Apache Beam and Ensemble Modeling: A Winning Combination for Machine Learning

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Who is ML6?

Machine Learning services company.

We help our clients build machine learning applications using technologies such as Apache Beam.

Credits

Philippe Moussalli
Machine Learning Engineer, ML6

Agenda

- Motivation
  - Ensemble Modeling for solving complex use-cases
- Solution
  - **Beam RunInference**:
    - Seamless integration of ML in a Beam pipeline for semantic enrichment
    - Use multiple Runinference transforms for pipelines with multiple ML models
- Example

Motivation

- Semantic Enrichment: ML models provide semantic information.

- Business needs often involve the use of multiple machine learning models, each addressing a specific subtask and contributing unique capabilities.

Semantic Enrichment of Data

- Categorise: Add specific label
- Summarize
- Sentiment Analysis
- Translate
- Extract important keywords
- Image Annotation
- Image Captioning
- Speech Recognition
- .....

Ensemble Modeling

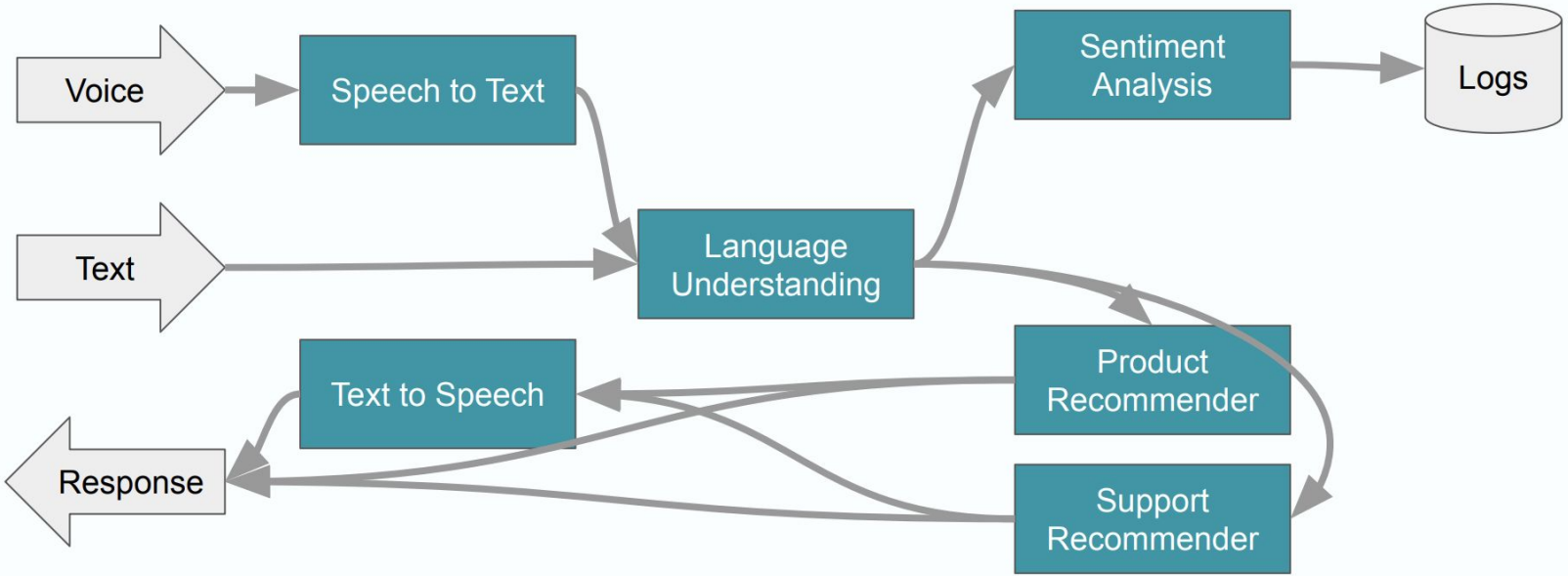
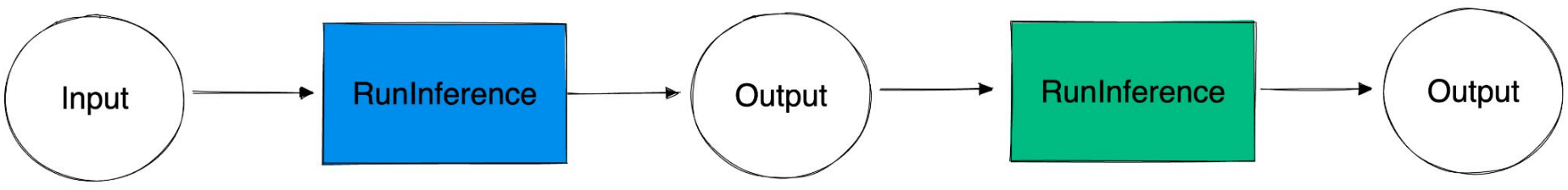
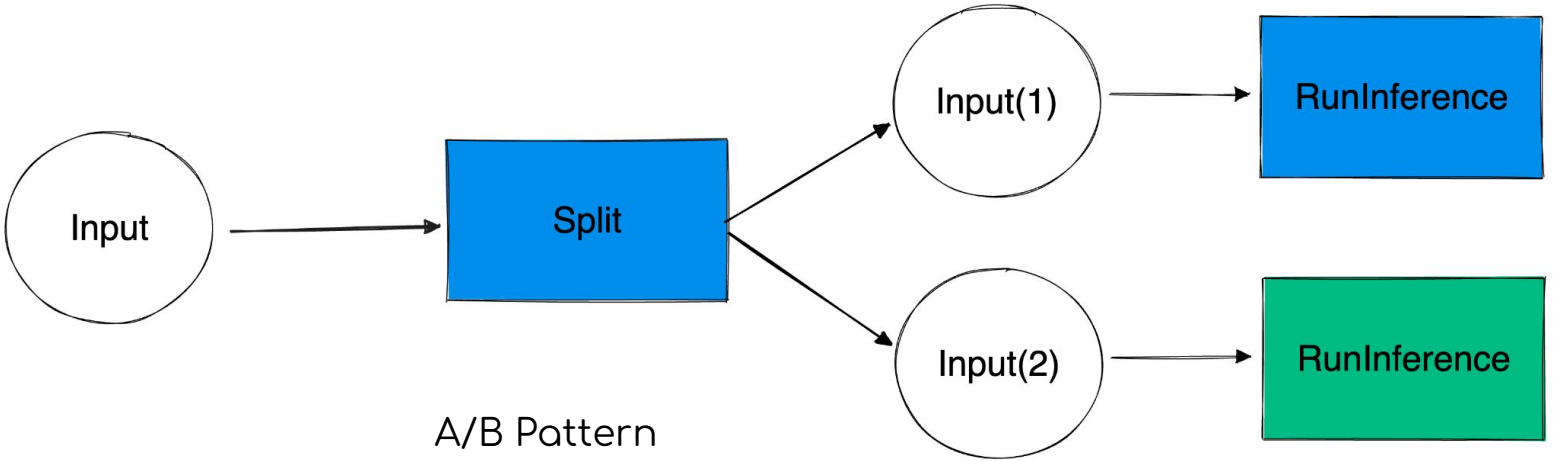


