

## a) Context free generation

$$\begin{aligned} \geq (-, -) &= (-, -) \\ \exists(\lambda x_i : -, \mathcal{X}) & \\ > (-, -) &\vee (-, -) \\ \forall(\lambda x_i : -, \mathcal{X}) &\wedge (-, -) \\ N^-(\lambda x_i : -, \mathcal{X}) & \end{aligned}$$

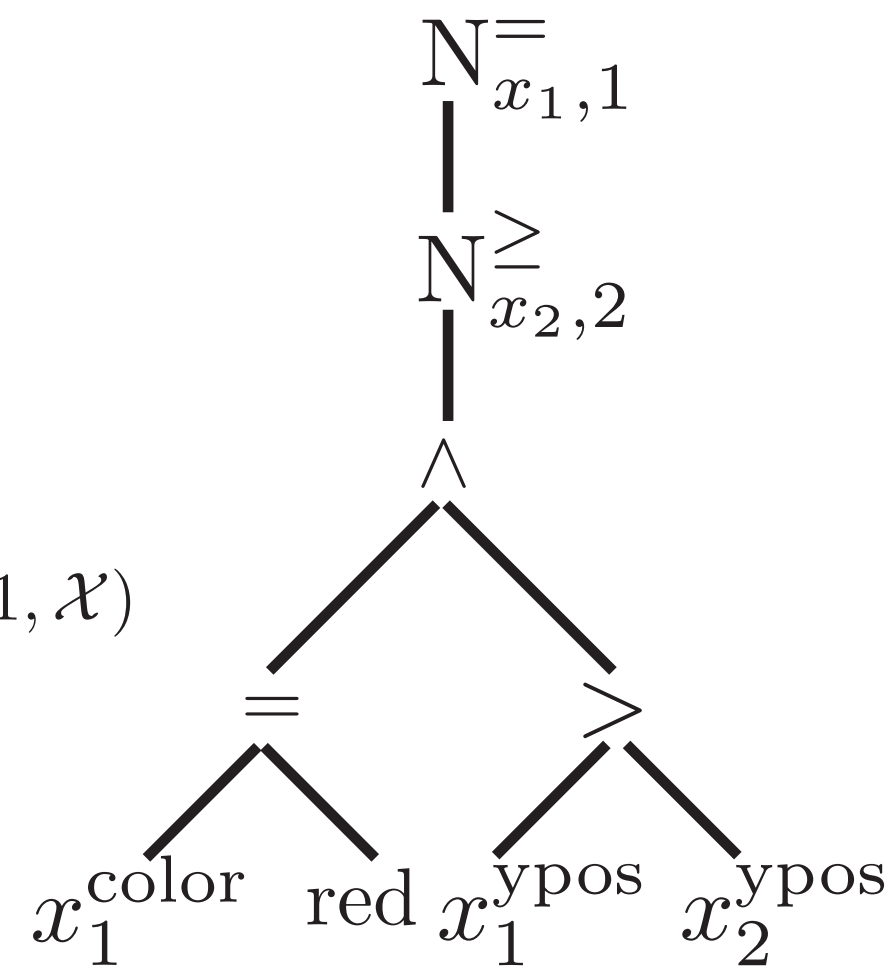
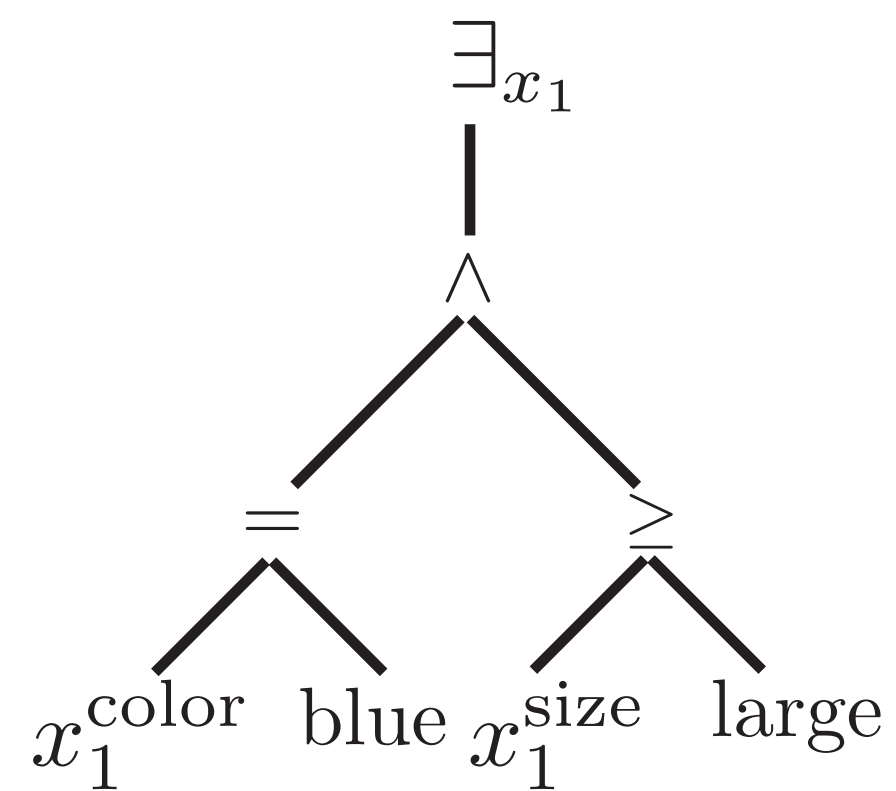
e.g.:

