Covariant canonical formalism
for gravity coupled to p-forms

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based on D'Adda and LC, hep-th 1906.11852

Sir William Rowan Hamilton, 1805 - 1865

0. The logic
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3. Form-Poisson bracket (FPB)
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0. The logic

- usual field momenta

$$\pi(x) = \frac{\partial L}{\partial(\partial_0 \phi(x))}$$

with *0* - form fields and Lagrangian

- form field momenta

$$\pi(x) = \frac{\partial L}{\partial(d\phi(x))}$$

with *p* - form fields and *d* - form Lagrangian

D'Adda, Nelson, Regge, Annals Phys. 165, 384 (1985)

0. The logic

- usual field momenta

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(*d* - *p* -*1*) - form

with *p* - form fields and *d* - form Lagrangian

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1. Motivations

- Many (if not all) field theories relevant for physics can be seen as theories of form fields living in a space M of dimension *d*

- The action is an integral of a *d* - form Lagrangian so that physics does not depend on the choice of M coordinates

$$\longleftrightarrow$$

geometric theories

- The prototypical example is gravity:

$$S = \int_{M^4} R^{ab}(\omega) \wedge V^c \wedge V^d \epsilon_{abcd}$$

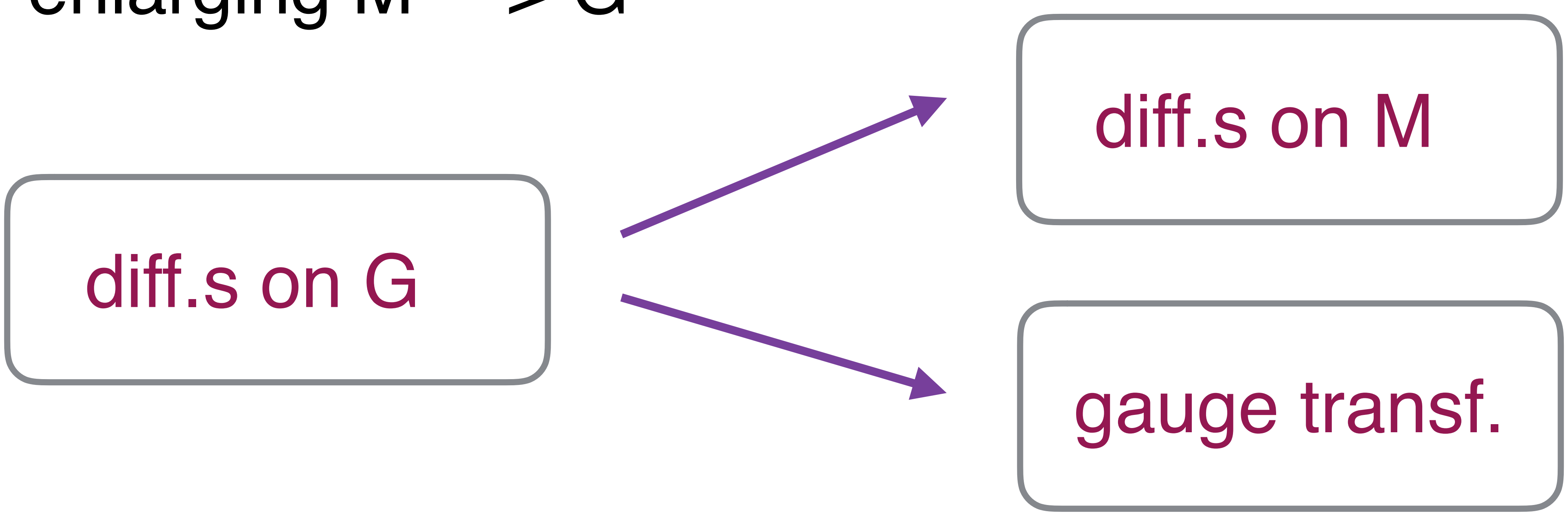
Invariances: diffeomorphisms + Lorentz gauge rotations