Fig.1. Example of a Multi model pipeline, taken from a tutorial on RunInference on Dataflow: Link

Ensemble Modeling: Sequential vs A/B



Sequential Pattern



A/B Pattern

Problem

Seamlessly integrate ML models in a Beam pipeline for semantic enrichment of data.

Business needs require combining multiple ML models. (Ensemble Modeling)

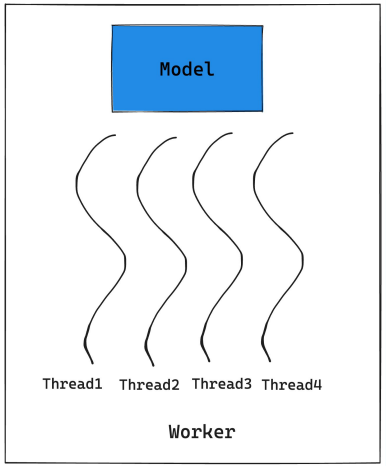
Solution

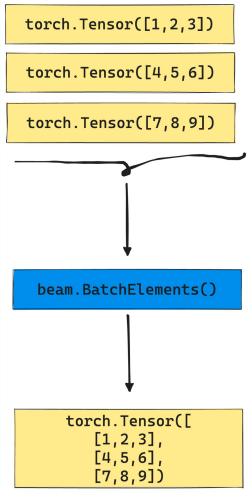
RunInference API = Inference with ML model in batch and streaming pipelines, without needing lots of boilerplate code.

RunInference API = Using multiple RunInference transforms, build a pipeline that consists of multiple ML models.

RunInference >> Custom DoFn

Seamlessly integrate ML model in a Beam pipeline for semantic enrichment of data.





