COPPALINI ARCHITECTURE

Memory Motion

Return, mirror transfer, and relative phase

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Abstract

Motion carries a physical state between time addresses. Memory is the inverse condition by which a relation returns to its own address while the carriage remains ordered. The axial metric flow advances a real coordinate by $2\log\varphi$ and closes its quotient reading after that advance. The mirror reverses the flow. Curvature records loop transport; material memory records state update and readout. The equations distinguish a changing carrier state, a returning read, and an ordered occurrence without erasing their difference.

1. Motion and memory

At time addresses $a \preceq b$, motion is a transport

$$T_{b\leftarrow a} : X_a \longrightarrow X_b, \qquad x_b = T_{b\leftarrow a} x_a. \tag{MM.0}$$

Time order composes exactly:

$$T_{c\leftarrow b} T_{b\leftarrow a} = T_{c\leftarrow a}, \qquad T_{a\leftarrow a} = I_{X_a}. \tag{MM.0a}$$

Memory is the inverse condition of an invertible carriage:

$$T_{a\leftarrow b} = T_{b\leftarrow a}^{-1}, \qquad T_{a\leftarrow b} T_{b\leftarrow a} = I_{X_a}. \tag{MM.0b}$$

Return is identity at its addressed carrier. A reader may close under a transport while the state continues to differ at the local address.

2. Axial lift and quotient

Let

$$Q = \begin{pmatrix} 1 & 1 \\ 1 & 0 \end{pmatrix}, \qquad \Omega = \begin{pmatrix} 0 & 1 \\ -1 & 0 \end{pmatrix}, \qquad C = -\Omega,$$

$$G = [Q, \Omega] = \begin{pmatrix} -2 & 1 \\ 1 & 2 \end{pmatrix}, \qquad H = \frac{G}{\sqrt{5}}, \qquad S = \frac{2Q - I}{\sqrt{5}}.$$

The common exact identities are

$$Q^2 = Q + I, \qquad C^2 = -I, \qquad G^2 = 5I, \qquad H^2 = S^2 = I,$$

$$H = CS, \qquad SG = \sqrt{5}\Omega = -GS, \qquad L_s := e^{sS}, \qquad L_s^{\mathsf{T}} G L_s = G, \qquad H L_s H = L_{-s}.$$

Let

$$\varphi = \frac{1+\sqrt{5}}{2}, \qquad s_0 = \log\varphi, \qquad \varpi = 2\log\varphi. \tag{MM.1}$$

The selected transport is

$$L_{\mathrm{ax}} := L_{s_0} = \frac{Q+2I}{\sqrt{5}}, \qquad T_{\mathrm{ax}} := -L_{\mathrm{ax}}. \tag{MM.2}$$

Let $v_\pm$ denote the null eigenvectors of Q, with $Qv_+ = \varphi v_+$ and $Qv_- = -\varphi^{-1}v_-$. On

$$X = \{z = av_+ + bv_- : ab \neq 0\}, \tag{MM.3}$$

define the lift coordinate

$$\xi_{\mathrm{lift}}(z) := \log\left|\frac{a}{b}\right|. \tag{MM.4}$$

Proposition 1 (Lift advance)**.** *For $z \in X$,*

$$\xi_{\mathrm{lift}}(L_s z) = \xi_{\mathrm{lift}}(z) + 2s, \qquad \xi_{\mathrm{lift}}(L_{\mathrm{ax}} z) = \xi_{\mathrm{lift}}(z) + \varpi. \tag{MM.5}$$

Proof. The flow $L_s = e^{sS}$ multiplies the two S-eigendirections by e^s and e^{-s}. Their coefficient ratio is therefore multiplied by e^{2s}. Taking the logarithm proves the result. □

The axial reader is

$$q_{\mathrm{ax}} : \mathbb{R} \longrightarrow \mathbb{R}/\varpi\mathbb{Z}, \qquad q_{\mathrm{ax}}(\xi) = [\xi]. \tag{MM.6}$$

It has the exact return-with-advance relation

$$q_{\mathrm{ax}}\big(\xi_{\mathrm{lift}}(L_{\mathrm{ax}} z)\big) = q_{\mathrm{ax}}(\xi_{\mathrm{lift}}(z)), \qquad \xi_{\mathrm{lift}}(L_{\mathrm{ax}} z) - \xi_{\mathrm{lift}}(z) = \varpi. \tag{MM.7}$$

Theorem 2 (Quotient and lift)**.** *The selected axial transport preserves the metric and reverses under the mirror:*

$$L_{\mathrm{ax}}^{\mathsf{T}} G L_{\mathrm{ax}} = G, \qquad H L_{\mathrm{ax}} H = L_{\mathrm{ax}}^{-1}. \tag{MM.8}$$

Its quotient return in MM.7 carries one reading across two distinct lift coordinates.

