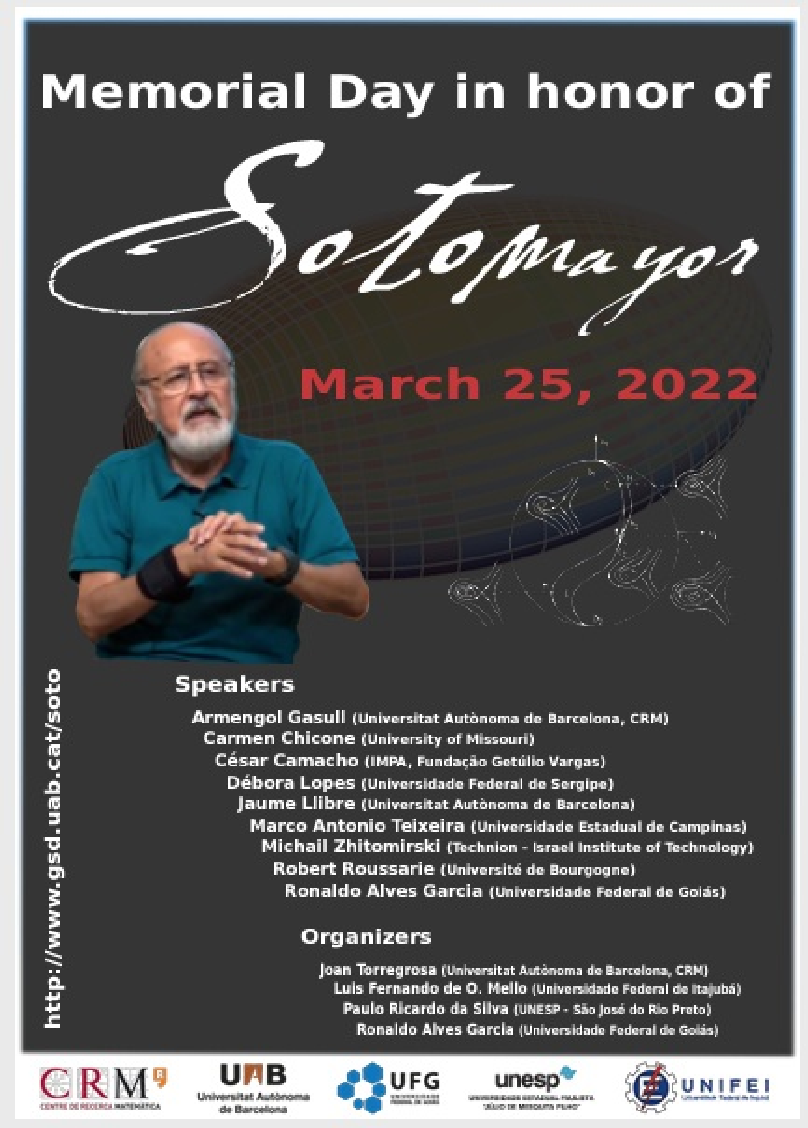
Memorial Day (25/03/2022)

Memórias sobre as contribuições de Jorge Sotomayor na teoria geométrica das bifurcações de edó's e na teoria qualitativa das edó's da geometria diferencial

Ronaldo Garcia / IME-UFG


Memorial Day in honor of
Sotomayor
March 25, 2022
Speakers
Armengol Gasull (Universitat Autònoma de Barcelona, CRM)
Carmen Chicone (University of Missouri)
César Camacho (IMPA, Fundação Getúlio Vargas)
Débora Lopes (Universidade Federal de Sergipe)
Jaume Llibre (Universitat Autònoma de Barcelona)
Marco Antonio Teixeira (Universidade Estadual de Campinas)
Michail Zhitomirski (Technion - Israel Institute of Technology)
Robert Roussarie (Université de Bourgogne)
Ronaldo Alves Garcia (Universidade Federal de Goiás)
Organizers
Joan Torregrosa (Universitat Autònoma de Barcelona, CRM)
Luis Fernando de O. Mello (Universidade Federal de Itajubá)
Paulo Ricardo da Silva (UNESP - São José do Rio Preto)
Ronaldo Alves Garcia (Universidade Federal de Goiás)
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Tese de doutorado

- Estabilidade estrutural de primeira ordem e variedades de Banach

Linhas de Curvatura

- Configuração principal, estabilidade principal, pontos umbílicos

Linha do tempo

- Encontro da teoria qualitativa das edo's e de curvas especiais em superfícies

Tese de doutorado

- Estabilidade estrutural de primeira ordem e variedades de Banach

Defendida no IMPA em 1964 aos 22 anos de idade sob orientação de Maurício Peixoto (1921-2019)

Teorema de Peixoto

Considere o conjunto de campos de vetores de classe C^r numa superfície compacta M^2.

$$\mathfrak{X}^r(M^2) = \{ X : M \xrightarrow{C^r} TM \}$$

campo de vetores

$$|X|_r = \sup_{p \in M} \{ |X(p)|, |DX(p)|, \dots |D^r X(p)| \}$$

Fato: $\left(\mathfrak{X}^r(M^2), |\,|_r \right)$ é um espaço vetorial completo de dimensão infinita.

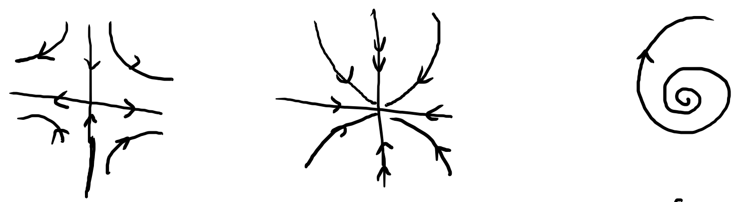
Seja Σ^r a classe de campos de vetores de $\mathfrak{X}^r(M^2)$ satisfazendo:

a) todos os pontos singulares de X são hiperbólicos.

b) todas as órbitas periódicas de X são hiperbólicas

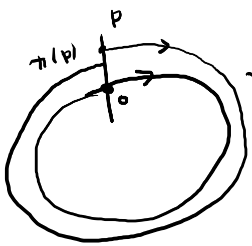
c) não existe conexões de separatrizes de selos.

d) o conjunto limite (ω e α) de todo ponto é um ponto singular ou órbita periódica, i.e, não existe recorrências não triviais a)



Sela   nó   foco

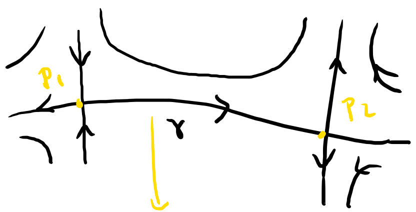
b)



$|\pi'(0)| \neq 1$

π – transformação de 1º retorno (ou de Poincaré)

c)

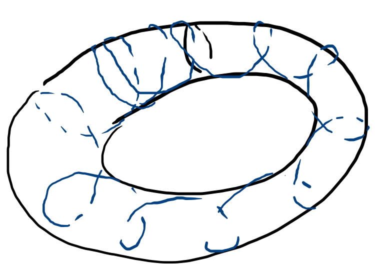


conexão de selas

$\alpha(\gamma) = \{p_1\}$

$\omega(\gamma) = \{p_2\}$

d) recorrência não trivial



→ órbitas são hélices toroidais com $\alpha(\gamma) = \omega(\gamma) = T^2$

- Analisar recorrências não triviais no toro de campos sem singularidades passa pelo estudo de difeos no círculo.