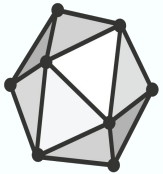
Custom DoFn

RunInference

RunInference supports popular ML frameworks

PyTorch

TensorFlow



ONNX

NVIDIA
TENSORRT

XGBoost

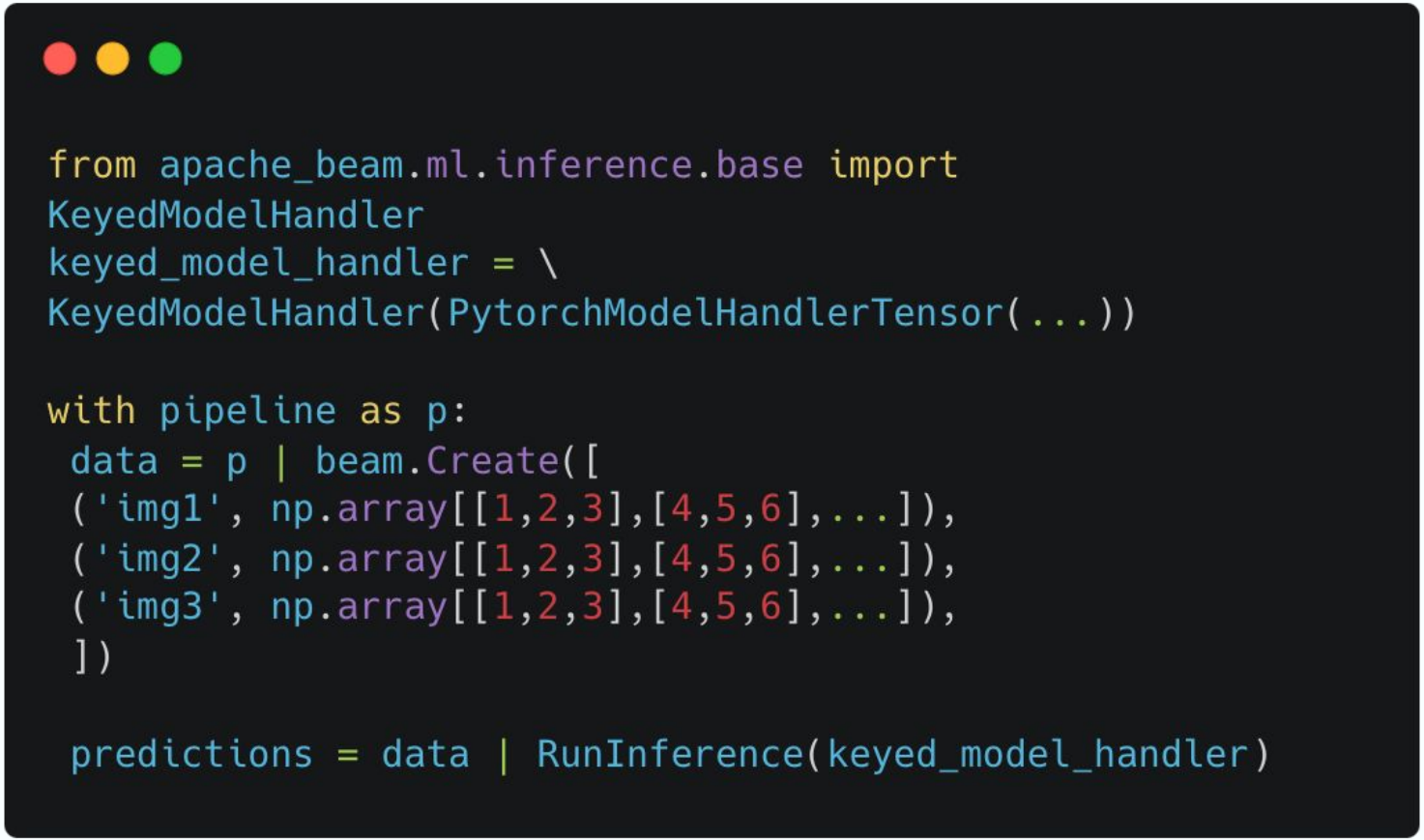
How to use RunInference ?

```
from apache_beam.ml.inference.base import RunInference
with pipeline as p:
 predictions = ( p | beam.ReadFromSource('a_source')
                   | RunInference(ModelHandler)
                 )
```

ModelHandlers

```
from apache_beam.ml.inference.sklearn_inference import SklearnModelHandlerNumpy
from apache_beam.ml.inference.sklearn_inference import SklearnModelHandlerPandas
from apache_beam.ml.inference.pytorch_inference import PytorchModelHandlerTensor
from apache_beam.ml.inference.pytorch_inference import
PytorchModelHandlerKeyedTensor
model_handler = SklearnModelHandlerNumpy(model_uri='model.pkl',
 model_file_type=ModelFileType.JOBLIB)

model_handler = PytorchModelHandlerTensor(state_dict_path='model.pth',
 model_class=PytorchLinearRegression,
 model_params={'input_dim': 1, 'output_dim': 1})
```

