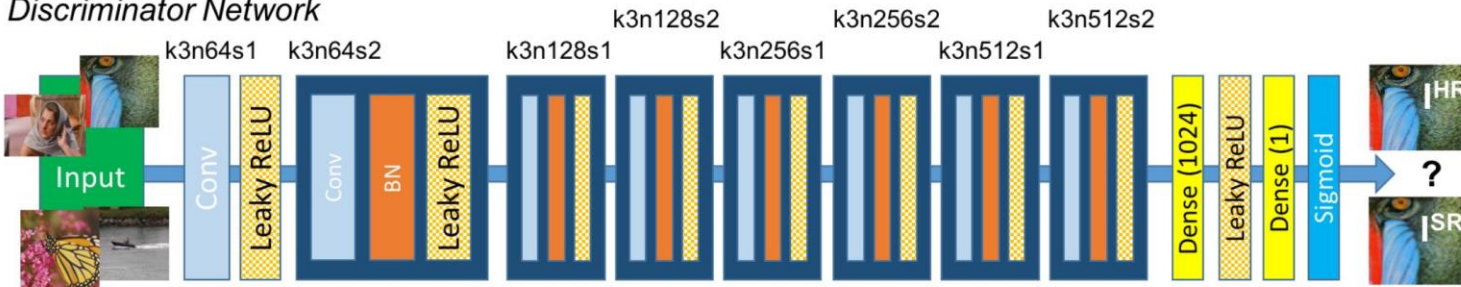


# Generator and Discriminator Networks

Generator Network

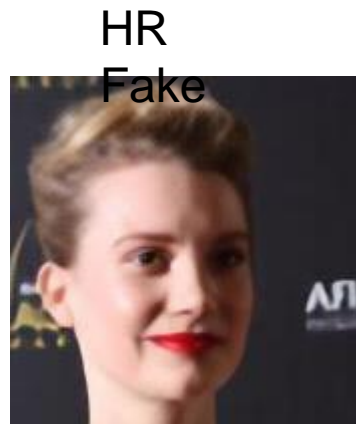


Discriminator Network



# Results

- We use implementation from Aitor Ruano, <https://github.com/aitorzip/PyTorch-SRGAN>
- We perform training on celebrity image set (CelebA), ~250K images
- We scale down the starting image 4 times (176x176px  $\rightarrow$  44x44px)



# Results

- We also scale down the starting image 8 times ( $176 \times 176 \text{px} \rightarrow 22 \times 22 \text{px}$ )

178x218

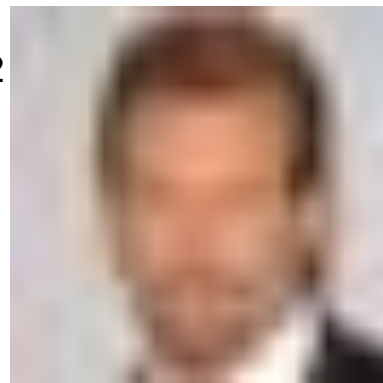


44x44



HR  
Fake

22x22



HR  
Fake



**Thank You!**

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