

Given:

$X$ : dense  $m \times n$  input

$val_W, idx_W$ : sparse representation of the sparse filter with  $nz$  non-zero values,  
with indices of type (row, column)

$O$ : dense  $om \times on$  output ( $om = m - k + 1, on = n - k + 1$ )

$\frac{\partial L}{\partial O}$ : dense  $om \times on$  errors

Targets:

dense  $m \times n$  matrix  $\frac{\partial L}{\partial X}$

sparse matrix  $val_{\frac{\partial L}{\partial W}}, idx_{\frac{\partial L}{\partial W}}$  with  $nz$  elements

Algorithm:

$\frac{\partial L}{\partial X} \leftarrow m \times n$  zero matrix

$idx_{\frac{\partial L}{\partial W}} \leftarrow$  copy of  $idx_W$

$val_{\frac{\partial L}{\partial W}} \leftarrow$  zero list of length  $nz$

**for**  $0 \leq p < om$  **do**

**for**  $0 \leq q < on$  **do**

$o \leftarrow \frac{\partial L}{\partial O}[p, q]$

**for**  $0 \leq si < nz$  **do**

$(r, c) \leftarrow idx_W[si]$

            add  $o \times val_W[si]$  to  $\frac{\partial L}{\partial X}[p + r, q + c]$

            add  $o \times X[p + r, q + c]$  to  $val_{\frac{\partial L}{\partial W}}[si]$

**end for**

**end for**

**end for**