KeyedModelHandler

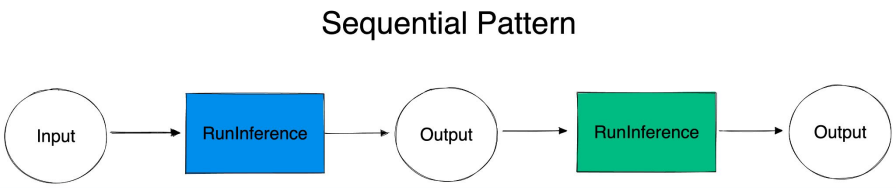


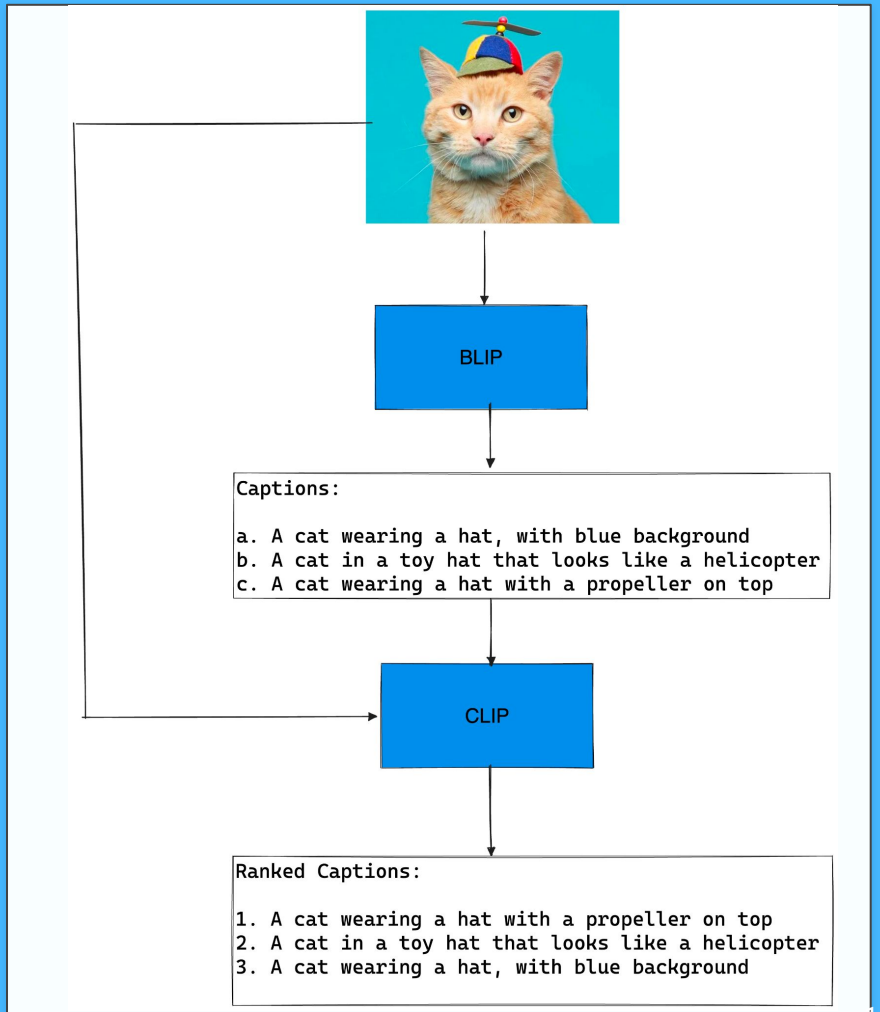
```
from apache_beam.ml.inference.base import
KeyedModelHandler
keyed_model_handler = \
KeyedModelHandler(PytorchModelHandlerTensor(...))

with pipeline as p:
 data = p | beam.Create([
 ('img1', np.array[[1,2,3],[4,5,6],...]),
 ('img2', np.array[[1,2,3],[4,5,6],...]),
 ('img3', np.array[[1,2,3],[4,5,6],...]),
 ])

 predictions = data | RunInference(keyed_model_handler)
```

Example

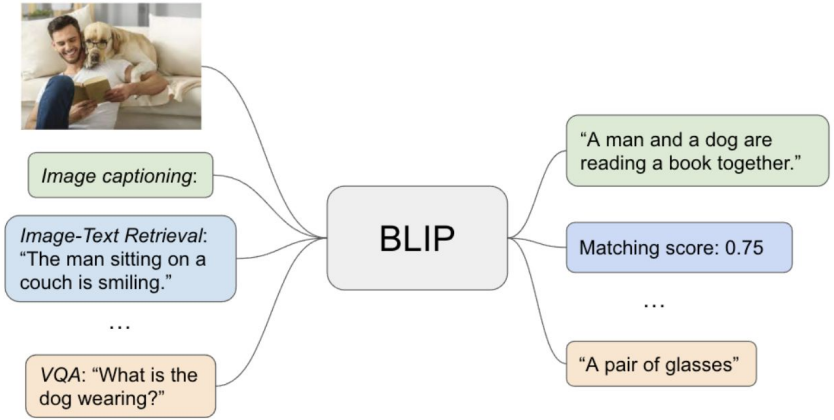
Image captioning and ranking with Sequential Pattern:

1. **BLIP**: Image Captioning
2. **CLIP**: Ranking captions

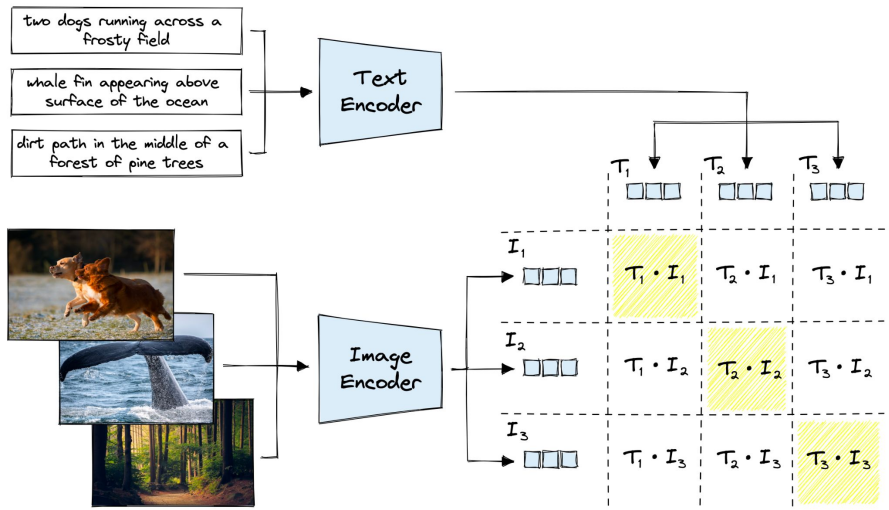




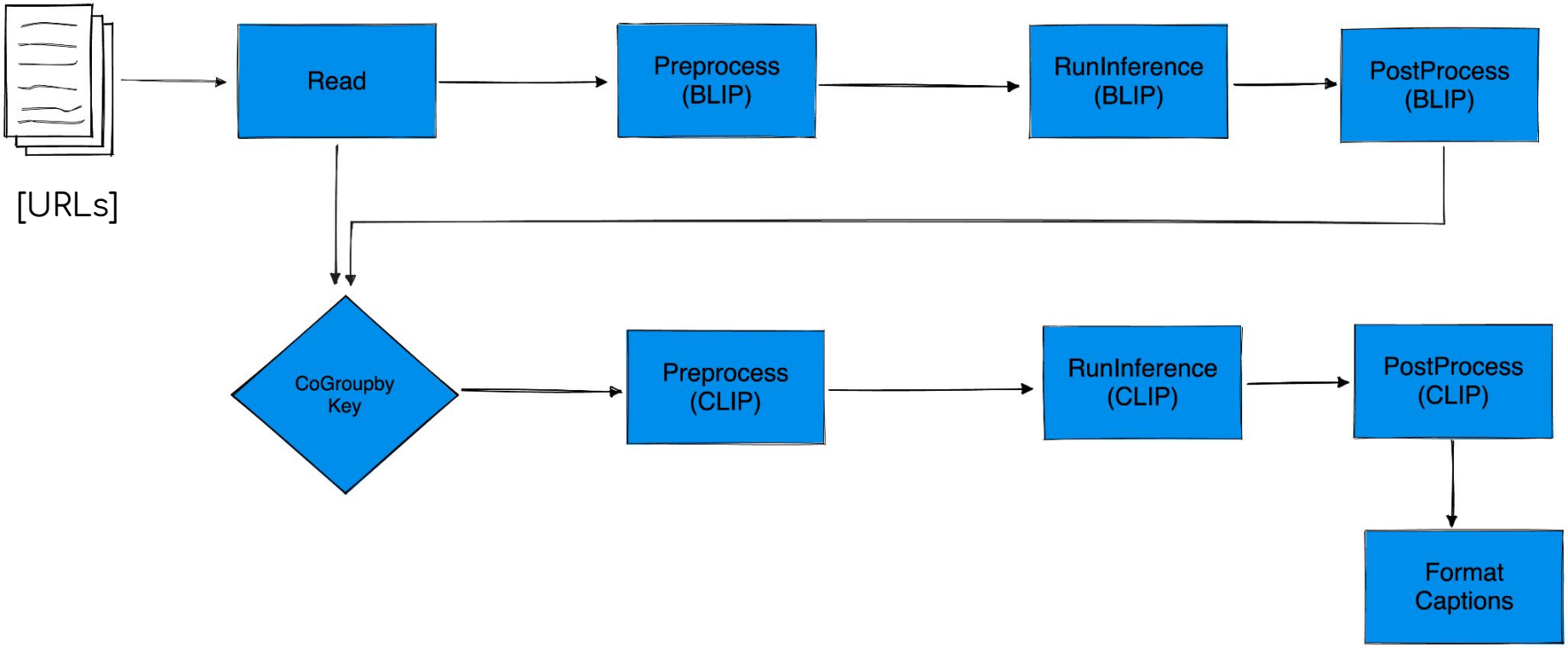
BLIP: Image Captioning



CLIP: Caption Ranking



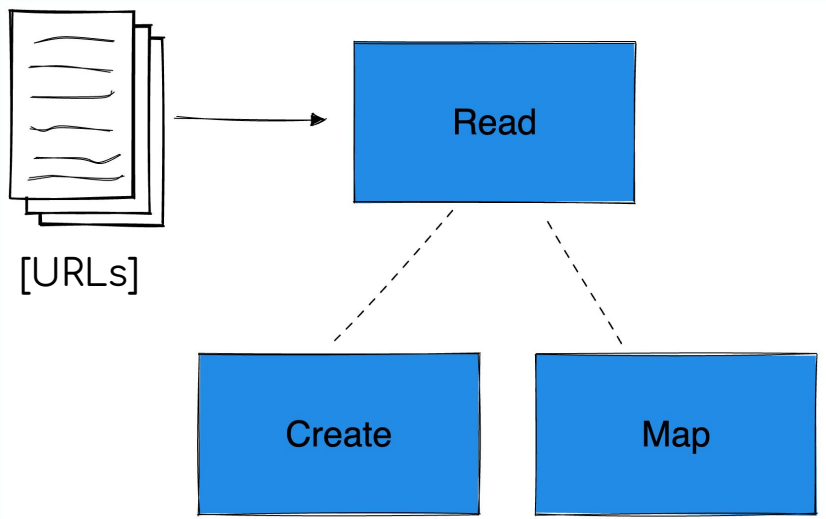
ML Inference Pipeline in Beam as a DAG



ML Inference Pipeline in Beam as a DAG

```
with beam.Pipeline() as pipeline:
    img_url_pil_img = (
        pipeline
        | "ReadUrl" >> beam.Create(images_url)
        | "ReadImages" >> beam.Map(read_img_from_url)
    )

    img_url_captions = (
        img_url_pil_img
        | "BLIPPreprocess" >> beam.MapTuple(lambda img_url, img: (
                img_url,
                blip_preprocess(img, processor=blip_processor),
            )
        )
        | "GenerateCaptions" >> RunInference(
            model_handler=KeyedModelHandler(blip_model_handler),
            inference_args={"max_length": 50, "min_length": 10,
                "num_return_sequences": 5, "do_sample": True,},
        )
        | "BLIPPostProcess" >> beam.ParDo(
          BLIPPostprocess(processor=blip_processor))
    )

    img_url_captions_ranking = (
        ({"image": img_url_pil_img, "captions": img_url_captions})
        | "CreateImageCaptionPair" >> beam.CoGroupByKey()
        | "CLIPPreprocess" >> beam.ParDo(CLIPPreprocess(processor=clip_processor))
