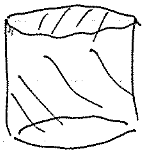
1.

Geometry of Entanglement and Emergent of Spacetime in AdS/CFT

$AdS_{d+1} \longleftrightarrow CFT_d$



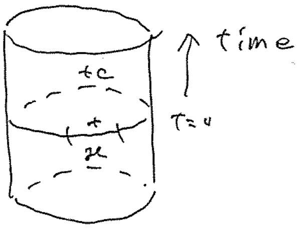
- gravity
- no gravity

gravity

AdS $\longleftrightarrow$ $|0\rangle$

BH $\longleftrightarrow$ $\frac{1}{Z} e^{-\beta H}$

CFT

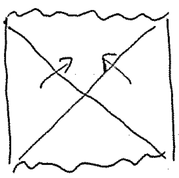


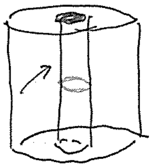
$$\mathcal{H} = \mathcal{H}_A \otimes \mathcal{H}_{A^c} \quad \text{envirorment} \Rightarrow |\psi\rangle$$

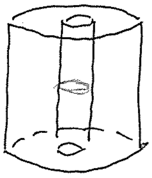
$$\mathcal{O} = \mathcal{O}_A \otimes 1$$

$$\langle\psi|\mathcal{O}|\psi\rangle = \mathrm{tr}\langle\psi|\mathcal{O}|\psi\rangle =$$

$$= \mathrm{tr}_A \underbrace{\mathrm{tr}_{A^c} |\psi\rangle\langle\psi|}_{\rho_A} \mathcal{O} = \mathrm{tr}_A \rho_A \mathcal{O}$$

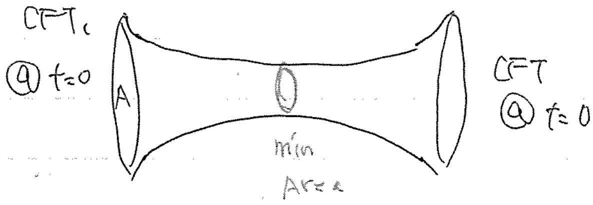






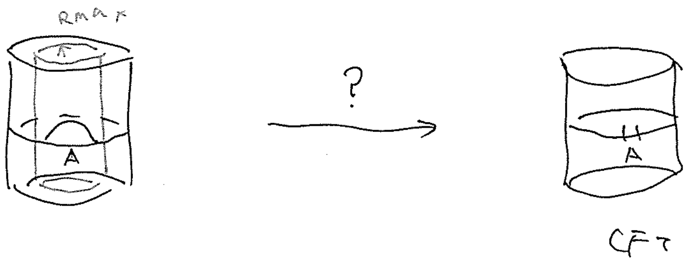
CFT CFT $\Rightarrow$

$$|\psi\rangle = |TFD\rangle = \frac{1}{Z^{\frac{1}{2}}} \sum_{n=1} e^{-\beta E_n/2} |E_n\rangle \otimes |E_n\rangle$$

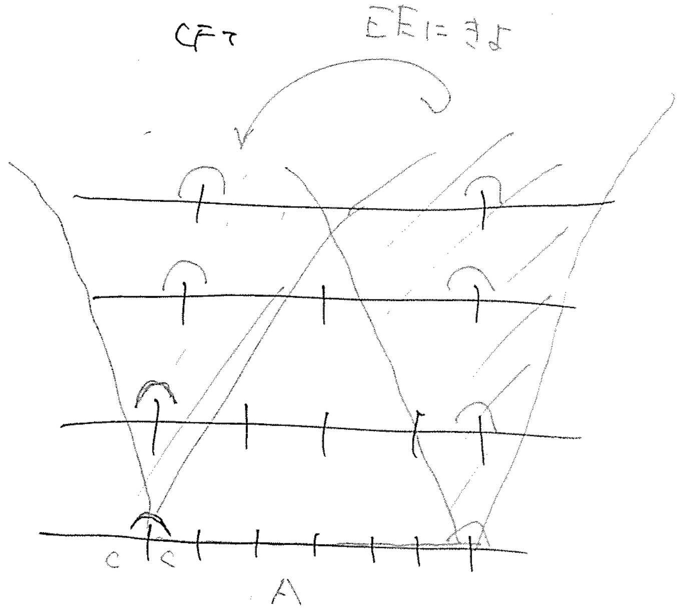


2.