- Also YM gauge theories can be formulated in a coordinate independent way:

$$S = \int_{M^4} Tr(F \wedge \star F)$$

Invariances: diffeomorphisms + gauge transformations

- In fact we can go a step further and unify diffeomorphisms and gauge transformations by enlarging M —> G



- A framework where all symmetries are expressed as diffeomorphisms on a (super)group G:

  diff.s on M
  gauge transformations
  supersymmetry transformations

  and the dynamical fields are the components of the G vielbein

- Example: *d = 4* supergravity
  G= superPoincaré , fields: V^a, ω^{ab}, ψ

- Algorithmic procedure to build actions
  Torino group geometric approach:
  Regge, Ne'eman, D'Adda, D' Auria, Fré, LC, Ceresole …

- Recent review: LC, Fortsch.Phys. 66 (2018), arXiv:1802.03407

2. Geometric theories with p-form fields: covariant hamiltonian formalism

ϕ_i are p_i - forms

$$S = \int_{\mathcal{M}^d} L(\phi_i, d\phi_i)$$

- Variational principle

$$\delta S = \int_{\mathcal{M}^d} \delta\phi_i \frac{\vec{\partial} L}{\partial \phi_i} + d(\delta\phi_i) \frac{\vec{\partial} L}{\partial (d\phi_i)}$$

all products are exterior products

- Euler-Lagrange eq.s

$$d \frac{\vec{\partial} L}{\partial (d\phi_i)} - (-)^{p_i} \frac{\vec{\partial} L}{\partial \phi_i} = 0$$

2. Geometric theories with p-form fields: covariant hamiltonian formalism

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- Variational principle

$$\delta S = \int_{\mathcal{M}^d} \delta\phi_i \boxed{\frac{\vec{\partial} L}{\partial \phi_i}} + d(\delta\phi_i) \boxed{\frac{\vec{\partial} L}{\partial (d\phi_i)}}$$

all products are exterior products

form derivatives acting from the left

- Euler-Lagrange eq.s

$$d\frac{\vec{\partial} L}{\partial (d\phi_i)} - (-)^{p_i} \frac{\vec{\partial} L}{\partial \phi_i} = 0$$

Form Legendre transformation

- *(d - p$_i$ -1)* - form momenta

$$\pi^i \equiv \frac{\vec{\partial} L}{\partial(d\phi_i)}$$

- *d* - form Hamiltonian

$$\boxed{H = d\phi_i \; \pi^i - L = H(\phi_i, \pi^i)}$$

- Hamilton eq.s

$$d\phi_i = (-)^{(d+1)(p_i+1)} \frac{\vec{\partial} H}{\partial \pi^i} = \frac{\overleftarrow{\partial} H}{\partial \pi^i}$$

$$d\pi^i = (-)^{p_i+1} \frac{\vec{\partial} H}{\partial \phi_i} = -(-)^{p_i d} \frac{\overleftarrow{\partial} H}{\partial \phi_i}$$

3. Form-Poisson bracket (FPB)

- from the on-shell differential:

$$dF = d\phi_i \frac{\overrightarrow{\partial} F}{\partial \phi_i} + d\pi^i \frac{\overrightarrow{\partial} F}{\partial \pi^i} =$$

$$\frac{\overleftarrow{\partial} H}{\partial \pi^i} \frac{\overrightarrow{\partial} F}{\partial \phi_i} - (-)^{p_i d} \frac{\overleftarrow{\partial} H}{\partial \phi_i} \frac{\overrightarrow{\partial} F}{\partial \pi^i} \equiv \{F, H\}$$

- The FPB $\{A, B\}$ is a *(a + b - d + 1)* - form since

$$\phi \ \pi$$

is always a *(d -1)* - form. In particular

$$\{\phi_i, \pi^j\} = \delta_i^j$$

- Properties of the form-Poisson bracket

$$\{B,A\} = -(-)^{(a+d+1)(b+d+1)}\{A,B\}$$

(anti)symmetry

$$\{A,BC\} = B\{A,C\} + (-)^{c(a+d+1)}\{A,B\}C$$

$$\{AB,C\} = \{A,C\}B + (-)^{a(c+d+1)}A\{B,C\}$$

derivation

$$(-)^{(a+d+1)(c+d+1)}\{A,\{B,C\}\} + cyclic = 0$$

$$(-)^{(a+d+1)(b+d+1)}\{\{B,C\},A\} + cyclic = 0$$

Jacobi

4. Infinitesimal canonical transformations

- on any *a* - form *A* :