- Analisar recorrências não triviais em campos com singularidades passa pelo estudo de intercâmbio de intervalos (IET's)

Teorema (Peixoto). Suponha M orientada

a) $\Sigma^r \subset \mathfrak{X}^r(M^2)$ é aberto e denso, para todo $r \geq 1$.

b) $X \in \mathfrak{X}^r(M^2)$ é estruturalmente estável $\iff$ $X \in \Sigma^r$

obs: Qdo M é não orientada o teorema vale para $r = 1$.

obs: Para uma apresentação didática sugerimos: Palis - Melo (cap IV)
Introdução aos Sistemas Dinâmicos
Projeto Euclides, IMPA, (1977)

Contexto da tese de Jorge Sotomayor

- Responder a um problema formulado por Maurício Peixoto no Seminário realizado no IMPA (1962)

- Veja o artigos de Jorge Sotomayor
  - Uma lista de problemas de edo's Revista de Matemática e Estatística da UNESP, (2000), vol. 18, pp. 223-245.
  - São Paulo Math. Journal of Sciences (2019) vol 13 pp. 177-194.

COMISSÃO DE POS-GRADUAÇÃO DA UNIVERSIDADE DO BRASIL

INSTITUTO DE MATEMÁTICA PURA E APLICADA

JORGE SOTOMAYOR

ESTABILIDADE ESTRUTURAL DE PRIMEIRA ORDEM
E
VARIEDADES DE BANACH

TESE DE DOUTORAMENTO

RIO - 1964

PREFÁCIO

O presente trabalho estende às variedades diferenciáveis compactas e orientáveis de dimensão dois, os resultados de A. Andronov e E. Leontovich sôbre estabilidade estrutural de primeira ordem dos campos de vetores definidos num disco plano; e estabelece a estrutura de variedade diferenciável de Banach do conjunto de campos estruturalmente estáveis de primeira ordem.

Agradeço ao professor Mauricio Peixoto, por ter me sugerido o problema e acompanhado com seu constante conselho e alento o seu desenvolvimento; os seus artigos [2,3] foram o ponto de partida da presente investigação.

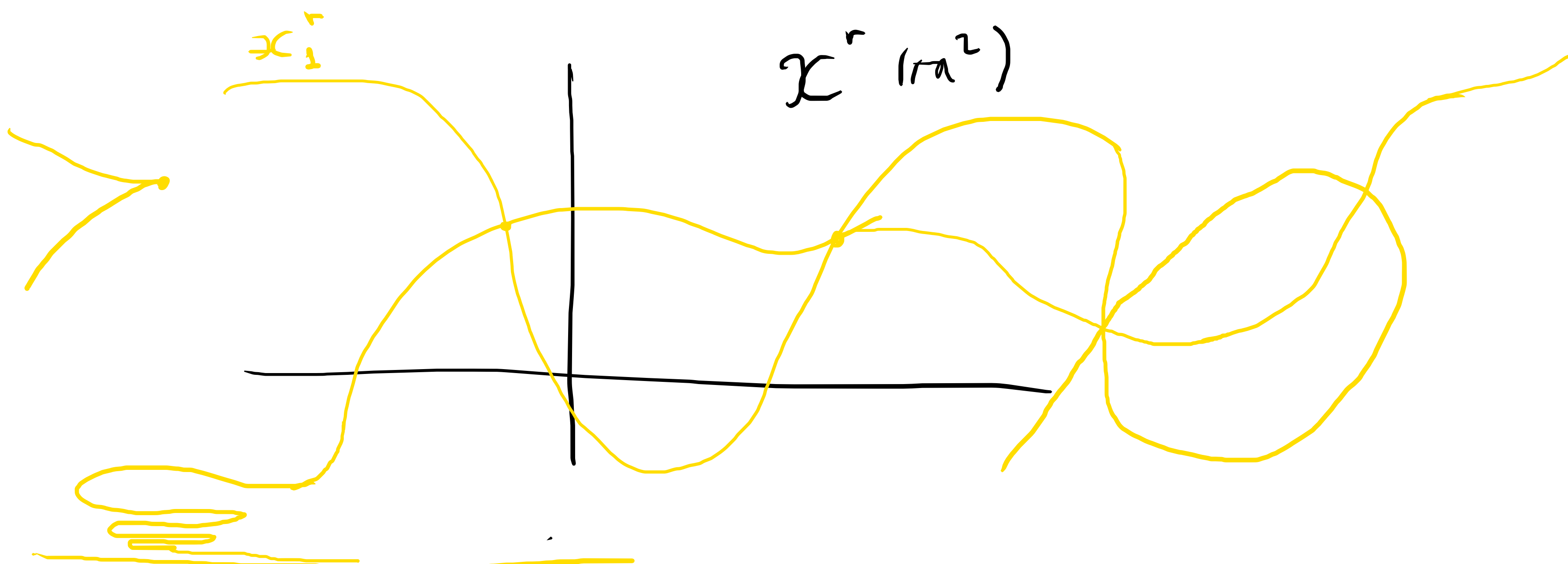
Desejo agradecer também aos colegas do IMPA professor I. Kupka, A. Augusto, M.L. Peixoto e A.C. Barreto pela troca de idéias sôbre temas relacionados com o aqui tratado, o que teve influência positiva na presente tese.

Êste trabalho contou com a ajuda parcial do Office Scientific Research U.S.A.F.

Jorge Sotomayor

$\mathcal{X}_1^r = \mathcal{X}^r \setminus \Sigma^r$ (complemento dos campos estruturalmente estáveis)

Consider the complement $\mathcal{X}_1^r$ of the set Σ^r of C^r-structurally stable vector fields, relative to the set $\mathcal{X}^r$ of all vector fields on a compact two-dimensional manifold. Let $\mathcal{X}_1^r$ be endowed with the induced C^r topology. Characterize the set Σ_1^r of those vector fields that are structurally stable with respect to arbitrarily small perturbations inside $\mathcal{X}_1^r$.



Jorge Sotomayor

This problem goes back to a 1938 research announcement of Andronov and Leontovich [3,4]. They formulated a characterization of Σ_1^r for a compact region in the plane. This step points toward a systematic study of the bifurcations (qualitative changes) that occur in families of vector fields as they cross $\mathcal{X}_1^r$. In the research announcement—contained in a dense four pages note—they stated that the most stable bifurcations occur in Σ_1^r [44,47].

