

First pass:  
 \* understand  
 \* local improve.  
 Second pass:  
 \* Make into a documented package  
 \* Clean Xp, Xm, ...

Pensieve header: My old Khovanov homology program from <http://www.math.toronto.edu/~drorbn/papers/Categorification/>, made to work with KnotTheory`.

```
<< KnotTheory`
Loading KnotTheory` version of September 6, 2014, 13:37:37.2841.
Read more at http://katlas.org/wiki/KnotTheory.

np[L_Link] := Count[L, X[i_, j_, k_, l_] /; j - l == 1 || l - j > 1];
nm[L_Link] := Count[L, X[i_, j_, k_, l_] /; l - j == 1 || j - l > 1];

SetAttributes[p, Orderless]
S[L_Link, s_String] := S[L, Characters[s] /. {"0" -> 0, "1" -> 1}]
S[L_Link, a_List] := Times@@(Thread[{List@@L, a}] /. {
  {X[i_, j_, k_, l_], 0} -> p[i, j][Min[i, j]] p[k, l][Min[k, l]],
  {X[i_, j_, k_, l_], 1} -> p[i, l][Min[i, l]] p[j, k][Min[j, k]],
  {x_X, "*"} -> x
}) // . p[i_, j_][m_] p[j_, k_][n_] -> p[i, k][Min[m, n]] // . {
  X[i_, j_, k_, l_] p[i_, j_][m_] p[k_, l_][n_] -> (c[m] c[n] -> c[Min[m, n]]),
  X[i_, j_, k_, l_] p[i_, l_][m_] p[j_, k_][n_] -> (c[Min[m, n]] -> c[m] c[n])
} // . p[_ , _][m_] ^ _ -> c[m]
```

$S_c[L]$

```
Deg[expr_] := Count[expr, v4_vp, {0, 1}] - Count[expr, v-_vm, {0, 1}]

V[L_Link, s_String, deg___] := V[L, Characters[s] /. {"0" -> 0, "1" -> 1}, deg]
V[L_Link, a_List] := List@@Expand[S[L, a] /. x_c -> ((vp@@x) + (vm@@x))]
V[L_Link, a_List, deg_Integer] := Select[V[L, a], (deg == Deg[#] + (Plus@@a)) &]
```

$V_k[L]$

```
d[L_Link, s_String] := d[L, Characters[s] /. {"0" -> 0, "1" -> 1}]
d[L_Link, a_List] := S[L, a] /. {
  (c[x_] c[y_] -> c[z_]) * _ ->
  {vp@x vp@y -> vp@z, vp@x vm@y -> vm@z, vm@x vp@y -> vm@z, vm@x vm@y -> 0},
  (c[z_] -> c[x_] c[y_]) * _ -> {vp@z -> vp@x vm@y + vm@x vp@y, vm@z -> vm@x vm@y}
}
```

RC (\* RC for Row (un-renormalized) ck<inst

```
KhBracket[L_Link, r_Integer, deg___] := If[r < 0 || r > Length[L],
  {0},
  (*else*) Join@@(((v@@#) V[L, #, deg]) & /@
    Permutations[Join[Table[0, {Length[L] - r}], Table[1, {r}]]])
]
```

```
CC[L_Link, r_Integer, deg_Integer] := KhBracket[L, r + nm[L], deg - np[L] + 2 nm[L]]
```

```
d[L_Link][expr_] := Expand[expr] /. s_ * a_v -> Expand[sign = 1;
  Sum[
```

```

If[a[[i]] == 0,
  sign * ReplacePart[a, 1, i] * s /. d[L, List@@ReplacePart[a, "*", i]],
  (*else*) sign == -1; 0
],
{i, Length[a]}
]
]

```

```

Rank[L_Link, r_Integer, deg_Integer] := Rank[L, r, deg] = (

```

clean {

```

  Off[Solve::svars];
  b0 = CC[L, r, deg];
  l1 = Length[b1 = CC[L, r + 1, deg]];
  eqs = (# == 0) & /@ d[L][b0] /. MapThread[Rule, {b1, vars = Array[b, l1]}];
  rk = If[b0 == {} || l1 == 0, 0, Length[First[Solve[eqs, vars]]]];
  On[Solve::svars];
  rk
);

```

```

Betti[L_Link, r_Integer, deg_Integer] := Betti[L, r, deg] = (

```

```

  b = Length[CC[L, r, deg]] - Rank[L, r, deg] - Rank[L, r - 1, deg];
  Print[StringForm["Betti[`, `] = `", r, deg, b]];
  b
)

```

```

qBetti[L_Link, r_Integer] := (

```

```

  degs = Union[Deg /@ KhBracket[L, r + nm[L]]] + np[L] - nm[L] + r;
  (Betti[L, r, #] & /@ degs) . q^degs
)

```

```

KhPoly[L_Link] :=

```

```

  KhPoly[L] = Expand[Sum[t^r * qBetti[L, r], {r, -nm[L], Length[L] - nm[L]}]]

```

```

{kp1 = Link@@PD[Knot[5, 1]] // KhPoly,

```

```

  kp1 /. t -> -1, Expand[(q + 1/q) Jones[Knot[5, 1]][q^2]]}

```

$$\left\{ \frac{1}{q^5} + \frac{1}{q^3} + \frac{1}{q^{15} t^5} + \frac{1}{q^{11} t^4} + \frac{1}{q^{11} t^3} + \frac{1}{q^7 t^2}, -\frac{1}{q^{15}} + \frac{1}{q^7} + \frac{1}{q^5} + \frac{1}{q^3}, -\frac{1}{q^{15}} + \frac{1}{q^7} + \frac{1}{q^5} + \frac{1}{q^3} \right\}$$

```

{kp2 = Link@@PD[Knot[10, 132]] // KhPoly,

```

```

  kp2 /. t -> -1, Expand[(q + 1/q) Jones[Knot[10, 132]][q^2]]}

```

$$\left\{ \frac{1}{q^3} + \frac{1}{q} + \frac{1}{q^{15} t^7} + \frac{1}{q^{11} t^6} + \frac{1}{q^{11} t^5} + \frac{1}{q^9 t^4} + \frac{1}{q^7 t^4} + \frac{1}{q^9 t^3} + \frac{1}{q^5 t^3} + \frac{2}{q^5 t^2} + \frac{1}{q t}, -\frac{1}{q^{15}} + \frac{1}{q^7} + \frac{1}{q^5} + \frac{1}{q^3}, -\frac{1}{q^{15}} + \frac{1}{q^7} + \frac{1}{q^5} + \frac{1}{q^3} \right\}$$