Trees and Wheels and Balloons and Hoops

Dror Bar-Natan, Zurich, September 2013
ωεβ:=http://www.math.toronto.edu/~drorbn/Talks/Zurich-130919

15 Minutes on Algebra

Let T be a finite set of "tail labels" and H a finite set of "head labels". Set

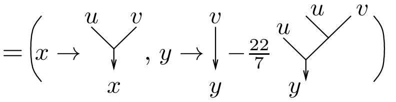
$$M_{1/2}(T;H) := FL(T)^H,$$

"H-labeled lists of elements of the degree-completed free Lie algebra generated by T".

$$FL(T) = \left\{2t_2 - \frac{1}{2}[t_1,[t_1,t_2]] + \dots\right\} \Big/ \left(\begin{matrix}\text{anti-symmetry}\\ \text{Jacobi}\end{matrix}\right)$$

... with the obvious bracket.

$$M_{1/2}(u,v;x,y) = \left\{\lambda = \left(x \to \dots, y \to \dots - \tfrac{22}{7} \dots\right) \dots\right\}$$



Operations $M_{1/2} \to M_{1/2}$. newspeak!

Tail Multiply tm^{uv}_w is $\lambda \mapsto \lambda /\!/ (u,v \to w)$, satisfies "meta-associativity", $tm^{uv}_u /\!/ tm^{uw}_u = tm^{vw}_v /\!/ tm^{uv}_u$.

Head Multiply hm^{xy}_z is $\lambda \mapsto (\lambda \setminus \{x,y\}) \cup (z \to \operatorname{bch}(\lambda_x,\lambda_y))$, where

$$\operatorname{bch}(\alpha,\beta) := \log(e^\alpha e^\beta) = \alpha + \beta + \frac{[\alpha,\beta]}{2} + \frac{[\alpha,[\alpha,\beta]] + [[\alpha,\beta],\beta]}{12} + \dots$$

satisfies $\operatorname{bch}(\operatorname{bch}(\alpha,\beta),\gamma) = \log(e^\alpha e^\beta e^\gamma) = \operatorname{bch}(\alpha,\operatorname{bch}(\beta,\gamma))$ and hence meta-associativity, $hm^{xy}_x /\!/ hm^{xz}_x = hm^{yz}_y /\!/ hm^{xy}_x$.

Tail by Head Action tha^{ux} is $\lambda \mapsto \lambda /\!/ RC_u^{\lambda_x}$, where $C_u^{-\gamma}\colon FL \to FL$ is the substitution $u \to e^{-\gamma} u e^{\gamma}$, or more precisely,

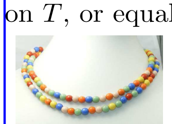
$$C_u^{-\gamma}\colon u \to e^{-\operatorname{ad}\gamma}(u) = u - [\gamma,u] + \frac{1}{2}[\gamma,[\gamma,u]] - \dots,$$

and $RC_u^\gamma = (C_u^{-\gamma})^{-1}$. Then $C_u^{\operatorname{bch}(\alpha,\beta)} = C_u^{\alpha /\!/ RC_u^{-\beta}} /\!/ C_u^\beta$ hence $RC_u^{\operatorname{bch}(\alpha,\beta)} = RC_u^\alpha /\!/ RC_u^{\beta /\!/ RC_u^\alpha}$ hence "meta $u^{xy} = (u^x)^y$",

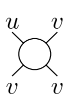
$$hm^{xy}_z /\!/ tha^{uz} = tha^{ux} /\!/ tha^{uy} /\!/ hm^{xy}_z,$$

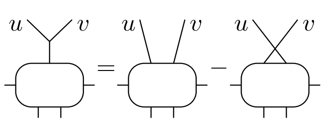
and $tm^{uv}_w /\!/ C_w^{\gamma /\!/ tm^{uv}_w} = C_u^{\gamma /\!/ RC_v^{-\gamma}} /\!/ C_v^\gamma /\!/ tm^{uv}_w$ and hence "meta $(uv)^x = u^x v^x$", $tm^{uv}_w /\!/ tha^{wx} = tha^{ux} /\!/ tha^{vx} /\!/ tm^{uv}_w$.

Wheels. Let $M(T;H) := M_{1/2}(T;H) \times CW(T)$, where $CW(T)$ is the (completed graded) vector space of cyclic words on T, or equaly well, on $FL(T)$:



ωεβ/antiq-ave

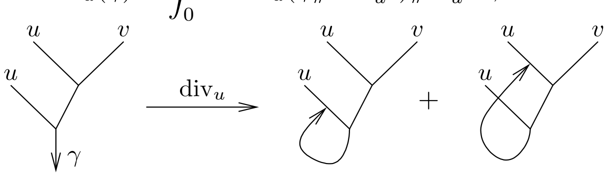




Operations. On $M(T;H)$, define tm^{uv}_w and hm^{xy}_z as before, and tha^{ux} by adding some J-spice:

$$(\lambda;\omega) \mapsto (\lambda, \omega + J_u(\lambda_x)) /\!/ RC_u^{\lambda_x},$$

where $J_u(\gamma) := \int_0^1 ds\, \operatorname{div}_u(\gamma /\!/ RC_u^{s\gamma}) /\!/ C_u^{-s\gamma}$, and



Alekseev

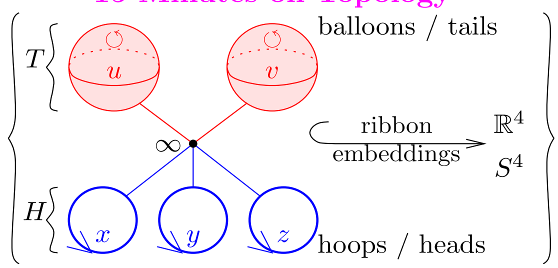
Torossian

Theorem Blue. All blue identities still hold.

