Light-cone gauge string field theory and dimensional regularization

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Based on

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- JHEP 10 (2009) 035, arXiv:0906.3577
- JHEP 12 (2009) 010, arXiv:0909.4675
- JHEP 01 (2010) 119, arXiv:0911.3704
- JHEP 08 (2010) 102, arXiv:0912.4811

Nobuyuki Ishibashi, K.M.

- arXiv:1011.0112, JHEP in press

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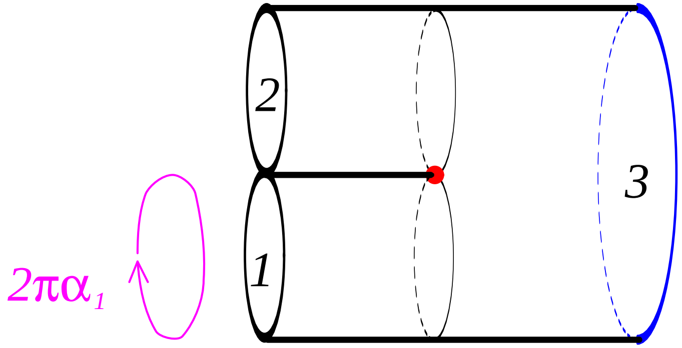
Light-cone gauge string field theory

$$S = \int dt \left[\frac{1}{2} \Phi \cdot \left(2p^+ i \frac{\partial}{\partial t} - \left(L_0^{\mathrm{LC}} + \tilde{L}_0^{\mathrm{LC}} - \frac{d-2}{8} \right) \right) \Phi + \frac{2g}{3} \Phi^3 \right]$$

$+$



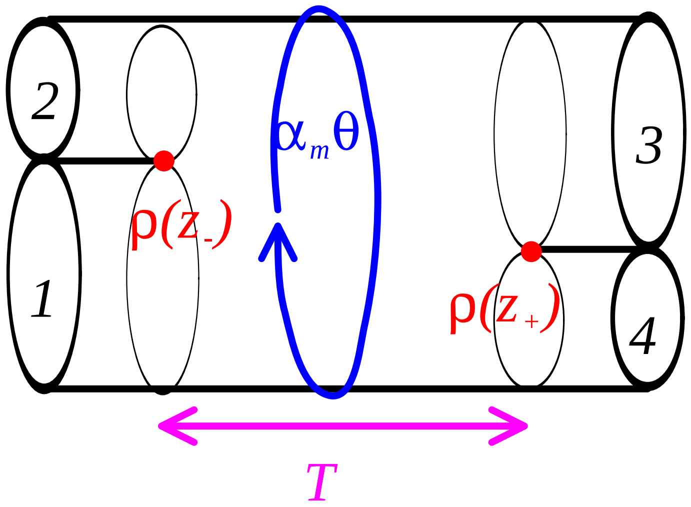
- $\alpha_r = 2p_r^+$: string-length parameter
- $\Phi \left[t, \alpha, X^i(\sigma); \psi^i(\sigma), \tilde{\psi}^i(\sigma) \right]$: string field
- $T_F^{\mathrm{LC}} \tilde{T}_F^{\mathrm{LC}}$ must be inserted at interaction point

  $\Leftarrow$ Lorentz invariance for $d = 10$ Mandelstam ('74), S.-J. Sin ('89) ...

Motivation: Divergences caused by colliding T_F^{LC}

e.g. 4pt amplitudes

$$\mathcal{A}_4 = \int d\mathcal{T} d\bar{\mathcal{T}}$$



- $\mathcal{T} = \rho(z_+) - \rho(z_-) = T + i\alpha_m\theta$
- At $\mathcal{T} = 0 \Leftrightarrow z_+ - z_- = 0$, unwanted divergence

$$T_F^{\mathrm{LC}}(z_+)T_F^{\mathrm{LC}}(z_-) \sim \frac{\frac{3}{2}(d-2)}{(z_+ - z_-)^3}$$

Some regularization is necessary even at tree level

Dimensional regularization in SFT?

- Scheme we propose

(1) Formulate LC gauge SFT in $d \neq 10$

(2) take d to be a large negative value

(3) analytic continuation $d \to 10$ in the end

Lorentz symmetry is failed for $d \neq 10$.

$\Leftarrow$ We are statisfied if Lorentz symmetry is recovered in the limit $d \to 10$ taken in the end.

What I would like to discuss in this talk:

Does dimensional regularization work in string field theory?

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$\Longrightarrow$ Yes.

(As far as we have investigated)

Question 1

Does our scheme actually regularize the divergences caused by the colliding supercurrents?

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- The amplitudes of the LC gauge SFT contains the contribution from the conformal anomaly (contribution from the Liouville factor of the worldsheet metric), $e^{-\frac{\hat{c}_{\mathrm{LC}}}{16}\Gamma}$ $(\hat{c}_{LC} = d-2)$ (Mandelstam ('86))

$$e^{-\frac{\hat{c}_{\mathrm{LC}}}{16}\Gamma} \sim \left|z_I - z_J\right|^{-\frac{\hat{c}_{\mathrm{LC}}}{8}} \qquad z_I\text{: interaction points}$$

$\Rightarrow$ This serves as a regularization factor for largely negative d

Question 2

Is dimensional regularization compatible with gauge symmetry of SFT?