$$\delta A = \varepsilon \{A, G\}$$

where the generator *G* is a *(d - 1)* - form

Then $\{A, G\}$ is a *a* - form like *A*

- preserve commutation relations with FPB

- the commutator of two infinitesimal canonical transformations generated by G_1 and G_2 is again a canonical transformation, generated by

$$\{G_1, G_2\}$$

5. Action invariance and Noether theorem

- canonical global transformations

$$\delta\phi_i = \{\phi_i, G\}, \quad \delta\pi^i = \{\pi^i, G\}$$

$$S = \int_{\mathcal{M}^d} d\phi_i \; \pi^i - H$$

$$\delta S = \int_{\partial\mathcal{M}^d} (\{\phi_i, G\}\pi^i - G) - \int_{\mathcal{M}^d} \{H, G\}$$

$\Longrightarrow$ The action is invariant, up to bdy term, under the canonical form-transf. generated by G iff

$$\boxed{\{H, G\} = 0 \qquad \text{up to total der}}$$

- Noether charges

on shell (i.e. using Hamilton eq.s):

$$dG = \{G, H\}$$

thus if G generates a symmetry, on shell *dG=0*.
Then by Stokes theorem, on shell the integral

$$\boxed{\mathcal{G}(t) = \int_{\mathcal{S}} G}$$

with $\mathcal{S}$ (d-1)-dim slice of the manifold $\mathcal{M}^d$, and
fields with suitable bdy conditions “at the end of the slice” ,

is conserved in *t,* the coordinate parametrizing the slice foliation

- canonical local transformations

$$\delta\phi_i = \varepsilon(x)\{\phi_i, G\}, \quad \delta\pi^i = \varepsilon(x)\{\pi^i, G\}$$

generated by $\varepsilon(x)G$. The action varies as

$$\delta S = \int_{\partial\mathcal{M}^d} (\{\phi_i, G\}\pi^i - G) + \int_{\mathcal{M}^d} (d\varepsilon\, G - \varepsilon\{H, G\})$$

- Thus invariant (up to bdy terms) for arbitrary $\varepsilon(x)$ iff

$$\boxed{G = 0, \quad \{H, G\} = 0}$$

—> constraints (primary and secondary)

- moreover $\boxed{\{constraints, G\} \approx 0}$ i.e *G* is first-class

(constraint surface preserved by canonical transf.)

- canonical local transf. generated by $\varepsilon(x)G + (d\varepsilon)\ F$

$$\delta S = \int_{\partial\mathcal{M}^d} \varepsilon(\{\phi_i, G\}\pi^i - G) + d\varepsilon(\{\phi_i, F\}\pi^i - F)$$

$$+ \int_{\mathcal{M}^d} [d\varepsilon\ (G - \{H, F\}) - \varepsilon\{H, G\}]$$

are symmetries (for arbitrary $\varepsilon(x)$) iff

$$\boxed{G - \{H, F\} = 0, \quad \{H, G\} = 0}$$

LC,1982

- moreover $\boxed{\{constraints, G\} \approx 0, \quad \{constraints, F\} \approx 0}$

i.e. *G* and *F* must be first class, but not necessarily constraints

6. Gravity in d=3

- Lagrangian

$$L(\phi, d\phi) = R^{ab} V^c \varepsilon_{abc} = d\omega^{ab} V^c \varepsilon_{abc} - \omega^a{}_e \omega^{eb} \varepsilon_{abc}$$

