Question 1

1.1

```
tracks = []

    for frame_id in range(start_frame, end_frame):
      current_image, current_detections = load_image_and_detections(frame_id)

      next_image, next_detections = load_image_and_detections(frame_id + 1)

      # sim has as many rows as len(current_detections) and as many columns as
      # len(next_detections).
      # sim[k, t] is the similarity between detection k in frame i, and detection
      # t in frame j.
      # sim[k, t] == 0 indicates that k and t should probably not be the same track.
      sim = compute_similarity(current_detections, next_detections,
                               current_image, next_image)

      while sim.size != 0:

        track_index = np.unravel_index(sim.argmax(), sim.shape)
        current_det = current_detections[track_index[0]].tolist()
        current_det[4] = frame_id
        next_det = next_detections[track_index[1]].tolist()
        next_det[4] = frame_id + 1

        if sim[track_index] != 0:
          added = False
          for track in tracks:
            if current_det in track:
              track.append(next_det)
              added = True
              break
          if not added:
            tracks.append([current_det, next_det])

        sim = np.delete(sim, track_index[0], axis=0)
        sim = np.delete(sim, track_index[1], axis=1)
        current_detections = np.delete(current_detections, track_index[0], axis=0)
        next_detections = np.delete(next_detections, track_index[1], axis=0)
```

1.2

```
tracks = [track for track in tracks if len(track) > 2]
    print(len(tracks))
    color_counter = 0
```

```
colors = ['black', 'green', 'red', 'yellow', 'blue', 'white', 'cyan']
for track in tracks:

  if len(track) < 5:

    continue
  color_counter += 1

  for detection in track:

    image_path = os.path.join(TRACKS_DIR, '%06d.jpg' % detection[4])
    image = Image.open(image_path).convert("RGBA")

    draw = ImageDraw.Draw(image)
    draw.rectangle([(detection[0], detection[1]), (detection[2], detection[3])],
    image.save(image_path, "JPEG")
```

1.3

- Train the DPM model with more image data
- Tune the parameter by trial-and-error

1.4

- Find court coordinates and actual dimension
- Use affine transformation to convert the player coordinates to actual location
- Calculate speed over frame (or seconds)

Question 2

2.1

$$
\begin{aligned}
\mathcal{L}(\mathbf{w}, b) &= -\frac{1}{M}\sum_{i=1}^{M}[y_i \log(h(\mathbf{w}^\intercal \mathbf{x}_i + b)) + (1-y_i)\log(1-h(\mathbf{w}^\intercal \mathbf{x}_i + b))] \\
&= -\frac{1}{M}\sum_{i=1}^{M}[y_i \log(\frac{1}{1+e^{-(\mathbf{w}^\intercal \mathbf{x}_i + b)}}) + (1-y_i)\log(1-\frac{1}{1+e^{-(\mathbf{w}^\intercal \mathbf{x}_i + b)}})] \\
&= -\frac{1}{M}\sum_{i=1}^{M}[y_i \log(\frac{1}{1+e^{-(\mathbf{w}^\intercal \mathbf{x}_i + b)}}) + (1-y_i)\log(\frac{e^{-(\mathbf{w}^\intercal \mathbf{x}_i + b)}}{1+e^{-(\mathbf{w}^\intercal \mathbf{x}_i + b)}})] \\
&= -\frac{1}{M}\sum_{i=1}^{M}[-y_i \log(1+e^{-(\mathbf{w}^\intercal \mathbf{x}_i + b)}) + (1-y_i)\{\log(e^{-(\mathbf{w}^\intercal \mathbf{x}_i + b)}) - \log(1+e^{-(\mathbf{w}^\intercal \mathbf{x}_i + b)})\}] \\
&= -\frac{1}{M}\sum_{i=1}^{M}[-y_i \log(1+e^{-(\mathbf{w}^\intercal \mathbf{x}_i + b)}) + (1-y_i)(-(\mathbf{w}^\intercal \mathbf{x}_i + b)) - (1-y_i)\log(1+e^{-(\mathbf{w}^\intercal \mathbf{x}_i + b)})] \\
&= -\frac{1}{M}\sum_{i=1}^{M}[(1-y_i)(-(\mathbf{w}^\intercal \mathbf{x}_i + b)) - \log(1+e^{-(\mathbf{w}^\intercal \mathbf{x}_i + b)})] \\
&= \frac{1}{M}\sum_{i=1}^{M}[(1-y_i)(\mathbf{w}^\intercal \mathbf{x}_i + b) + \log(1+e^{-(\mathbf{w}^\intercal \mathbf{x}_i + b)})]
\end{aligned}
$$