$$\begin{aligned} S &\rightarrow \\ \exists(\lambda x_1 : A, \mathcal{X}) &\rightarrow \\ \exists(\lambda x_1 : B, \mathcal{X}) &\rightarrow \\ \exists(\lambda x_1 : H(B, B), \mathcal{X}) &\rightarrow \\ \exists(\lambda x_1 : \wedge(= (x_1, D1), I(x_1, D2)), \mathcal{X}) &\rightarrow \\ \exists(\lambda x_1 : \wedge(= (x_1, \text{blue, colour}), \geq (x_1, \text{medium, size})), \mathcal{X}) & \end{aligned}$$

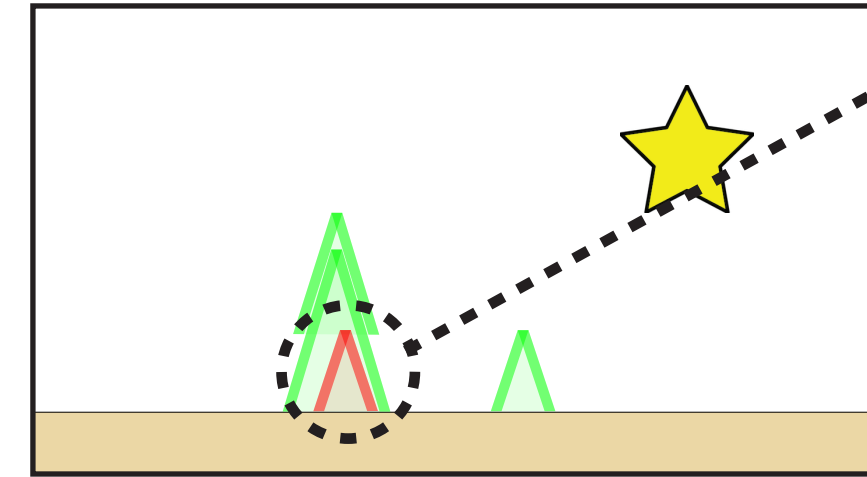
**There is a blue cone that is at least medium sized**

$$\begin{aligned} S &\rightarrow \\ N^=(\lambda x_1 : A, 1, \mathcal{X}) & \\ N^=(\lambda x_1 : S, 1, \mathcal{X}) & \\ N^=(\lambda x_1 : N^{\geq}(\lambda x_2 : A, 2, \mathcal{X}), 1, \mathcal{X}) : & \\ N^=(\lambda x_1 : N^{\geq}(\lambda x_2 : B, 2, \mathcal{X}), 1, \mathcal{X}) : & \\ N^=(\lambda x_1 : N^{\geq}(\lambda x_2 : \wedge(B, B), 2, \mathcal{X}), 1, \mathcal{X}) : & \\ N^=(\lambda x_1 : N^{\geq}(\lambda x_2 : \wedge(= (x_1, D1), I(x_1, x_2, E2)), 2, \mathcal{X}), 1, \mathcal{X}) & \\ N^=(\lambda x_1 : N^{\geq}(\lambda x_2 : \wedge(= (x_1, \text{red, colour}), > (x_1, x_2, \text{ypos})), 2, \mathcal{X}), 1, \mathcal{X}) & \end{aligned}$$