Proof. The first two identities are instances of the shared root. The lift difference in MM.7 is nonzero because $\varpi = 2\log\varphi > 0$. Hence the states have distinct lift coordinates. □

3. Reader, state, and record

A physical field has an interface

$$\begin{aligned}\mathfrak{I}_J := (&J, \Gamma_J, \mathrm{Src}_J; A_J, X_J, Y_J, T_J, \Sigma_J, \mathrm{Con}_J,\\ &\rho_J, O_J, K_J, B_J, \theta_J), \qquad \rho_J : X_J \to Y_J, \quad O_J : X_J \to \mathcal{O}_J, \quad \theta_J : X_J \to \{0,1\}.\end{aligned} \tag{MM.9a}$$

Its occurrence type is

$$\begin{aligned}\mathsf{Occ}_J := \{&(\mathfrak{I}_J; \Theta, x, \rho_J(x), \kappa, \boldsymbol{\varepsilon}, \theta_J(x)) :\\ &\Theta \in A_J,\ x \in X_J,\ \kappa \in K_J,\ \boldsymbol{\varepsilon} \in \mathbb{R}^3_{\geq 0}\}.\end{aligned} \tag{MM.9b}$$

An indexed occurrence $\mathsf{Occ}_{J,n}$ is an element of Occ_J.

For $J = \mathsf{MM}$, let

$$\mathrm{Ref}_{\mathrm{MM}} : \mathsf{Occ}_{\mathsf{MM}} \to \mathcal{R}_{\mathrm{MM}}, \qquad \Delta_{\mathrm{MM}} : \mathsf{Occ}_{\mathsf{MM}} \to \mathcal{D}_{\mathrm{MM}} \tag{MM.9c}$$

be the declared reference and difference fields. The memory–motion receipt is the projection

$$r_n := \mathrm{pr}_{\mathrm{MM}}(\mathsf{Occ}_{\mathsf{MM},n}) = (\mathrm{Ref}_{\mathrm{MM}}(\mathsf{Occ}_{\mathsf{MM},n}), \Delta_{\mathrm{MM}}(\mathsf{Occ}_{\mathsf{MM},n}), y_n, \Theta_n). \tag{MM.9d}$$

An ordered record is

$$R_{n+1} = \mathrm{snoc}(R_n, r_{n+1}). \tag{MM.10}$$

The record carries occurrence order while preserving every earlier occurrence at its own address.

Definition 3 (Reader-relative return)**.** For a transport T and reader ρ, a return at z is

$$\rho(Tz) = \rho(z). \tag{MM.11}$$

A carrier difference is separately tested by $Tz \neq z$ or by a declared difference map $\Delta(Tz, z)$.

The axial instance is

$$\rho = q_{\mathrm{ax}} \circ \xi_{\mathrm{lift}}, \qquad T = L_{\mathrm{ax}}, \tag{MM.12}$$

and satisfies both MM.11 and the nonzero lift condition in MM.7.

4. Relative phase and mirror transfer

Phase transport is

$$U_\alpha = e^{\alpha C},$$

with

$$U_{\alpha+\beta} = U_\alpha U_\beta, \qquad HU_\alpha H = U_{-\alpha}. \tag{MM.13}$$

For two addresses $a \preceq b$, their phase difference is

$$\Delta\alpha_{b,a} := \alpha(b) - \alpha(a) \quad \text{in } \mathbb{R}/2\pi\mathbb{Z}. \tag{MM.14}$$

The phase difference orders rotation between the two addresses. The axial lift and the phase circle therefore remain separately readable coordinates.

A mirror-covariant reader obeys

$$\rho(Hz) = \overline{H}_\rho(\rho(z)). \tag{MM.15}$$

When $\overline{H}_\rho$ is injective, equality and departure under ρ transfer exactly between a trajectory and its mirror. For the projective reader $\rho(z) = [z]$, the half-turn satisfies

$$U_\pi z = -z \neq z, \qquad [U_\pi z] = [z], \tag{MM.15a}$$

and gives an exact instance of reader-relative return.

5. Curvature and physical memory

For a connection A on a bundle, curvature is the two-form

$$F = dA + A \wedge A. \tag{MM.16}$$

A loop comparison requires a specified transport P_γ and reader ρ_γ. A reader-relative return takes the form

$$\rho_\gamma(P_\gamma x) = \rho_\gamma(x). \tag{MM.17}$$

The loop relation carries a state around a closed physical path and compares the returned read with its initial read.

A physical memory implementation likewise requires a material state space, update, readout, and record:

$$m_{n+1} = \mathcal{U}(m_n, u_n, d_n), \qquad y_n = \rho_m(m_n). \tag{MM.18}$$

The state update, input, disturbance, readout, and occurrence address give a material memory its physical form.