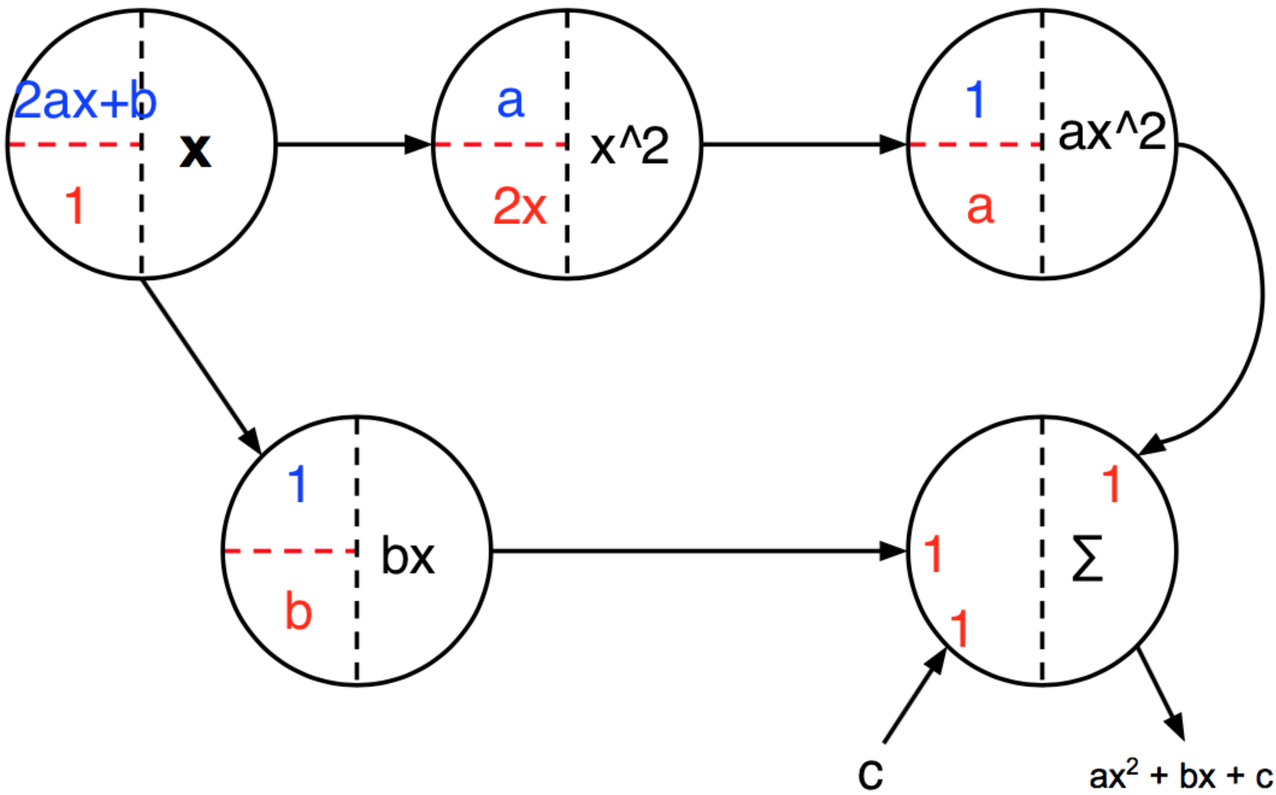
Let $\mathbf{x}_i^{(j)}$ be the j-th feature descriptor of sample $\mathbf{x}_i$.

$$
\begin{aligned}
\frac{\partial \mathcal{L}}{\partial w_1} &= \frac{1}{M}\sum_{i=1}^{M}[(1-y_i)\cdot \mathbf{x}_i^{(1)} - \frac{\mathbf{x}_i^{(1)} \cdot e^{-(\mathbf{w}^\intercal \mathbf{x} + b)}}{1+e^{-(\mathbf{w}^\intercal \mathbf{x} + b)}}] \\
&= \frac{1}{M}\sum_{i=1}^{M}\mathbf{x}_i^{(1)}[(1-y_i) - \frac{e^{-(\mathbf{w}^\intercal \mathbf{x} + b)}}{1+e^{-(\mathbf{w}^\intercal \mathbf{x} + b)}}] \\
&= \frac{1}{M}\sum_{i=1}^{M}\mathbf{x}_i^{(1)}[1 - \frac{e^{-(\mathbf{w}^\intercal \mathbf{x} + b)}}{1+e^{-(\mathbf{w}^\intercal \mathbf{x} + b)}} - y_i] \\
&= \frac{1}{M}\sum_{i=1}^{M}\mathbf{x}_i^{(1)}[\frac{1}{1+e^{-(\mathbf{w}^\intercal \mathbf{x} + b)}} - y_i] \\
&= \frac{1}{M}\sum_{i=1}^{M}\mathbf{x}_i^{(1)}[h(\mathbf{w}^\intercal \mathbf{x} + b) - y_i]
\end{aligned}
$$