**One red cone is above at least two other cones**

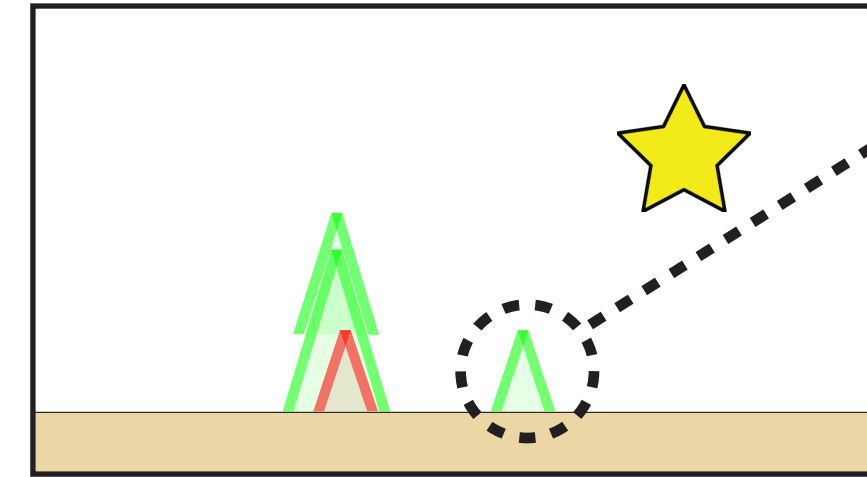


## b) Context based generation



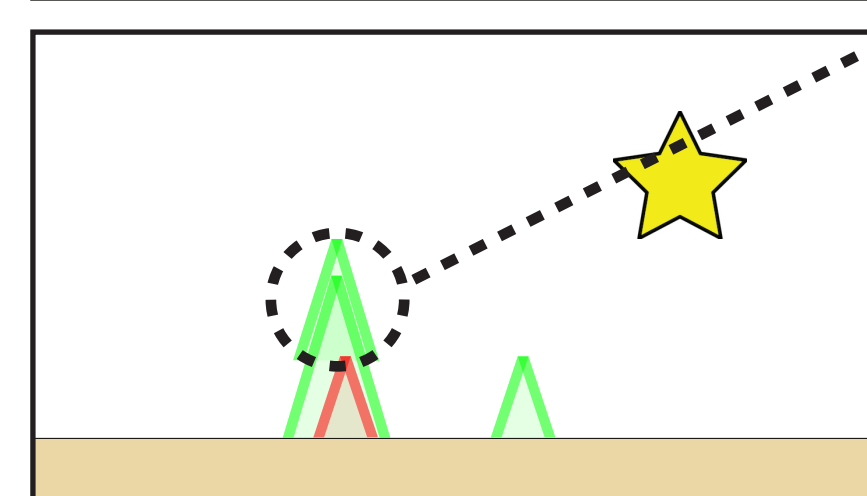
$$\begin{aligned} \text{red, colour} &\rightarrow \\ = (x_1, \text{red, colour}) &\rightarrow \\ \wedge(= (x_1, \text{red, colour}), = (x_1, \text{small, size})) &\rightarrow \\ \exists(\lambda x_1 : \wedge(= (x_1, \text{red, colour}), = (x_1, \text{small, size})), \mathcal{X}) & \end{aligned}$$

**There is a small red cone**



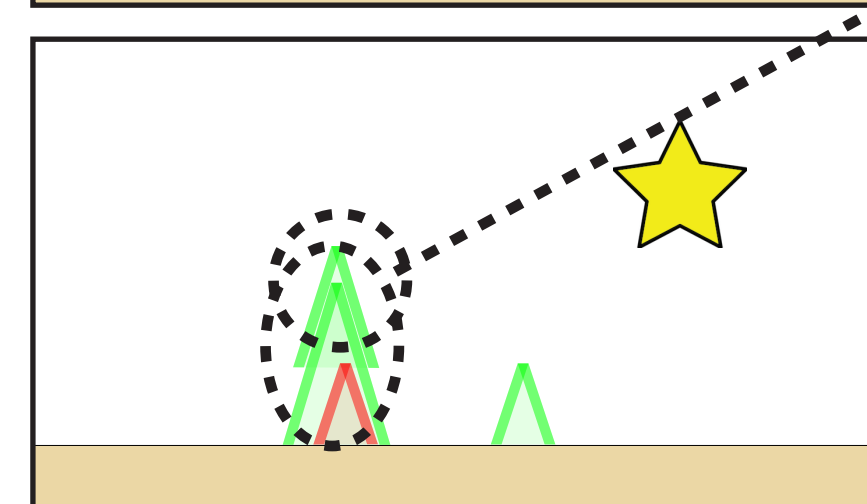
$$\begin{aligned} \text{green, colour} &\rightarrow \\ = (x_1, \text{green, colour}) &\rightarrow \\ N^{\geq}(\lambda x_1 : = (x_1, \text{green, colour}), 3, \mathcal{X}) & \end{aligned}$$

**There are at least three green cones**



$$\begin{aligned} \text{medium, size} &\rightarrow \\ \geq (x_1, \text{medium, size}) &\rightarrow \\ N^=(\lambda x_1 : x_1, \geq (\text{medium, size}), 2, \mathcal{X}) & \end{aligned}$$

**Two cones of at least medium size**



$$\begin{aligned} \text{contact} &\rightarrow \\ = (x_1, x_2, \text{contact}) &\rightarrow \\ \wedge(\wedge(= (x_1, \text{green, colour}), = (x_2, \text{green, colour})), = (x_1, x_2, \text{contact})) &\rightarrow \\ \exists(\lambda x_1 : \exists(\lambda x_2 : \wedge(\wedge(= (x_1, \text{green, colour}), = (x_2, \text{green, colour})), & \\ = (x_1, x_2, \text{contact})), \mathcal{X}), \mathcal{X}) & \end{aligned}$$

**Two green cones touch**