Conceituação de estabilidade estrutural relativa à $\mathfrak{X}_1^r(\mathbb{R}^2) = \mathfrak{X}_1^r$

In the written composition of my doctoral thesis (DT) was deposited most of what I had learned during 1962–1963:
The Calculus in Banach spaces and manifolds,
The invariant manifolds *a la* Coddington-Levinson,
The Structural Stability papers of Peixoto,
The personal digest I had scribbled on the understanding of Andronov–Leontovich (AL) announcement note [4].

Keeping in mind the analogy with the previous works of Andronov and Pontrjagin, as improved by Peixoto, the note of AL, [3], can be outlined as consisting of:

1. An axiomatic definition for the class Σ_1^r as the part of $\mathcal{X}_1^r = \mathcal{X}^r \setminus \Sigma^r$ that violate minimally the conditions of Andronov–Pontrjagin and Peixoto that define Σ^r.
2. A definition of the class $\mathcal{S}_1^r$ of the systems in $\mathcal{X}_1^r$ that are structurally stable under small perturbations inside $\mathcal{X}_1^r$.
3. The statement identifying Σ_1^r with $\mathcal{S}_1^r$.

I transliterated the terminology for the systems in [3] as being “first order structurally stable”. However Russian translators use the name : “first order structurally unstable”. In fact, they are the “most stable among the unstable ones”. See Andronov–Leontovich

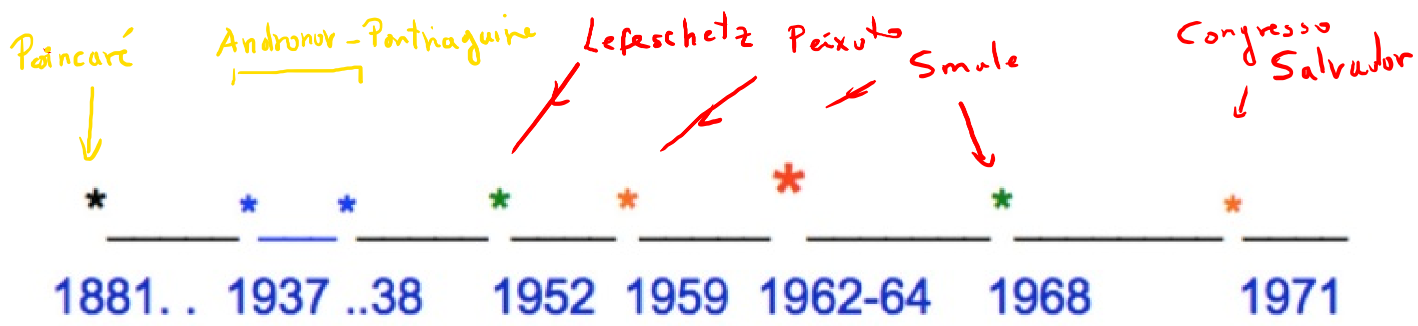


Fig. 4 Timeline with colored landmarks, weighted by the size of stars, for the beginning of Dynamical Systems interest in Brazil, with organizing center on the years 1962–1964. Brazil (red): Peixoto's works, Seminar and Symposium [34]; France (black): Poincaré QTDE; Russia (blue): The Gorkii School Landmark; USA (green): Lefschetz, 1949-52, and Smale, Visit to IMPA, 1961, Seminar in Berkeley: 1966-67, and his landmark papers Differentiable Dynamical System, 1967, and What is Global Analysis?, 1969 (Color figure online)

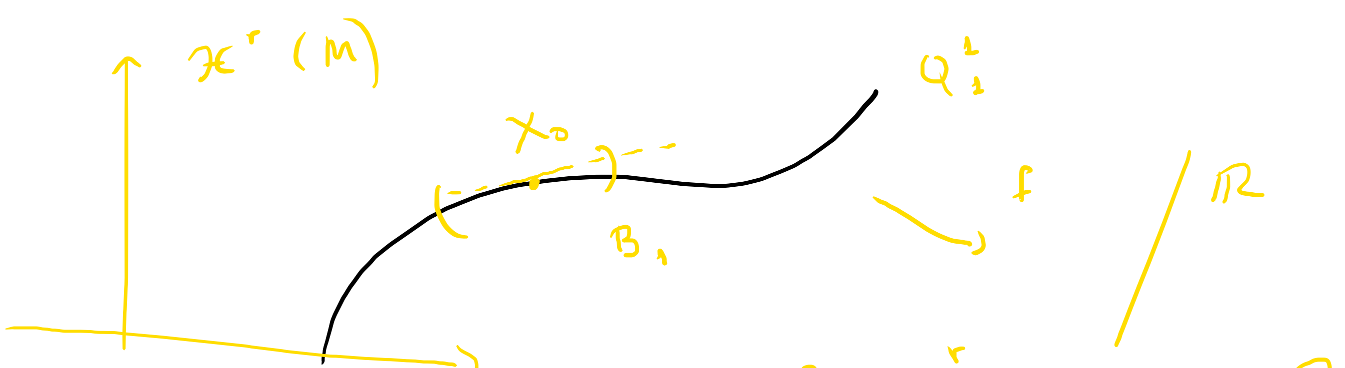
Sela-nó

Proposition **(3.5)**. — *Denote by* Q_1^1 *the collection of* $X \in \mathfrak{X}^r$, $r \geq 2$, *such that:*

1) X *has a saddle-node as unique non-generic singular point.*
2) X *has only generic periodic trajectories.*
3) *The* α *and* ω*-limit sets of any trajectory of* X *are singular points or periodic trajectories.*
4) X *has no saddle connections.*

Then:

a) Q_1^1 *is open in* $\mathfrak{X}_1^r$.
b) *It is an imbedded Banach submanifold of class* C^{r-1} *and codimension one of* $\mathfrak{X}^r$; *and*
c) *Every* $X \in Q_1^1$ *has a neighborhood* B_1 *in* Q_1^1 *such that every* $Y \in B_1$ *is topologically equivalent to* X.



$f : \mathfrak{X}^r(M) \longrightarrow \mathbb{R}$

$X \longmapsto f(X)$

0 é valor regular de f

Lemma **(3.2)**. — *Let p be a saddle-node of* $X \in \mathfrak{X}^r$, $r \geq 2$. *Then there is a neighborhood* B *of* X, *a neighborhood* N *of* p, *and a* C^{r-1} *function* $f: B \to \mathbf{R}$ *such that:*

1) $Y \in B$ *has a saddle-node as unique singular point in* N *if and only if* $f(Y)=0$; *if* $f(Y)<0$, Y *has two singular points, both generic, one saddle and one node, in* N; *if* $f(Y)>0$, Y *has no singular point in* N. *See* Fig. (3.1).

2) $f(X)=0$ *and* $df_X \neq 0$.