- 1-form momenta

$$\pi_a = \frac{\partial L}{\partial (dV^a)} = 0 \qquad \pi_{ab} = \frac{\partial L}{\partial (d\omega^{ab})} = V^c \varepsilon_{abc}$$

both momenta definitions are primary constraints

$$\Phi_a \equiv \pi_a = 0, \quad \Phi_{ab} \equiv \pi_{ab} - V^c \varepsilon_{abc} = 0$$

since they do not involve the “velocities” $dV^a; \; d\omega^{ab}$

- Hamiltonian

$$H = dV^a\ \pi_a + d\omega^{ab}\ \pi_{ab} - d\omega^{ab}\ V^c\varepsilon_{abc} + \omega^a{}_e\ \omega^{eb}\ V^c\varepsilon_{abc} =$$

$$= dV^a\ \Phi_a + d\omega^{ab}\ \Phi_{ab} + \omega^a{}_e\ \omega^{eb}\ V^c\varepsilon_{abc}$$

- Hamilton eq.s

$$dV^a = \frac{\partial H}{\partial \pi_a} = dV^a$$

$$d\omega^{ab} = \frac{\partial H}{\partial \pi_{ab}} = d\omega^{ab}$$

$$d\pi_a = \frac{\partial H}{\partial V^a} = -2R^{bc}\epsilon_{abc}$$

$$d\pi_{ab} = \frac{\partial H}{\partial \omega^{ab}} = 2\omega^c{}_{[a}V^d\epsilon_{b]cd}$$

- Hamiltonian

$$H = dV^a\ \pi_a + d\omega^{ab}\ \pi_{ab} - d\omega^{ab}\ V^c \varepsilon_{abc} + \omega^a{}_e\ \omega^{eb}\ V^c \varepsilon_{abc} =$$

$$= dV^a \boxed{\Phi_a} + d\omega^{ab} \boxed{\Phi_{ab}} + \omega^a{}_e\ \omega^{eb}\ V^c \varepsilon_{abc}$$

primary constraints

- Hamilton eq.s

$$dV^a = \frac{\partial H}{\partial \pi_a} = dV^a$$

$$d\omega^{ab} = \frac{\partial H}{\partial \pi_{ab}} = d\omega^{ab}$$

$$d\pi_a = \frac{\partial H}{\partial V^a} = -2R^{bc}\epsilon_{abc}$$

$$d\pi_{ab} = \frac{\partial H}{\partial \omega^{ab}} = 2\omega^c{}_{[a} V^d \epsilon_{b]cd}$$

- Hamiltonian

$$H = dV^a\ \pi_a + d\omega^{ab}\ \pi_{ab} - d\omega^{ab}\ V^c \varepsilon_{abc} + \omega^a{}_e\ \omega^{eb}\ V^c \varepsilon_{abc} =$$

$$= dV^a \boxed{\Phi_a} + d\omega^{ab} \boxed{\Phi_{ab}} + \omega^a{}_e\ \omega^{eb}\ V^c \varepsilon_{abc}$$

primary constraints

- Hamilton eq.s

$$\left.\begin{aligned} dV^a &= \frac{\partial H}{\partial \pi_a} = dV^a \\ d\omega^{ab} &= \frac{\partial H}{\partial \pi_{ab}} = d\omega^{ab} \end{aligned}\right\} \text{undetermined at this stage}$$

$$d\pi_a = \frac{\partial H}{\partial V^a} = -2R^{bc}\epsilon_{abc}$$

$$d\pi_{ab} = \frac{\partial H}{\partial \omega^{ab}} = 2\omega^c{}_{[a} V^d \epsilon_{b]cd}$$

- compatibility of d with constraints ("conservation")

$$d\Phi_a = \{\Phi_a, H\} = 0 \quad \Rightarrow \quad R^{bc}\varepsilon_{abc} = 0$$

$$d\Phi_{ab} = \{\Phi_{ab}, H\} = 0 \quad \Rightarrow \quad R^{c}\varepsilon_{abc} = 0$$

implying vanishing of Lorentz curvature and torsion
—> field eq.s of d=3 gravity <—

- these eq.s completely determine the "velocities"

$$dV^a = \omega^a{}_b \, V^b, \quad d\omega^a{}_b = \omega^a{}_c \, \omega^{cb}$$

- constraint algebra

$$\{\Phi_a, \Phi_b\} = \{\Phi_{ab}, \Phi_{cd}\} = 0; \quad \{\Phi_a, \Phi_{bc}\} = -\varepsilon_{abc}$$

Thus constraints are second-class, and this is consistent with all the ``velocities” getting fixed by requiring “conservation” of the primary constraints.