2) ~~Digerg.~~ Divergence in R-T



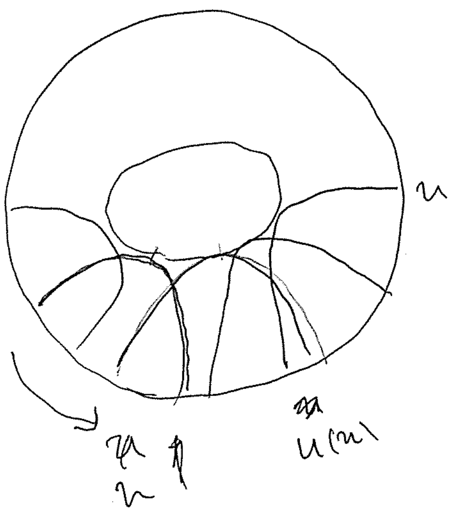
$$\frac{1}{4G}\left(\begin{matrix}\text{geodesic}\\ \text{length}\end{matrix}\right) = S(A)$$



R-T formula のどの部分が constant な part?

← CFT でいみある所
(奇数次元で)

$R_{max} = \dfrac{1}{\varepsilon_{uv}}$



$$S_{ent} = \int \frac{dS_{ent}}{d(\text{Scale})}\, d\text{Scale}$$

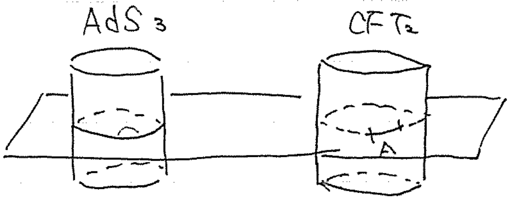
$$\text{length} = \int d\nu \left.\frac{dS_{ent}}{d\text{scale}}\right|_{\text{scale} = \text{scale}(}$$

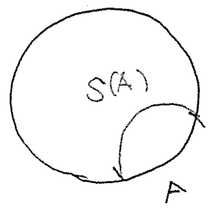
differential entropy

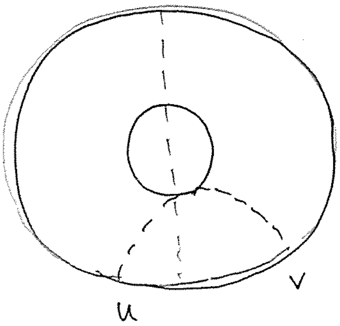
$$= \int d\nu \left.\frac{\partial S_{ent}(u\nu)}{\partial \nu}\right|_{u_* = u_*(\nu)}$$

2

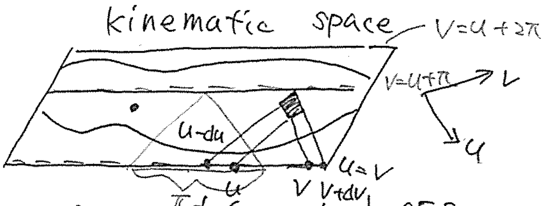
1.







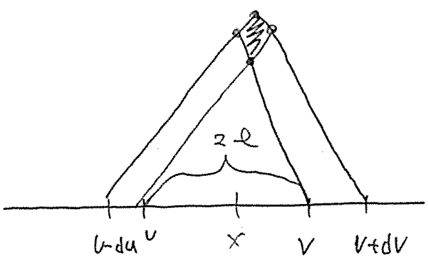
$$\frac{\text{Length}}{4G} = \int du\,dv\,\frac{\partial^2 S_{ent}(u,v)}{\partial u\,\partial v}$$



- space of interval of CFT

- space of geodesics of AdS

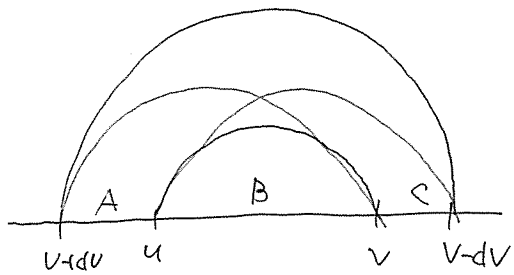
• dual $= \frac{\partial^2 S_{ent}}{\partial u\,\partial v}\,du\,dv$



k.s.