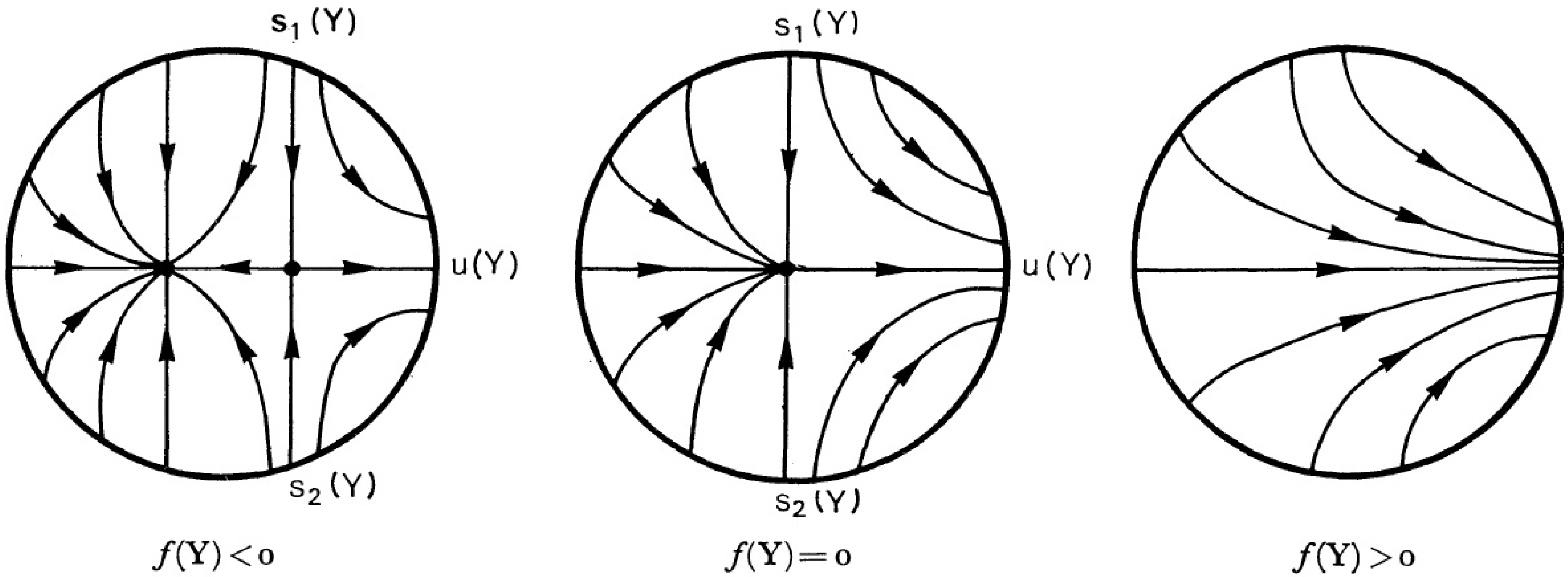
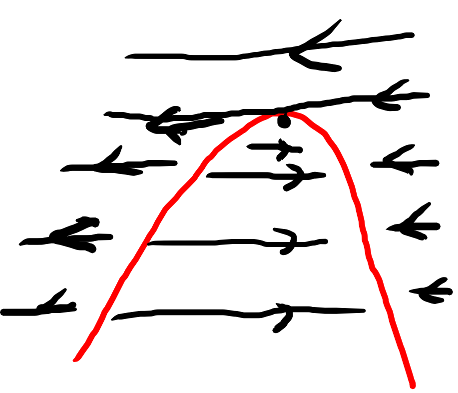
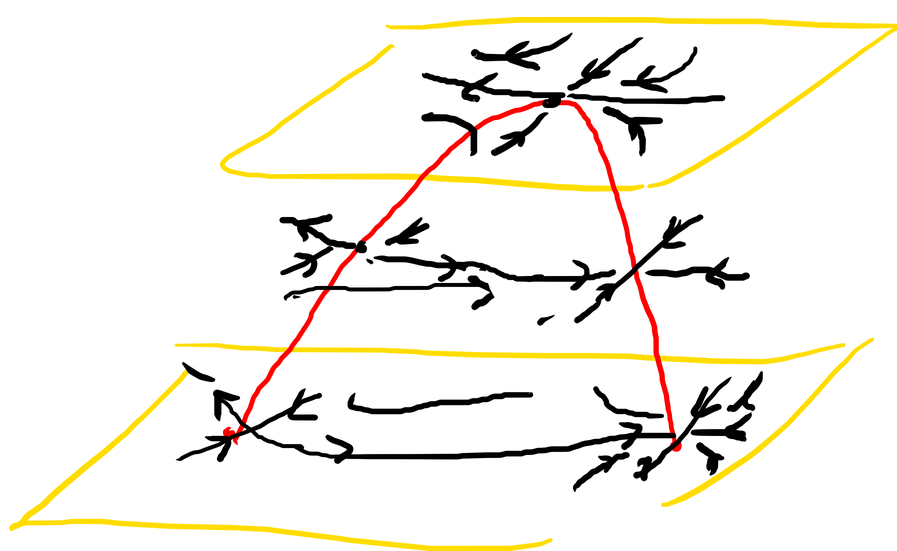


FIG. 3.1. — Saddle-node





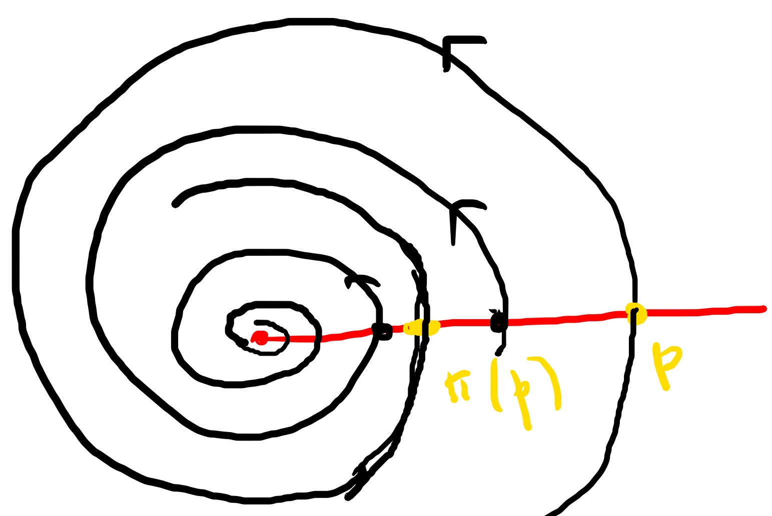
Foco não hiperbólico

Proposition **(3.12).** — *Denote by* Q_1^2 *the set of vector fields* $X \in \mathfrak{X}^r$, $r \geq 4$ *such that:*

1) X *has a composed focus as unique non-generic singular point.*
2) X *has only generic periodic trajectories.*
3) *The* α *and* ω*-limit sets of any trajectory of* X *are singular points or periodic trajectories.*
4) X *has no saddle connections.*

Then:

a) Q_1^2 *is open in* $\mathfrak{X}_1^r$.
b) *It is an imbedded Banach submanifold of class* C^{r-1} *and codimension one of* $\mathfrak{X}^r$; *and*
c) *Every* $X \in Q_1^2$ *has a neighborhood* B_1 *in* Q_1^2 *so that it is topologically equivalent to every* $Y \in B_1$.