- equivalently, setting $\Xi^a = \frac{1}{2}\epsilon^{abc}\Phi_{bc}$

$$\{\Phi_a, \Xi^b\} = \delta_a^b$$

all other FPB vanishing. Thus the constraints become conjugate variables

- form Dirac brackets

$$\{f,g\}^* \equiv \{f,g\} - \{f,\Phi_a\}\{\Xi^a,g\} - \{f,\Xi^a\}\{\Phi_a,g\}$$

inherit same properties of FPB

- Using Dirac brackets the second-class constraints (i.e. all the constraints of the $d = 3$ theory) disappear from the game:

$$\{any,\Phi_a\}^* = \{any,\Xi^a\}^* = 0$$

- and we can use the 3-form Hamiltonian

$$\boxed{H = \omega^a{}_e\, \omega^{eb}\, V^c \varepsilon_{abc}}$$

- Dirac brackets between basic fields (and momenta)

$$\{V^a, V^b\}^* = 0, \quad \{\omega^{ab}, \omega^{cd}\}^* = 0, \quad \{V^a, \omega^{bc}\}^* = -\frac{1}{2}\epsilon^{abc}$$

$$\{any, \pi_a\}^* = 0, \quad \{V^a, \pi_{bc}\}^* = 0, \quad \{\omega^{ab}, \pi_{cd}\}^* = \delta^{ab}_{cd}$$

- Hamilton eq.s with Dirac brackets

$$dV^a = \{V^a, H\}^* = \{V^a, \omega^d{}_e\ \omega^{eb}\ V^c \varepsilon_{bcd}\}^* = \omega^a{}_b V^b \quad \Rightarrow \boxed{R^a = 0}$$

$$d\omega^{ab} = \{\omega^{ab}, H\}^* = \{\omega^{ab}, \omega^d{}_e\ \omega^{ef}\ V^c \varepsilon_{fcd}\}^* = \omega_e{}^{[a} \omega^{b]}{}_e \quad \Rightarrow \boxed{R^{ab} = 0}$$

$$d\pi_a = \{\pi_a, H\}^* = 0$$

$$d\pi_{ab} = \{\pi_{ab}, H\}^* = 2\omega^c{}_{[a} V^d \epsilon_{b]cd} = \epsilon_{abc}\omega^c{}_d V^d \quad \Rightarrow d\Phi_{ab} = 0$$

Gauge generators

$$\mathbb{G} = (d\varepsilon)F + \varepsilon(x)G$$

- Lorentz rotations

$$\boxed{\mathbb{G} = d\epsilon^{ab}F_{ab} + \epsilon^{ab}G_{ab} = d\epsilon^{ab}\pi_{ab} + 2\epsilon^{ab}\omega^{c}{}_{[a}V^{d}\epsilon_{b]cd} = (\mathcal{D}\varepsilon^{ab})\pi_{ab}}$$

$$\delta V^a = \{V^a, \mathbb{G}\}^* = 2\{\omega^{[b}{}_{d}, V^a\}^*\epsilon^{c]d}\pi_{bc} = \epsilon^{a}{}_{b}V^b$$
$$\delta\omega^{ab} = \{\omega^{ab}, \mathbb{G}\}^* = \mathcal{D}\varepsilon^{ab}$$

$$\delta\pi_a = \{\pi_a, \mathbb{G}\}^* = 0$$
$$\delta\pi_{ab} = \{\pi_{ab}, \mathbb{G}\}^* = \{\epsilon_{abc}V^c, \mathbb{G}\}^* = \varepsilon^{c}{}_{[a}\pi_{b]c}$$