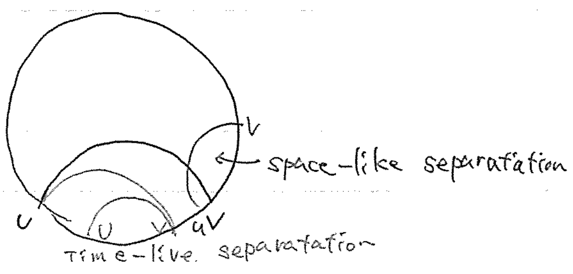
$l = \frac{v-u}{2}$

$x = \frac{u+v}{2}$



$$S(AB)+S(BC)-S(B)-S(ABC) \geq 0$$

$$= \boxed{I(A,C|B)}$$



Light-like separation? $u=U$, $v=V$

• Metric : $ds^2 = \frac{\partial^2 S_{ent}}{\partial u \partial v} du \otimes dv$

• Causal structure :

· dual ~ $\frac{\partial^2 S_{ent}}{\partial u \partial v} du\, dv \geq 0$

State in CFT

↓

$S_{ent}(u, v)$

↓

~~spa~~ metric of k.s.

↓

metric on space like slice of AdS

scales

tensor network

$|0\rangle$ no horizon at ± 0.lc.

↓

$S_{ent}(u,v) = \frac{c}{3} \log \left(\frac{u-v}{\mu} \right)$

↓

$ds_{k.s} = \frac{c}{3} \frac{du\, dv}{|u-v|^2} = \frac{-d\ell^2 + dx^2}{\ell^2}$ $\boxed{ds_-}$

↓

$ds^2(\mathbb{H}_2) \leftarrow SO(2,1)$

$d\rho^2 +$

$SO(2,2) = SO(2,1) \times SO(2,1)$

tensor networks

• u

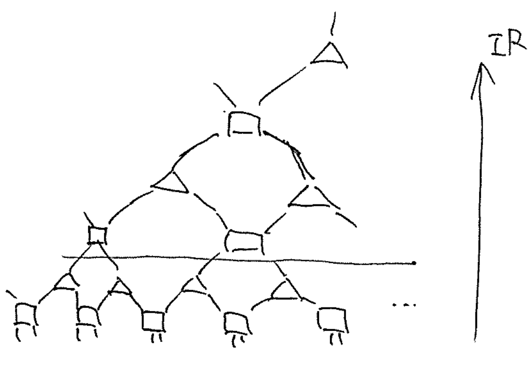
— u^μ $\mu = 1, \dots, \alpha$

α = Bond dimension

—— $u^\mu \delta_{\mu\nu} u^\nu$

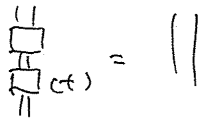
○ $u^{\mu\nu} \delta_{\mu\nu}$

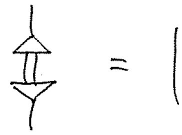
MERA:



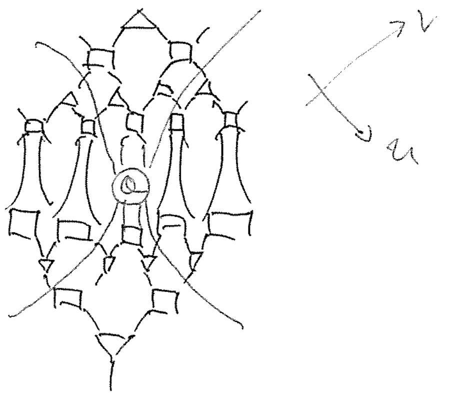
$W^{x_1 \otimes x_2 \otimes x_3} \phi_{x_1} \otimes \phi_{x_2} \otimes \phi_{x_3} \cdots$

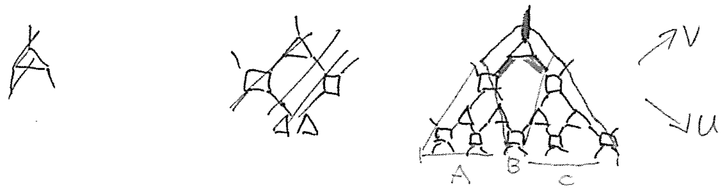
2

 unitary disentanglers – isolate UV entanglement 

 isometry – isolate UV dof's. 

Causality in MERA $\langle\psi|O|\psi\rangle$ ← MERA | Causal structure





MERA: causal sturacture – dvd = (# isometries) $du dv$

$$ds^2_{MERA} = (\#\,\text{isometry})\,(du)(dv)$$