$\pi'(0) = 1$

$\pi''(0) = 0$

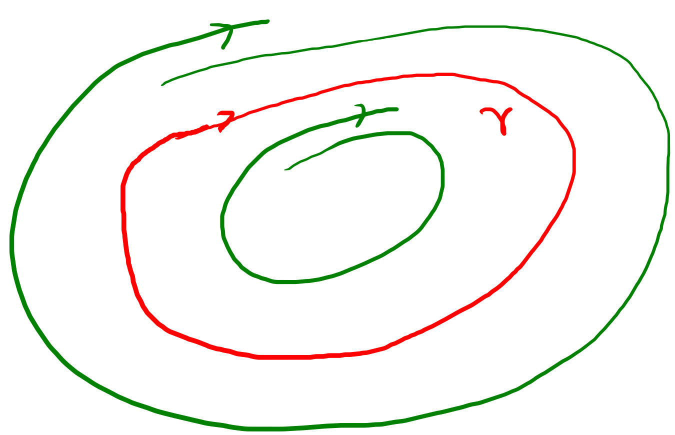
$\pi'''(0) \neq 0$

Orbita periódica semi-hiperbólica

Proposition **(2.2).** — *Denote by* Q_2 *the set of vector fields* $X \in \mathfrak{X}^r$, $r \geq 3$ *such that:*

1) X *has one quasi-generic periodic trajectory as unique non-generic periodic trajectory.*
2) X *has only generic singular points and does not have saddle connections.*
3) *The* α *and* ω*-limit sets of any trajectory of* X *are singular points or periodic trajectories.*

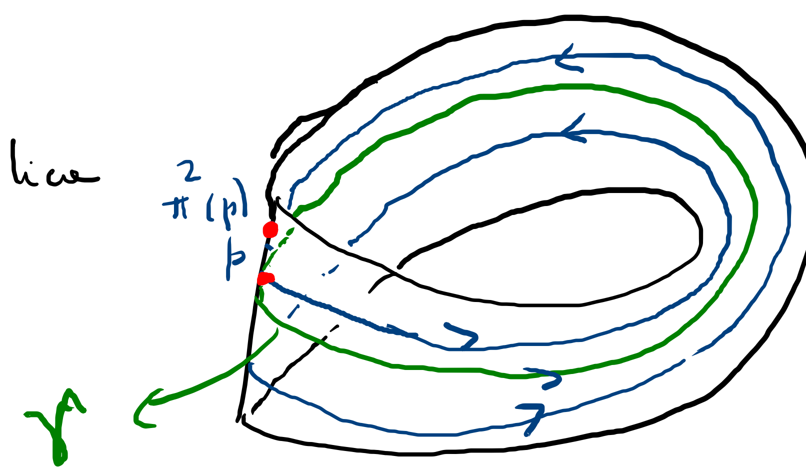
Then, Q_2 *is an immersed Banach submanifold of class* C^{r-1} *and codimension one of* $\mathfrak{X}^r$; *furthermore, every* $X \in Q_2$ *has a neighborhood* B_1 *in* Q_2 *so that every* $Y \in B_1$ *is topologically equivalent to* X.



γ - semi hiperbólica

$\pi'(0) = 1$

$\pi''(0) \neq 0$.



$\pi'(0) = -1$

$(\pi^2)'''(0) \neq 0$

Lemma **(2.6)**. — *Let* $X \in \mathfrak{X}^r$, $r \geq 3$, *have a quasi-generic periodic trajectory* γ_X *of period* $\tau(X)$ *such that* $\pi_X^1(0) = -1$ *and* $(\pi_X^2)^{(3)}(0) \neq 0$. *Then, given* $\varepsilon > 0$, *there are neighborhoods* B *of* X *and* N *of* γ_X *and a* C^{r-1} *function* $f : B \to \mathbf{R}$ *such that*:

1) ∂N *is a curve transversal to every* $Y \in B$.

2) $Y \in B$ *has one periodic trajectory, which is quasi-generic and one-sided, contained in* N *if and only if* $f(Y) = 0$; *if* $f(Y) > 0$, Y *has two periodic trajectories both generic, only one being one-sided, contained in* N; *if* $f(Y) < 0$, $Y \in B$ *has one one-sided periodic trajectory, which is generic, contained in* N. *Furthermore,* $f(X) = 0$ *and* $df_X \neq 0$.

3) *A periodic trajectory of* $Y \in B$ *contained in* N *has period within* ε *of* $\tau(X)$ *if it is one-sided, and within* ε *of* $2\tau(X)$ *if it is two-sided.*

Lemma **(2.7)**. — *Call* $Q'_2(n)$ *the set of* $X \in Q_2$ (Prop. (2.2)) *such that its quasi-generic periodic trajectory,* γ_X, *is one-sided, with period* $\tau(X) < n$.

$Q'_2(n)$ *is an imbedded Banach submanifold of class* C^{r-1} *and codimension one of* $\mathfrak{X}^r$.

Furthermore, $Q'_2(n)$ *is open in* $\mathfrak{X}^r_1$ *and every* $X \in Q'_2(n)$ *has a neighborhood* B_1 *in* $Q'_2(n)$ *such that every* $Y \in B_1$ *is topologically equivalent to* X.

Conexão de selas hiperbólicas

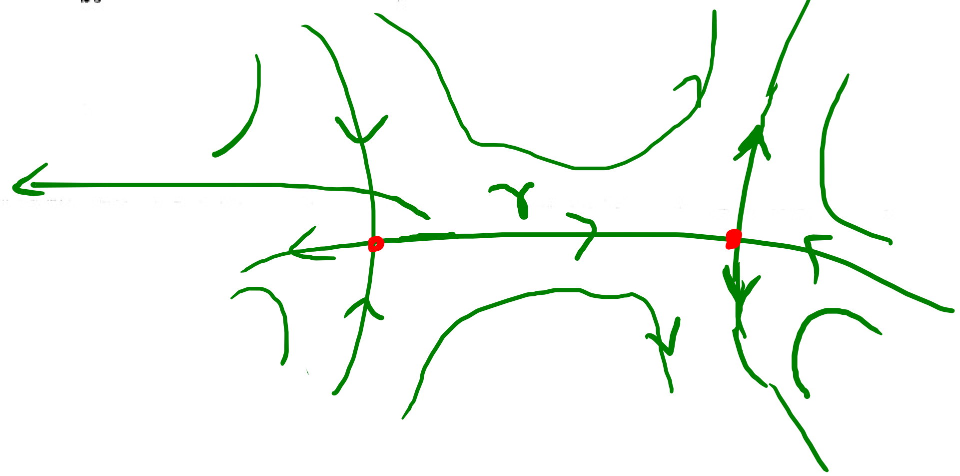
Proposition **(4.2)**. — *Let* Q_3 *denote the set of vector fields* $X \in \mathfrak{X}^r$, $r \geq 2$ *such that:*

1) X *has one saddle connection, which in case of being a loop is a simple loop.*

2) X *has only generic singular points and generic periodic trajectories.*

3) *The* α *and* ω*-limit sets of every trajectory of* X *are singular points, periodic trajectories, or loops.*

γ: heteroclínica



γ = homoclínica

Then Q_3 *is a Banach submanifold of class* C^{r-1} *and codimension one immersed in* $\mathfrak{X}^r$; *furthermore, every* $X \in Q_3$ *has a neighborhood* B_1 *in* Q_3 *such that every* $Y \in B_1$ *is topologically equivalent to* X.