        | "CaptionRanking"
        >> RunInference(model_handler=KeyedModelHandler(clip_model_handler))
        | "CLIPPostProcess" >>
beam)ParDo(CLIPPostProcess(processor=clip_processor))

    img_url_captions_ranking | "FormatCaptions" >> beam.ParDo(FormatCaptions(3))
```

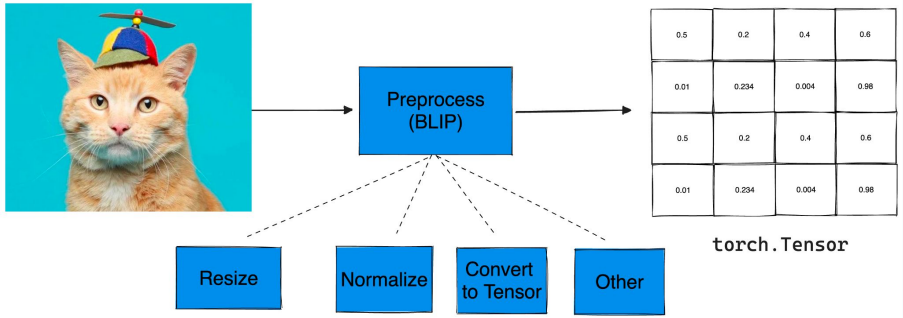
Read Images from URLs




```python
def read_img_from_url(img_url: str) -> Tuple[str,
Image.Image]:
    image = Image.open(requests.get(img_url, stream=True).raw)
    return img_url, image

with beam.Pipeline() as pipeline:
    img_url_pil_img = (
        pipeline
        | "ReadUrl" >> beam.Create(images_url)
        | "ReadImages" >> beam.Map(read_img_from_url)
    )
```

(Img URL, Image)

Preprocess Inputs for BLIP

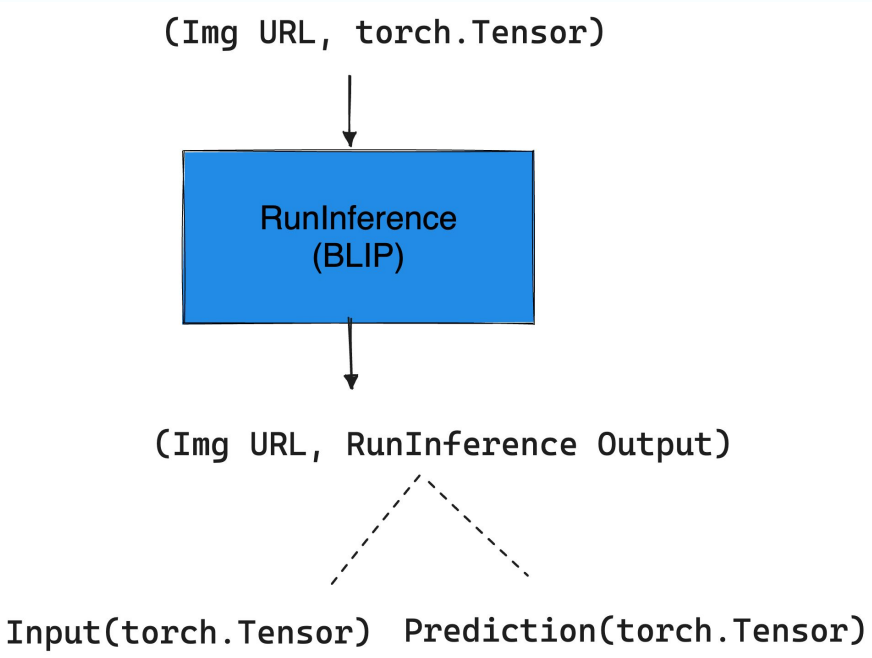



```python
def blip_preprocess(image: Image.Image, processor: BlipProcessor)-> torch.Tensor:
    inputs = processor(images=image, return_tensors="pt")
    return inputs.pixel_values

blip_processor = BlipProcessor.from_pretrained("Salesforce/blip-image-captioning-base")

img_url_captions = (
    img_url_pil_img
    | "BLIPPreprocess"
    >> beam.MapTuple(
        lambda img_url, img: (
            img_url,
            blip_preprocess(img, processor=blip_processor),
        )
    )
```

(Img URL, torch.Tensor)