We have carried out at the first quantized level

BRST invariant amplitudes of worldsheet theory in conformal gauge $(\hat{c} = 0)$

limit $d \to 10$ $\Longrightarrow$

usual results of first quantization

without adding contact terms as counter-terms

gauge fixing $\Downarrow \Uparrow \otimes$ $X^{\pm}$ CFT $(\hat{c} = 12 - d)$ $\otimes$ ghosts

amplitudes of LC gauge SFT for $d \neq 10$
$\equiv$ amplitudes of worldsheet CFT
$(\hat{c} = d - 2)$

Question 3

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- In the end, we take $d \to 10$ $\to$ this limit is smooth

  $\Rightarrow$ no need for contact interaction term as a counter-term

Question 4

What about the Ramond sector
in the conformal gauge formulation?

Immediate difficulty $\Rightarrow$ spin field

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What about the Ramond sector
in the conformal gauge formulation?

Immediate difficulty $\Rightarrow$ spin field

bosonization??? $\longleftarrow$ $X^{\pm}$ CFT is an interacting theory

- We have find
  the free field description for the system $X^{\pm}$ CFT $\otimes$ ghosts.

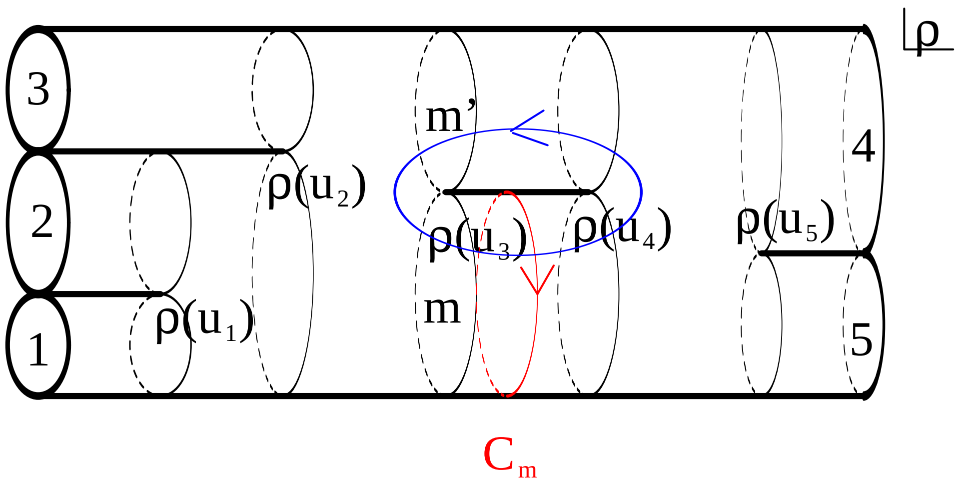
$$X^{+}, X^{-}; \psi^{+}, \psi^{-}; b, c; \beta, \gamma$$

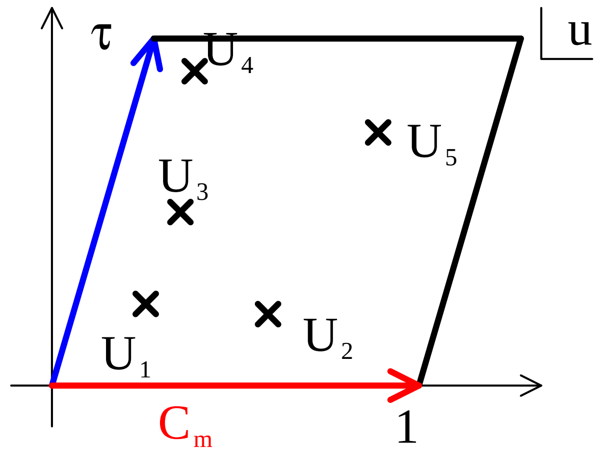
Question 5

What about one-loop amplitudes?

In particular

- modular invariance?
- BRST invariant form of amplitudes?





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- BRST invariant form of amplitudes?

We have verified in the LC gauge bosonic SFT for $d \neq 26$

- amplitudes are modular invariant
- can be recast into a BRST invariant from using $X^{\pm}$ CFT

Problem: (NS,R) and (R,NS) sectors ($\Longleftrightarrow$ spacetime fermions)

closed string theory $\Longrightarrow$ level matching condition

For (NS,R) sector in spacetime dimensions d $(\neq 10)$

$$\mathcal{N} = \tilde{\mathcal{N}} + \frac{d-2}{16}$$

no states satisfying this condition (also for (R,NS) sector)

$\Longrightarrow$ no spacetime fermion for generic d

▶ a solution (work in progress)

In dimensional regularization scheme, the shift of the transverse Virasoro central charge $\hat{c}_{\mathrm{LC}}$, rather than spacetime dimensions, is essential.

Instead of shifting d, we consider the CFT for the transverse sector

$$X^i, \psi^i, \tilde{\psi}^i \quad (i = 1, \ldots, 8) \quad \otimes \quad \text{CFT with large negative } \hat{c}$$

Thus,

Dimensional Regularization works well in SFT,

so far.

Outlook

- loop amplitudes of super SFT?

- What is the gauge invariant SFT corresponding to our CFT in the conformal gauge?

  $\Rightarrow \alpha = p^+$ HIKKO type theory?

- Is the dimensional regularization applicable to other super SFT's?

etc.