We define $S_i = Q_1 \cup Q_2(i) \cup Q'_2(i) \cup Q_3(i)$. By (3.13) and (4.8.1) *d*), S_i is an imbedded submanifold of $\mathfrak{X}^r$. Hence, $\Sigma_1^r = \bigcup_i S_i$ is an immersed submanifold of $\mathfrak{X}^r$.

Theorem 1. — a) *Σ_1^r defined above is an immersed Banach submanifold of class* C^{r-1} *and codimension one of $\mathfrak{X}^r$, $r \geq 4$.*

b) *Σ_1^r is dense in $\mathfrak{X}_1^r$.*

c) *Every* $X \in \Sigma_1^r$ *has a Σ_1^r-neighborhood* B_1, i.e., *a neighborhood in the intrinsic topology of Σ_1^r, such that* X *is topologically equivalent to every* $Y \in B_1$.

J. Sotomayor, Generic one parameter families of vector fields on two dimensional manifolds, IHES, (1974), vol 43 - pp. 5-46.

Jorge Sotamayor em Lima (Bairro San Borja)

Esquina das ruas Gaspard Monge e Leonhard Euler

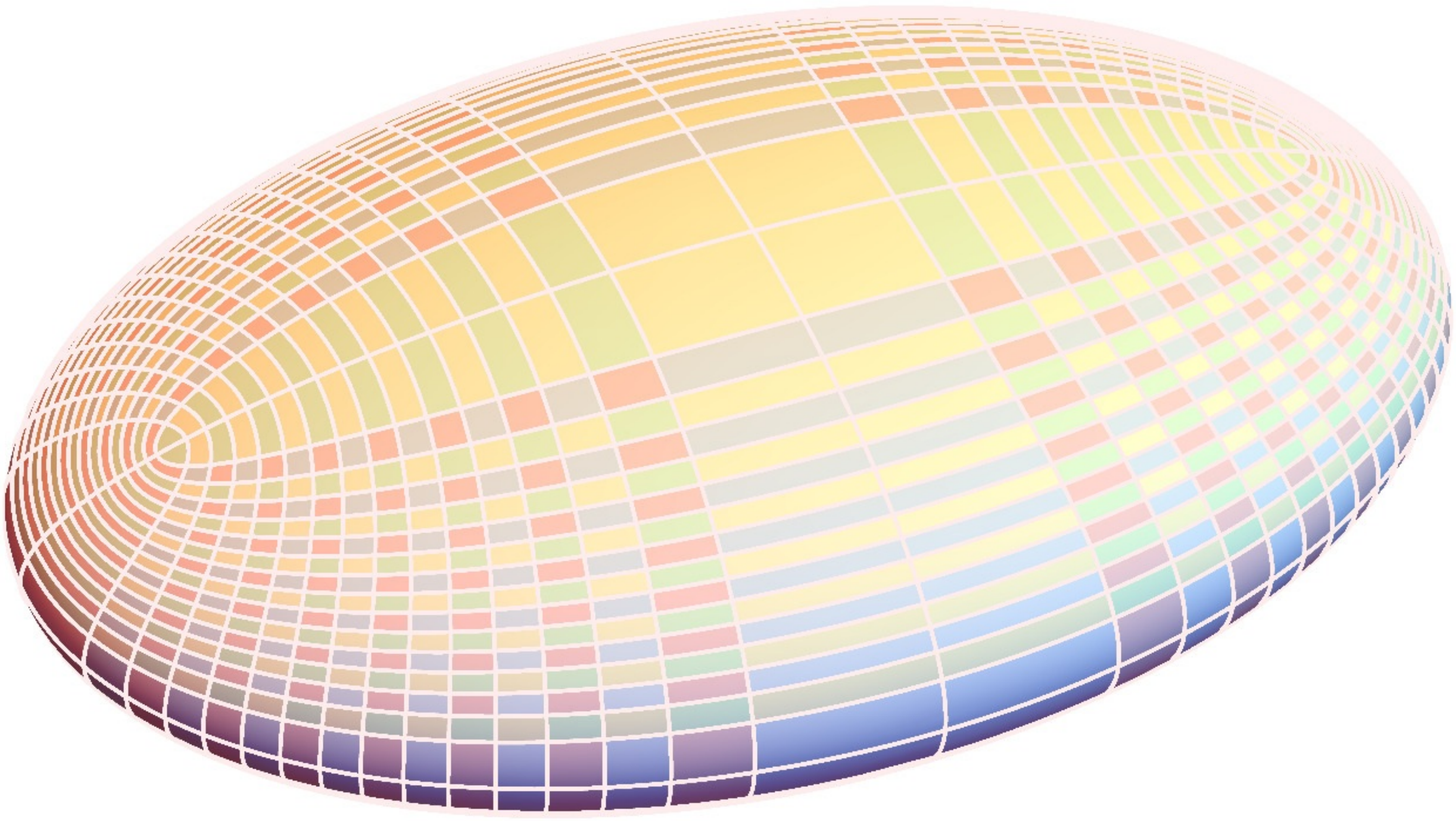
- Linhas de curvatura em superfícies imersas em $\mathbb{R}^3$

- Folheações singulares $\mathcal{F}_1$ e $\mathcal{F}_2$.
- Pontos umbílicos $\mathcal{U}$
- Configuração principal