$$
\frac{\partial \mathcal{L}}{\partial w_2} = \frac{1}{M}\sum_{i=1}^{M}\mathbf{x}_i^{(2)}[h(\mathbf{w}^\intercal \mathbf{x} + b) - y_i]
$$

$$\frac{\partial \mathcal{L}}{\partial b} = \frac{1}{M}\sum_{i=1}^{M}[h(\mathbf{w}^\top \mathbf{x} + b) - y_i]$$

2.2



2.3 & 2.4

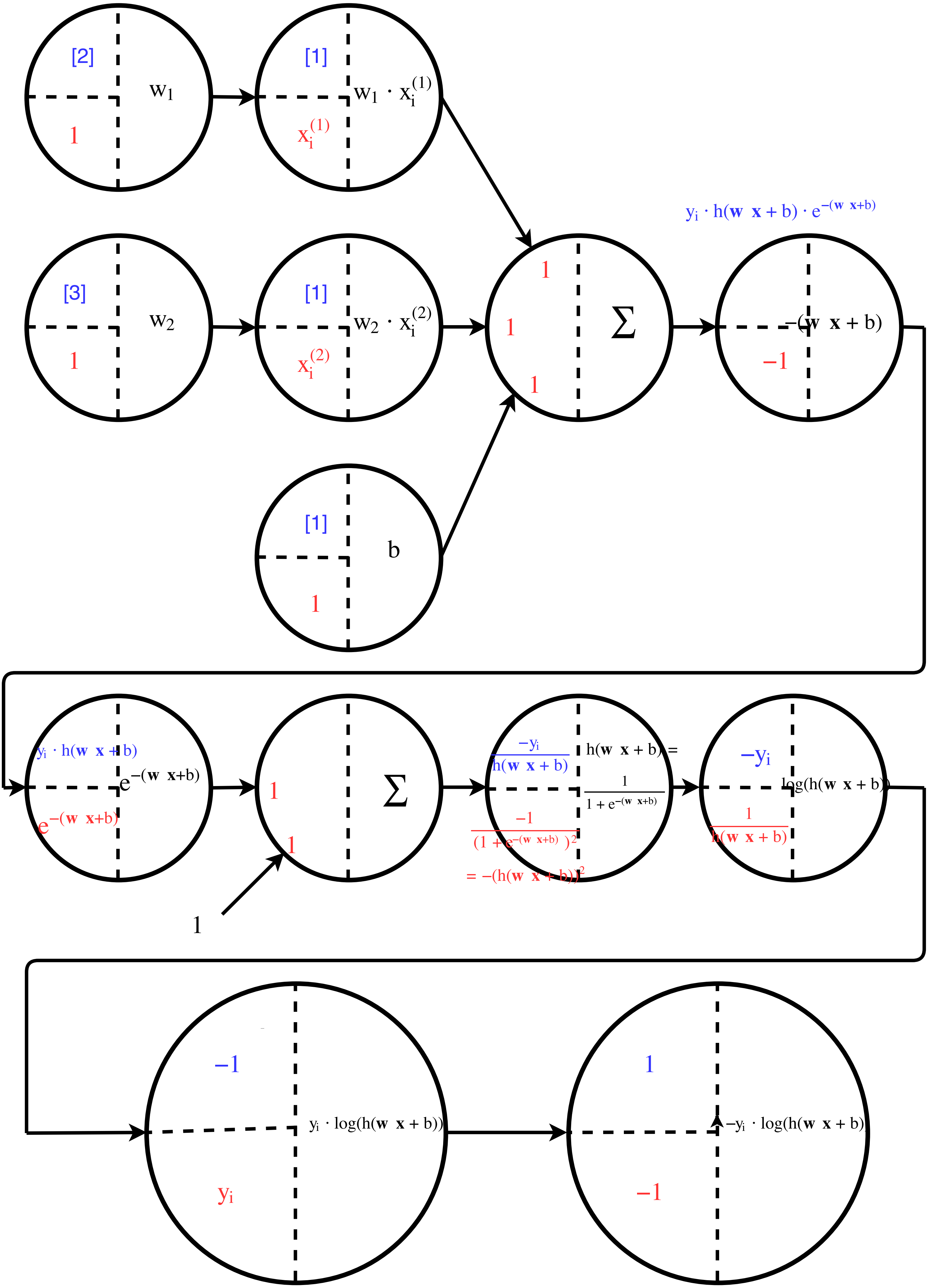
Notation in graph:

[1] $y_i \cdot h(\mathbf{w}^\top \mathbf{x} + b) \cdot e^{-(\mathbf{w}^\top \mathbf{x}+b)}$

[2] $-y_i \cdot h(\mathbf{w}^\top \mathbf{x} + b) \cdot e^{-(\mathbf{w}^\top \mathbf{x}+b)}$

[3] $-y_i \cdot x_i^{(1)} \cdot h(\mathbf{w}^\top \mathbf{x} + b) \cdot e^{-(\mathbf{w}^\top \mathbf{x}+b)}$

[4] $-y_i \cdot x_i^{(2)} \cdot h(\mathbf{w}^\top \mathbf{x} + b) \cdot e^{-(\mathbf{w}^\top \mathbf{x}+b)}$


[2]
w_1
1
[1]
$w_1 \cdot x_i^{(1)}$
$x_i^{(1)}$
[3]
w_2
1
[1]
$w_2 \cdot x_i^{(2)}$
$x_i^{(2)}$
[1]
b
1
1
1
1
Σ
$y_i \cdot h(\mathbf{w}\ \mathbf{x} + b) \cdot e^{-(\mathbf{w}\ \mathbf{x}+b)}$
$-(\mathbf{w}\ \mathbf{x} + b)$
-1
$y_i \cdot h(\mathbf{w}\ \mathbf{x} + b)$
$e^{-(\mathbf{w}\ \mathbf{x}+b)}$
$e^{-(\mathbf{w}\ \mathbf{x}+b)}$
1
1
Σ
1
$\frac{-y_i}{h(\mathbf{w}\ \mathbf{x} + b)}$
$h(\mathbf{w}\ \mathbf{x} + b) = \frac{1}{1 + e^{-(\mathbf{w}\ \mathbf{x}+b)}}$
$\frac{-1}{(1 + e^{-(\mathbf{w}\ \mathbf{x}+b)})^2}$
$= -(h(\mathbf{w}\ \mathbf{x} + b))^2$
$-y_i$
$\log(h(\mathbf{w}\ \mathbf{x} + b))$
$\frac{1}{h(\mathbf{w}\ \mathbf{x} + b)}$
-1
$y_i \cdot \log(h(\mathbf{w}\ \mathbf{x} + b))$
y_i
1
$-y_i \cdot \log(h(\mathbf{w}\ \mathbf{x} + b))$
-1

Question 3

3.1

$$\begin{aligned}\mathbf{w}^\intercal\mathbf{x} + b &= 5 \times 1.1 + 10 \times -6.0 + 2 \\ &= 5.5 - 60 + 2 \\ &= -52.5\end{aligned}$$

$$h(\mathbf{w}^\intercal\mathbf{x} + b) = h(-52.5) = \frac{1}{1 + e^{(-(-52.5))}} \approx 0$$

$$\begin{aligned}\frac{\partial \mathcal{L}}{\partial w_1} &= \frac{1}{M}\sum_{i=1}^{M} \mathbf{x}_i^{(1)}[h(\mathbf{w}^\intercal\mathbf{x} + b) - y_i] \\ &= 5 \times [0 - 1] \\ &= -5\end{aligned}$$

$$\begin{aligned}\frac{\partial \mathcal{L}}{\partial w_2} &= \frac{1}{M}\sum_{i=1}^{M} \mathbf{x}_i^{(2)}[h(\mathbf{w}^\intercal\mathbf{x} + b) - y_i] \\ &= 10 \times [0 - 1] \\ &= -10\end{aligned}$$

$$\begin{aligned}\frac{\partial \mathcal{L}}{\partial b} &= \frac{1}{M}\sum_{i=1}^{M}[h(\mathbf{w}^\intercal\mathbf{x} + b) - y_i] \\ &= [0 - 1] \\ &= -1\end{aligned}$$

3.2

```
x = [5; 10];
    y = 1;
    w = [1.1; -6.0];
    b = 2;

    dLdw1 = x(1)*( h(w, x, b)-y);
    dLdw2 = x(2)*( h(w, x, b)-y);
    dLdb = h(w, x, b)-y;
```

```
disp(dLdw1);
disp(dLdw2);
disp(dLdb);

function result = h(w, x, b)
    result = 1/(1+exp(-1*((w.'*x)+b)));
end
```