- diffeomorphisms

$$\boxed{\mathbb{G} = d\varepsilon^a F_a + \varepsilon^a G_a = (d\varepsilon^a)\epsilon_{abc}\omega^{bc} + \varepsilon^a \epsilon_{abc}\ \omega^b{}_d \omega^{dc} = \mathcal{D}\varepsilon^a \varepsilon_{abc}\omega^{bc}}$$

$$\delta V^a = \{V^a, \mathbb{G}\}^* = \mathcal{D}\varepsilon^a$$

$$\delta\omega^{ab} = \{\omega^{ab}, \mathbb{G}\}^* = 0$$

$$\delta\pi_a = \{\pi_a, \mathbb{G}\}^* = 0$$

$$\delta\pi_{ab} = \{\pi_{ab}, \mathbb{G}\}^* = \{\epsilon_{abc}V^c, \mathbb{G}\}^* = \epsilon_{abc}\mathcal{D}\varepsilon^c$$

7. Gravity in d=4

- Lagrangian

$$L(\phi, d\phi) = R^{ab} V^c V^d \varepsilon_{abcd} = d\omega^{ab} V^c V^d \varepsilon_{abcd} - \omega^a{}_e \omega^{eb} V^c V^d \varepsilon_{abcd}$$

- 2 - form momenta

$$\pi_a = \frac{\partial L}{\partial(dV^a)} = 0$$

$$\pi_{ab} = \frac{\partial L}{\partial(d\omega^{ab})} = V^c V^d \varepsilon_{abcd}$$

both momenta definitions are primary constraints

$$\Phi_a \equiv \pi_a = 0, \quad \Phi_{ab} \equiv \pi_{ab} - V^c V^d \varepsilon_{abcd} = 0$$

- Hamiltonian

$$H = dV^a \; \pi_a + d\omega^{ab} \; \pi_{ab} - d\omega^{ab} \; V^c V^d \varepsilon_{abcd} + \omega^a{}_e \; \omega^{eb} \; V^c V^d \varepsilon_{abcd} =$$

$$= dV^a \; \Phi_a + d\omega^{ab} \; \Phi_{ab} + \omega^a{}_e \; \omega^{eb} \; V^c V^d \varepsilon_{abcd}$$

- Hamilton eq.s

$$d\pi_a = \frac{\partial H}{\partial V^a} = -2R^{bc} V^d \epsilon_{abcd}$$

$$d\pi_{ab} = \frac{\partial H}{\partial \omega^{ab}} = 2\omega^c{}_{[a} V^d V^e \epsilon_{b]cde}$$

velocities dV^a and $d\omega^{ab}$ undetermined at this stage

- compatibility of d with constraints (“conservation”)

$$d\Phi_a = \{\Phi_a, H\} = 0 \quad \Rightarrow \quad R^{bc}\, V^d \varepsilon_{abcd} = 0$$ Einstein eq.s

$$d\Phi_{ab} = \{\Phi_{ab}, H\} = 0 \quad \Rightarrow \quad R^c\, V^d \varepsilon_{abcd} = 0$$ zero torsion

- these eq.s partially determine the “velocities”

$$dV^a = \omega^a{}_b\, V^b$$

$d\omega^{ab}$ constrained by Einstein eq.s

- constraint algebra

$$\{\Phi_a, \Phi_b\} = \{\Phi_{ab}, \Phi_{cd}\} = 0; \quad \{\Phi_a, \Phi_{bc}\} = -2\varepsilon_{abcd}V^d$$

Thus constraints are not all first-class, and this is consistent with some ``velocities” getting fixed by requiring “conservation” of the primary constraints.

- Dirac brackets ?

Difficulty in inverting $\{\Phi_a, \Phi_{bc}\}$. Then use FPB

Gauge generators

$$\mathbb{G} = (d\varepsilon)F + \varepsilon(x)G$$

- Lorentz rotations

$$\boxed{\mathbb{G} = \varepsilon^{ab}G_{ab} + d\varepsilon^{ab}F_{ab} = \varepsilon^{ab}(2\omega^c{}_a\pi_{bc} - V_a\pi_b) + (d\varepsilon^{ab})\pi_{ab} = \mathcal{D}\varepsilon^{ab}\pi_{ab} - \varepsilon^{ab}V_a\pi_b}$$

$$\delta V^a = \{V^a, \mathbb{G}\} = \varepsilon^a{}_b V^b, \quad \delta\omega^{ab} = \{\omega^{ab}, \mathbb{G}\} = \mathcal{D}\varepsilon^{ab}$$

$$\delta\pi_a = \{\pi_a, \mathbb{G}\} = \varepsilon_a{}^b\pi_b, \qquad \delta\pi_{ab} = \varepsilon^c{}_{[a}\pi_{b]c}$$