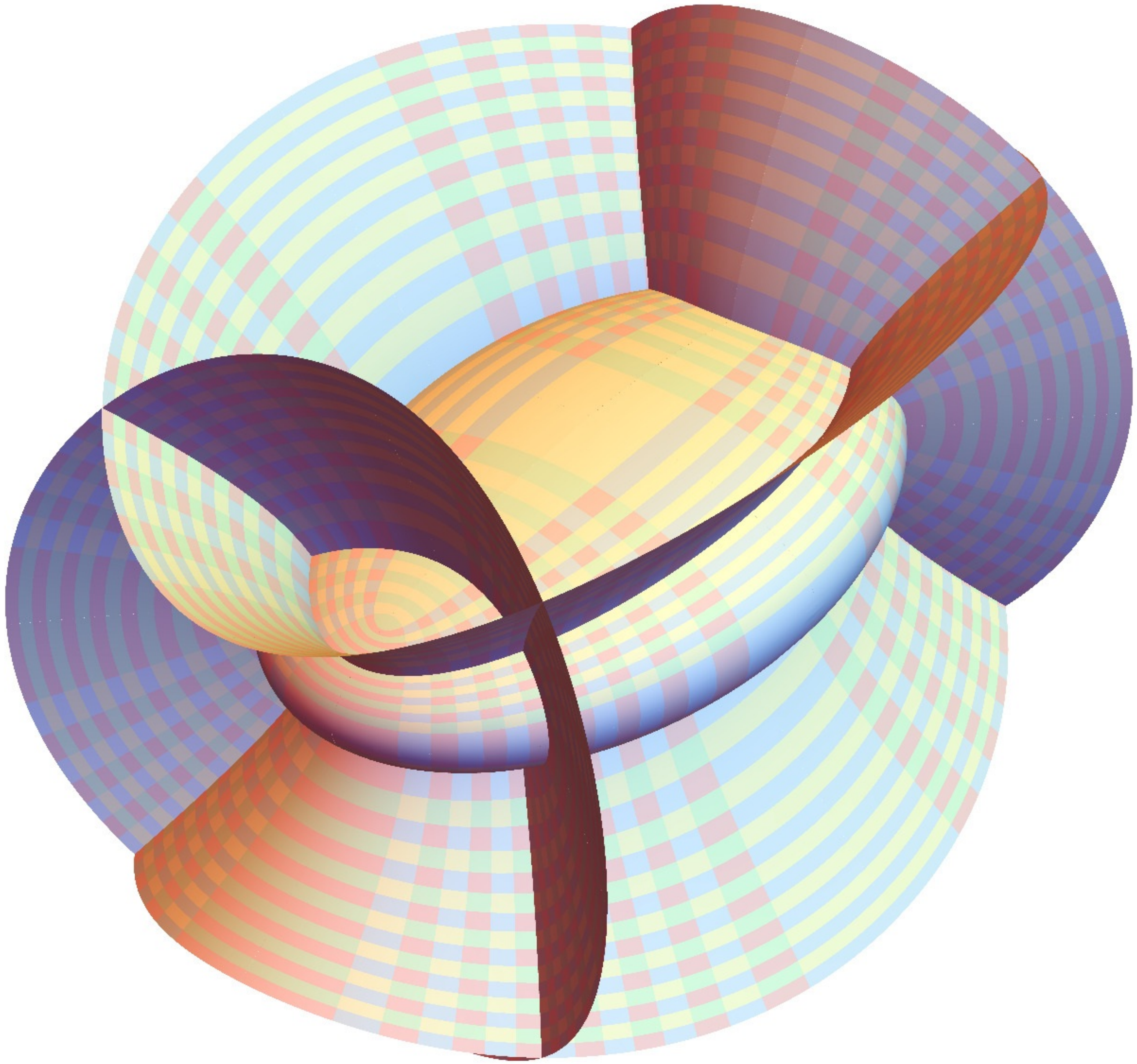
$$\mathcal{P} = \{\mathcal{U}, \mathcal{F}_1, \mathcal{F}_2\}$$

- Equivalência topológica entre duas configurações principais
- Estabilidade estrutural das configurações principais

o Elipsóide de Monge



Sistema triplamente ortogonal de quádricas



$$\frac{x^2}{a^2-\lambda} + \frac{y^2}{b^2-\lambda} + \frac{z^2}{c^2-\lambda} = 1$$

Teorema de Dupin

(tbém reinvidicado por Binet)

O Elipsóide de Monge

Jorge Sotomayor

RMU (1993)
da
SBM

Esta história se inicia numa escaldante noite de setembro de 1970, na cidade do Rio de Janeiro. Vítima da insônia, decidi bisbilhotar os livros que minha esposa havia primorosamente arrumado na estante. Tinha ela trazido recentemente uma porção de livros seus e lá os havia colocado.

Minha cândida e descontraída atitude contrastava com uma estranha tensão que dimanava da estante. Intrigado, e entregue à curiosidade, me senti impelido a investigar a sua causa...

Espremido num cantinho, ataviado de elegante capa verde, pulsava inquieto o livro de Struik *"Lecciones de Geometria Diferencial Clássica"*.

Minha natural atração pela Geometria e pela Língua de Cervantes me levou, descompromissadamente, a abri-lo.

Pasmem! Fí-lo, justamente na página donde a seguinte figura do elipsóide tri-axial surgiu, como espreitando-me.

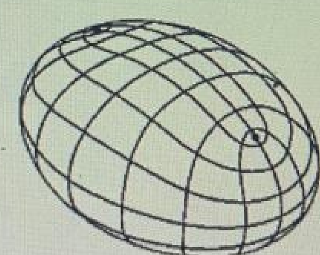
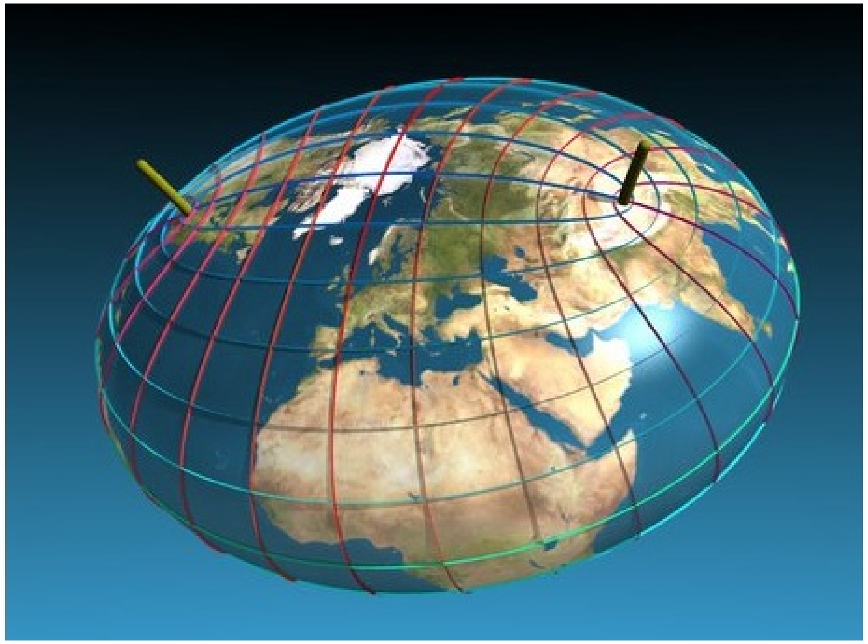


Fig. 1: Elipsóide de eixos diferentes, suas linhas de curvatura e pontos umbilicos.

Subitamente, assaltou-me a sensação de estar caindo numa armadilha.

