Montreal Alexander handout, June 17

June-17-13
10:31 AM

Meta–Groups, Meta–Bicrossed–Products, and the Alexander Polynomial, 1

Dror Bar-Natan in Montreal, June 2013.

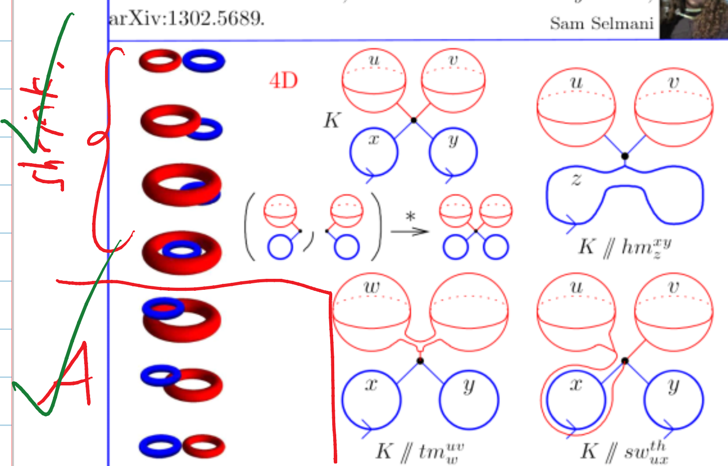
http://www.math.toronto.edu/~drorbn/Talks/Montreal-1306/

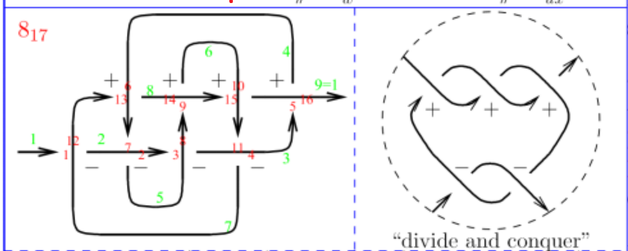
Abstract. I will define "meta-groups" and explain how one specific meta-group, which in itself is a "meta-bicrossed-product", gives rise to an "ultimate Alexander invariant" of tangles, that contains the Alexander polynomial (multivariable, if you wish), has extremely good composition properties, is evaluated in a topologically meaningful way, and is least-wasteful in a computational sense. If you believe in categorification, that's a wonderful playground.

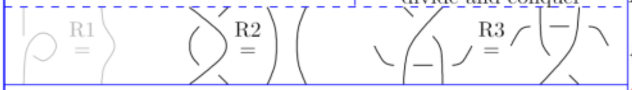
This work is closely related to work by Le Dimet (Comment. Math. Helv. **67** (1992) 306–315), Kirk, Livingston and Wang (arXiv:math/9806035) and Cimasoni and Turaev (arXiv:math.GT/0406269).

See also Dror Bar-Natan and Sam Selmani, *Meta-Monoids, Meta-Bicrossed Products, and the Alexander Polynomial*, arXiv:1302.5689.

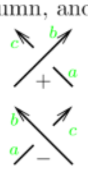
Sam Selmani







A Standard Alexander Formula. Label the arcs 1 through $(n+1)=1$, make an $n\times n$ matrix as below, delete one row and one column, and compute the determinant:



	a	b	c
c	-1	$1-X$	X

	a	b	c
c	$-X$	$X-1$	1

$$\begin{pmatrix} 1 & 0 & 0 & 0 & 0 & X-1 & 0 & -X \\ -1 & X & 0 & 0 & 0 & 0 & 1-X & 0 \\ 0 & -1 & X & 0 & 1-X & 0 & 0 & 0 \\ X-1 & 0 & -X & 1 & 0 & 0 & 0 & 0 \\ 0 & 1-X & 0 & -1 & X & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & -X & 1 & 0 & X-1 \\ 0 & 0 & 1-X & 0 & 0 & -1 & X & 0 \\ 0 & 0 & 0 & X-1 & 0 & 0 & -X & 1 \end{pmatrix}$$

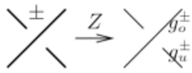
```
[[1 ;; 7, 1 ;; 7]] // Det
```

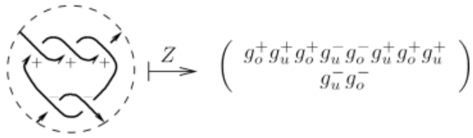
$-1+4X-8X^2+11X^3-8X^4+4X^5-X^6$

Alexander Issues.