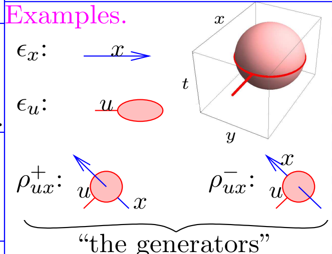
Merge Operation. $(\lambda_1;\omega_1) * (\lambda_2;\omega_2) := (\lambda_1 \cup \lambda_2; \omega_1 + \omega_2)$.

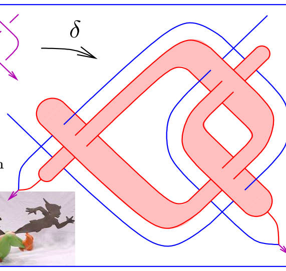
15 Minutes on Topology

$\mathcal{K}^{bh}(T;H)$. "Ribbon-knotted balloons and hoops"



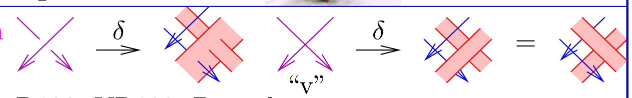
Examples.



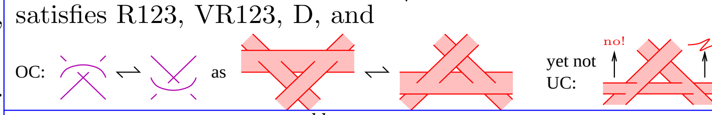


Shin Satoh

More on δ



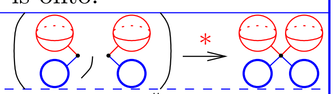
satisfies R123, VR123, D, and



- δ injects u-knots into $\mathcal{K}^{bh}$ (likely u-tangles too).
- δ maps v-tangles to $\mathcal{K}^{bh}$; the kernel contains the above and conjecturally (Satoh), that's all.
- Allowing punctures and cuts, δ is onto.

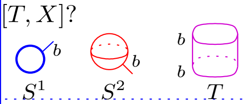
Operations Punctures & Cuts

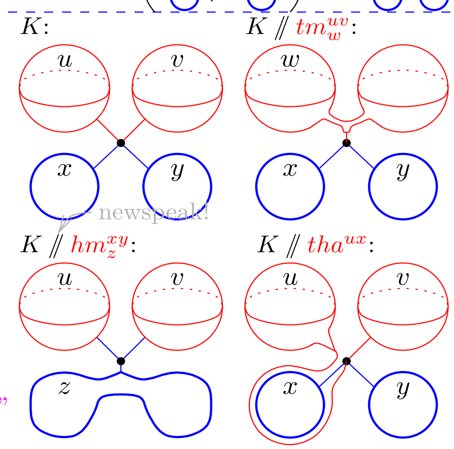
Connected Sums.



If X is a space, $\pi_1(X)$ is a group, $\pi_2(X)$ is an Abelian group, and π_1 acts on π_2.

Riddle. People often study $\pi_1(X) = [S^1, X]$ and $\pi_2(X) = [S^2, X]$. Why not $\pi_T(X) := [T, X]$?



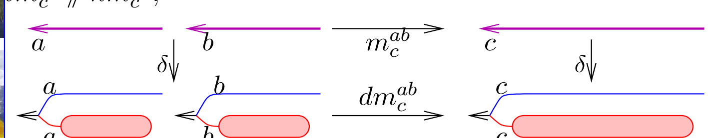


"Meta-Group-Action"

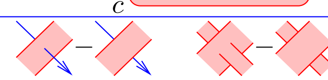
Properties.

- Associativities: $m^{ab}_a /\!/ m^{ac}_a = m^{bc}_b /\!/ m^{ab}_a$, for $m = tm, hm$.
- "$(uv)^x = u^x v^x$": $tm^{uv}_w /\!/ tha^{wx} = tha^{ux} /\!/ tha^{vx} /\!/ tm^{uv}_w$,
- "$u^{(xy)} = (u^x)^y$": $hm^{xy}_z /\!/ tha^{uz} = tha^{ux} /\!/ tha^{uy} /\!/ hm^{xy}_z$.

Tangle concatenations $\to \pi_1 \ltimes \pi_2$. With $dm^{ab}_c := tha^{ab} /\!/ tm^{ab}_c /\!/ hm^{ab}_c$,



Finite type invariants make sense in the usual way, and "algebra" is (the primitive part of) "gr" of "topology".



Video and more at http://www.math.toronto.edu/~drorbn/Talks/Geneva-130917/, .../Toronto-1303/ and at .../Chicago-1303/