- diffeomorphisms

$$\delta A = \ell_\varepsilon A \equiv (\iota_\varepsilon d + d\iota_\varepsilon) A$$

$$\delta V^a = \mathcal{D}\varepsilon^a + 2R^a{}_{bc}\;\varepsilon^b V^c$$
$$\delta\omega^{ab} = 2R^{ab}{}_{cd}\;\varepsilon^c V^d$$

$$\delta\pi_a = \iota_\varepsilon(\mathcal{D}\pi_a) + \mathcal{D}(\iota_\varepsilon \pi_a)$$
$$\delta\pi_{ab} = \iota_\varepsilon(\mathcal{D}\pi_{ab}) + \mathcal{D}(\iota_\varepsilon \pi_{ab})$$

up to a Lorentz transformation with parameter $\eta^{ab} = \varepsilon^\mu \omega^{ab}_\mu$

8. Doubly covariant hamiltonian formalism

take curvatures as "velocities"

- example: d=4

$$\pi_a = \frac{\partial L}{\partial R^a} = 0$$

$$\pi_{ab} = \frac{\partial L}{\partial R^{ab}} = V^c V^d \varepsilon_{abcd}$$

same primary constraints

$$\Phi_a \equiv \pi_a = 0, \quad \Phi_{ab} \equiv \pi_{ab} - V^c V^d \varepsilon_{abcd} = 0$$

- Hamiltonian

$$H = R^a \; \pi_a + R^{ab} \; \pi_{ab} - R^{ab} V^c V^d \varepsilon_{abcd} = R^a \; \pi_a + R^{ab} \; \Phi_{ab}$$

- Hamilton eq.s

$$R^a = \{V^a, H\} = R^a$$

$$R^{ab} = \{\omega^{ab}, H\} = R^{ab}$$

$$\mathcal{D}\pi_a = \{\pi_a, H\} = -2R^{bc}V^d\epsilon_{abcd}$$

$$\mathcal{D}\pi_{ab} = \{\pi_{ab}, H\} = 0$$

- conservation of primary constraints

$$\mathcal{D}\Phi_a = \{\Phi_a, H\} = 0 \quad \Rightarrow \quad R^{ab}\, V^d\varepsilon_{abcd} = 0$$

$$\mathcal{D}\Phi_{ab} = \{\Phi_{ab}, H\} = 0 \quad \Rightarrow \quad R^c\, V^d\varepsilon_{abcd} = 0$$

field eq.s of d=4 vierbein gravity

9. Conclusions and outlook

- extend Hamilton to form-fields
- covariant : no time direction is selected
- well adapted to geometric theories with p-forms
- constraint analysis (à la Dirac) much simpler:

  Compare with canonical analysis of d=4 vielbein gravity in components, P. van Nieuwenhuizen, M. Pilati, LC, Phys. Rev. D 26, 352 (1982)
- in progress: application to supergravities

Bibliography

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multimomenta and multisymplectic

De Donder 1935, Weyl, 1935, ….

Constructive algorithm for all gauge generators in theories with local invariances

LC, 1982

Constrained hamiltonian systems

Dirac, Yeshiva Lectures 1964

Hanson, Regge , Teitelboim, Accad. Lincei, 1976

Henneaux and Teitelboim, 1992

Thank you !

- canonical generator for diffeomorphisms ?

$$\mathbb{G} = \varepsilon^a (2R^b{}_{ac} V^c \pi_a + 2R^{bc}{}_{ad} V^d \pi_{bc}) + (\mathcal{D}\varepsilon^a)\pi_a$$

generates correct infinitesimal diff.s on vielbein and spin connection, but NOT on momenta

AND does not satisfy conditions for being a gauge generator, since π_a is not first class