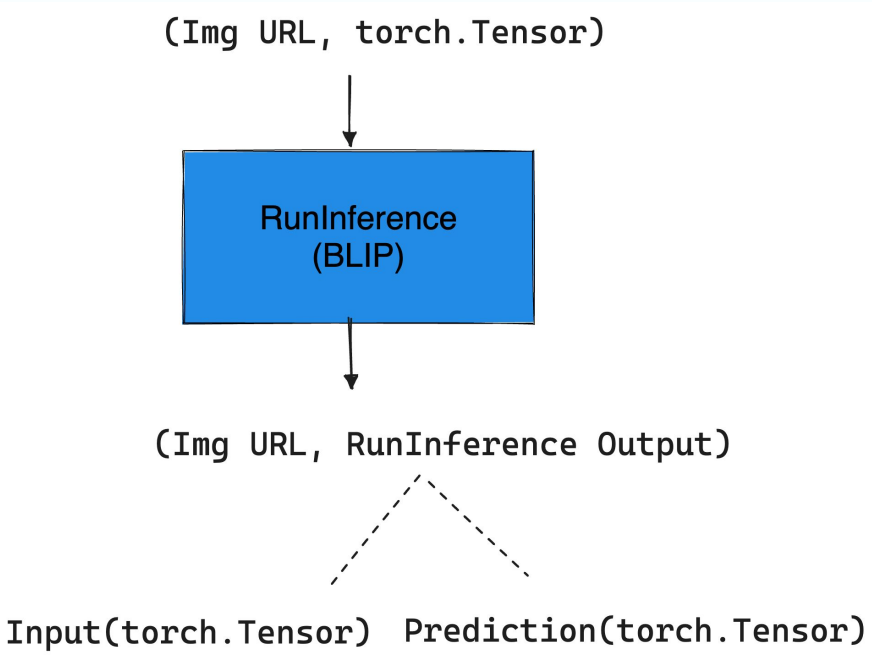
Hugging Face

Inference using BLIP




```
        | "GenerateCaptions"
        >> RunInference(
          model_handler=blip_model_handler,
          inference_args={
                "max_length": 50,
                "min_length": 10,
                "num_return_sequences": 5,
                "do_sample": True,
            },
        )
```

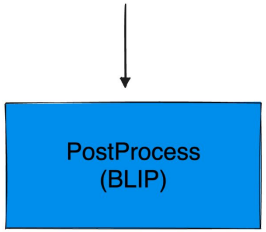
Inference using BLIP




```
gen_fn = mod_make_tensor_model_fn('generate')

blip_model_handler = KeyedModelHandler(
  PytorchModelHandlerTensor(
    state_dict_path="./blip_model.pth",
    model_class=BlipForConditionalGeneration,
    model_params={
        "config": AutoConfig.from_pretrained(model_id)
    },
    max_batch_size=1,
    device = "gpu"
    inference_fn=gen_fn))
```

PostProcess BLIP Output

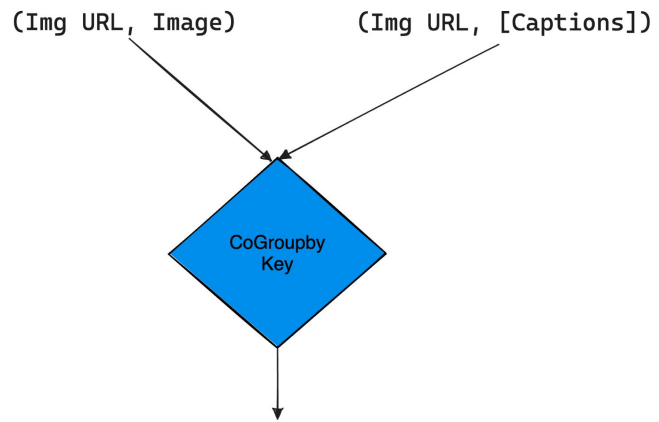
(Img URL, RunInference Output)




```
(Img URL, [ A cat wearing a hat, with blue background,
            A cat in a toy hat that looks like a helicopter,
            A cat wearing a hat with a propeller on top ]
```

```python
class BLIPPostprocess(beam.DoFn):
  def __init__(self, processor: BlipProcessor):
    self._processor = processor

  def process(self, element):
    img_url, output = element
    captions = blip_processor.batch_decode(output.inference,
skip_special_tokens=True)
    yield img_url, captions


| "BLIPPostProcess" >> beam.ParDo(BLIPPostprocess(processor=blip_processor))
```

Grouping Image and BLIP Output




```
(Img URL, {'image': [Image], 'captions': [
              [A cat wearing a hat, with blue background,
               A cat in a toy hat that looks like a helicopter,
               A cat wearing a hat with a propeller on top]
               ]
           }
)
```