- Quick to compute, but computation departs from topology.
- Extends to tangles, but at an exponential cost.
- Hard to categorify.

Idea. Given a group G and two "YB" pairs $R^\pm=(g_o^\pm,g_u^\pm)\in G^2$, map them to xings and "multiply along", so that

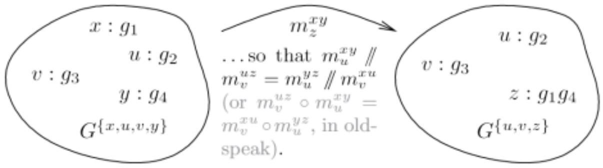




$$\begin{pmatrix} g_o^+ g_u^+ g_o^+ g_u^- g_o^- g_u^+ g_o^+ g_u^+ \\ g_u^- g_o^- \end{pmatrix}$$

This Fails! R2 implies that $g_o^\pm g_o^\mp=e=g_u^\pm g_u^\mp$ and then R3 implies that g_o^+ and g_u^+ commute, so the result is a simple counting invariant.

A Group Computer. Given G, can store group elements and perform operations on them:



Also has S_x for inversion, e_x for unit insertion, d_x for register deletion, Δ^z_{xy} for element cloning, ρ^x_y for renamings, and $(D_1,D_2)\mapsto D_1\cup D_2$ for merging, and many obvious composition axioms relating those. $P=\{x:g_1,y:g_2\}\Rightarrow P=\{d_yP\}\cup\{d_xP\}$

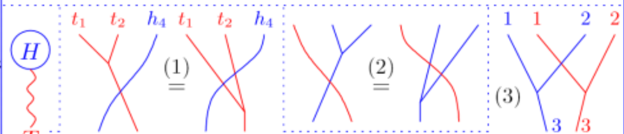
A Meta-Group. Is a similar "computer", only its internal structure is unknown to us. Namely it is a collection of sets $\{G_\gamma\}$ indexed by all finite sets γ, and a collection of operations m^{xy}_z, S_x, e_x, d_x, Δ^z_{xy} (sometimes), ρ^x_y, and $\cup$, satisfying the exact same *linear* properties.

Example 0. The non-meta example, $G_\gamma:=G^\gamma$.

Example 1. $G_\gamma:=M_{\gamma\times\gamma}(\mathbb{Z})$, with simultaneous row and column operations, and "block diagonal" merges. Here if $P=\begin{pmatrix} x: & a & b \\ y: & c & d\end{pmatrix}$ then $d_yP=(x:a)$ and $d_xP=(y:d)$ so $\{d_yP\}\cup\{d_xP\}=\begin{pmatrix} x: & a & 0 \\ y: & 0 & d\end{pmatrix}\neq P$. So this G is truly meta.

Claim. From a meta-group G and YB elements $R^\pm\in G_2$ we can construct a knot/tangle invariant.

Bicrossed Products. If $G=HT$ is a group presented as a product of two of its subgroups, with $H\cap T=\{e\}$, then also $G=TH$ and G is determined by H, T, and the "swap" map $sw^{th}:(t,h)\mapsto(h',t')$ defined by $th=h't'$. The map sw satisfies (1) and (2) below; conversely, if $sw:T\times H\to H\times T$ satisfies (1) and (2) (+ lesser conditions), then (3) defines a group structure on $H\times T$, the "bicrossed product".



$tm^{12}_1 /\!\!/ sw_{14} = sw_{24} /\!\!/ sw_{14} /\!\!/ tm^{12}_1$

$gm^{12}_3 := sw_{12} /\!\!/ tm^{12}_3 /\!\!/ hm^{12}_3$

$h_1t_1h_2t_2=h_1(h'_2t'_1)t_2=(h_1h'_2)(t'_1t_2)=h_3t_3$

A: People study $\pi_1(X) := [$  $_b, X]$ & $\pi_2(X) := [$  $_b, X]$

Why not $\pi_T(X) := [$  $^b_b, X]$?