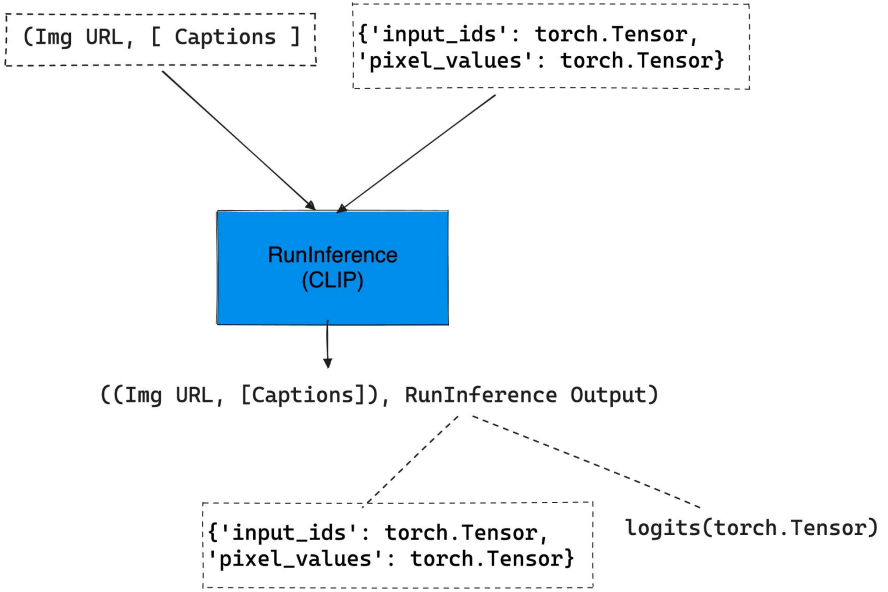
```
img_url_captions_ranking = (
  ({"image": img_url_pil_img, "captions": img_url_captions})
  | "CreateImageCaptionPair" >> beam.CoGroupByKey()
```

Preprocess Inputs for CLIP


```python
class CLIPPreprocess(beam.DoFn):
  def __init__(self, processor: CLIPProcessor):
    self._processor = processor

  def process(self, element):
    img_url, grouped_val = element
    pil_img, captions = grouped_val['image'], grouped_val['captions'][0]
    processed_output = self._processor(text=captions,
                                       images=pil_img,
                                       return_tensors="pt",
                                       padding=True)

    yield (img_url, captions), processed_output

clip_processor = CLIPProcessor.from_pretrained("openai/clip-vit-base-patch32")
```

Hugging Face

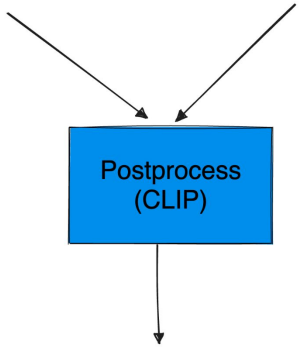
Inference using CLIP




```python
class CLIPWrapper(CLIPModel):

  def forward(self, **kwargs: Dict[str, torch.Tensor]):
    # Squeeze because RunInference adds an extra dimension, which is empty.
    kwargs = {key: tensor.squeeze(0) for key, tensor in kwargs.items()}
    output = super().forward(**kwargs)
    logits = output.logits_per_image
    return logits


clip_model_handler = KeyedModelHandler(PytorchModelHandlerKeyedTensor(
    state_dict_path="./clip_model.pth",
    model_class=CLIPWrapper,
    model_params={
        "config": AutoConfig.from_pretrained("openai/clip-vit-base-patch32")
    },
    max_batch_size=1,))


| "CaptionRanking" >> RunInference(model_handler=clip_model_handler)
```

PostProcess CLIP Output

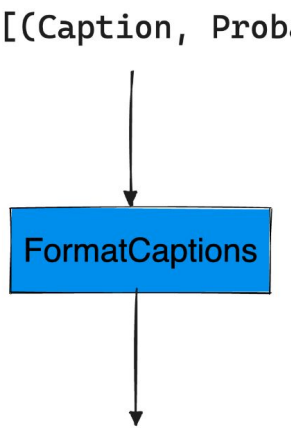
((Img URL, [Captions]), RunInference Output)




```
(
https://image_captioning/cat_with_hat.jpg,
[('A cat wearing a hat with a propeller on top',
0.43382697),
('A cat in a toy hat that looks like a helicopter',
0.32000825),
('A cat wearing a hat, with blue background',
0.16968591)]
)
```

```python
class CLIPPostProcess(beam.DoFn):
  def __init__(self, processor: CLIPProcessor):
    self._processor = processor

  def process(self, element):
    (image_url, captions), prediction = element
    prediction_results = prediction.inference
    prediction_probs = prediction_results.softmax(dim=-1).cpu().detach().numpy()
    ranking = np.argsort(-prediction_probs)
    sorted_caption_prob_pair = [(captions[idx], prediction_probs[idx]) for idx in
ranking]
    return [(image_url, sorted_caption_prob_pair)]


| "CLIPPostProcess" >> beam.ParDo(CLIPPostProcess(processor=clip_processor))
```

Printing the results nicely




```
Image: cat_with_hat
Top 3 captions ranked by CLIP:
1: A cat wearing a hat with a propeller on top
(Caption probability: 0.4338)
2: A cat in a toy hat that looks like a helicopter.
(Caption probability: 0.3200)
3: A cat wearing a hat, with blue background.
(Caption probability: 0.1697)
```

Takeaways

- RunInference transform eliminates the need for extensive boilerplate code in pipelines with machine learning models.
- Multiple RunInference transforms enable complex pipelines with minimal code for multi-ML models.
- Example pipeline can be used for captioning images for finetuning Stable Diffusion.

Code and Tutorial Link

Code: GitHub Link

Tutorial: Apache Beam Documentation Link

Slides: GitHub Link

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QUESTIONS?


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