Havia ele esperado quase um século e meio desde a data em que o ilustre matemático francês Gaspard Monge o concebeu, localizando-lhe seus 4 pontos umbílicos e calculando-lhe as linhas de curvatura principal. Nesse lapso, percorreu milhares de quilômetros, transpôs montanhas e cruzou largos mares, impresso em livro, restrito a uma limitada e asfixiante existência bidimensional, para que nessa



Homepage de Etienne Ghys (Lyon)

www.josleys.com

Call $\Sigma(a,b,c,d)$ the set of smooth compact oriented surfaces $\mathbf{S}$ which verify the following conditions.

a) All umbilic points are Darbouxian.

b) All principal cycles are hyperbolic. This means that the corresponding return map is *hyperbolic*; that is, its derivative is different from 1. It has been shown [redacted] that hyperbolicity of a principal cycle γ is equivalent to the requirement that

$$\int_\gamma \frac{d\mathcal{H}}{\sqrt{\mathcal{H}^2 - \mathcal{K}}} \neq 0,$$

where $\mathcal{H} = (k_1 + k_2)/2$ is the mean curvature and $\mathcal{K} = k_1 k_2$ is the gaussian curvature.

c) The limit set of every principal line is contained in the set of umbilic points and principal cycles of $\mathbf{S}$.

The α-(resp. ω) *limit set* of an oriented principal line γ, defined on its maximal interval $\mathcal{I} = (w_-, w_+)$ where it is parametrized by arc length s, is the collection $\alpha(\gamma)$-(resp. $\omega(\gamma)$) of limit point sequences of the form $\gamma(s_n)$, convergent in $\mathbf{S}$, with s_n tending to the left (resp. right) extreme of $\mathcal{I}$. The *limit set* of γ is the set $\Omega = \alpha(\gamma) \cup \omega(\gamma)$.

Examples of surfaces with *non trivial recurrent* principal lines, which violate condition **c** are given [redacted] for ellipsoidal and toroidal surfaces.

There are no examples of these situations in the classical geometry literature.

d) All umbilic separatrices are separatrices of a single umbilic point.

Separatrices which violate **d** are called *umbilic connections*; an example can be seen in the ellipsoid [redacted]

Teoremas de Gutierrez - Sotomayor

Asterisque vol 98-99 1982

Theorem 2. (Structural Stability of Principal Configurations [redacted] The set of surfaces $\Sigma(a,b,c,d)$ is open in the C^3 sense and each of its elements is C^3-principal structurally stable.

Lect. Notes in Math. Nº 1007 1983

Theorem 3. (Density of Principal Structurally Stable Surfaces, [redacted] The set $\Sigma(a,b,c,d)$ is dense in the C^2 sense.

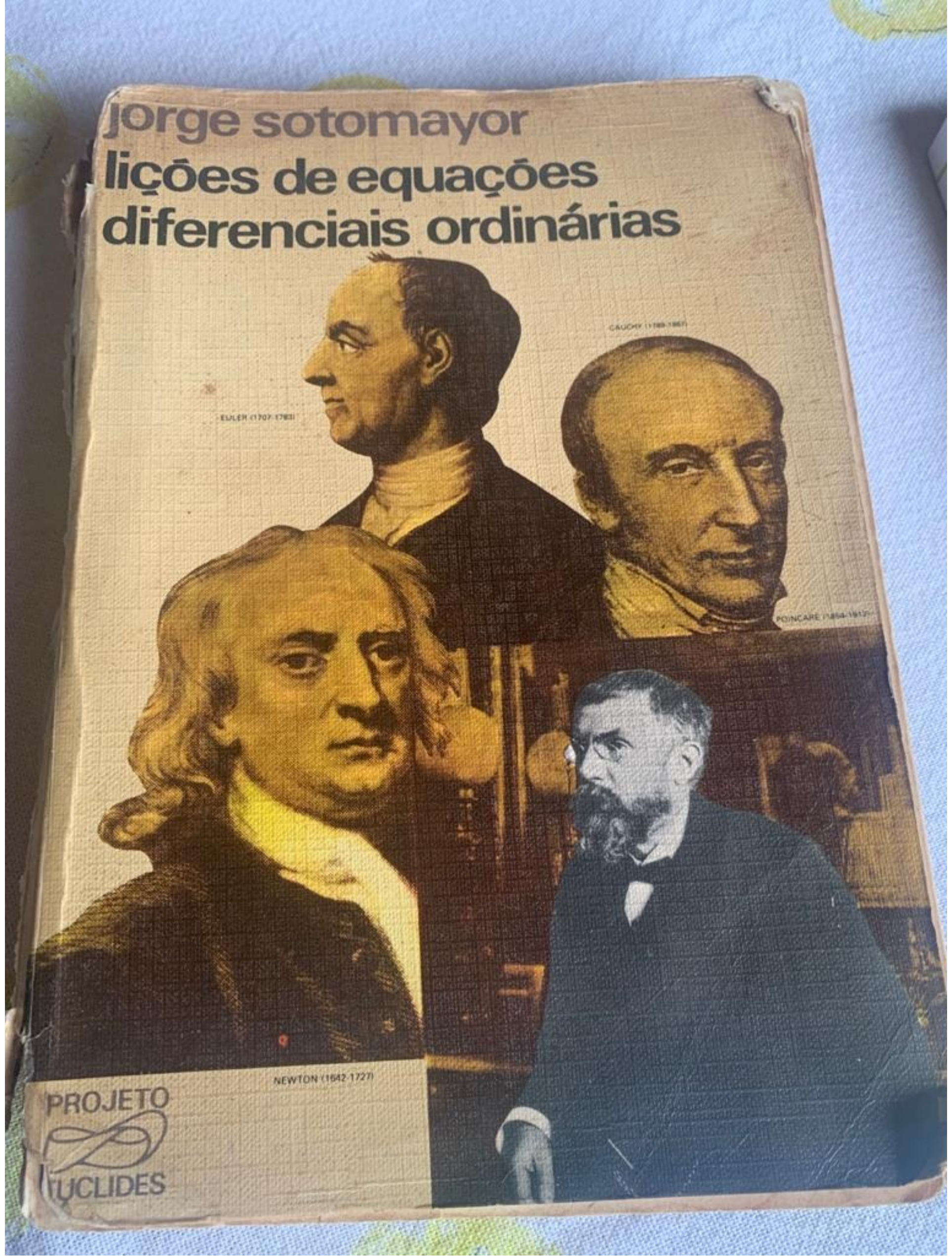
[redacted]

Problem 1. Raise from 2 to 3 the differentiability class in the density Theorem 3.

This remains among the most intractable questions in this subject, involving difficulties of Closing Lemma type, [redacted] which also permeate other differential equations of classical geometry, [redacted]

sim

Problem 2. Is it possible to have a smooth embedding of the Torus $\mathbb{T}^2$ into $\mathbb{R}^3$ with both maximal and minimal non-trivial recurrent principal curvature lines?



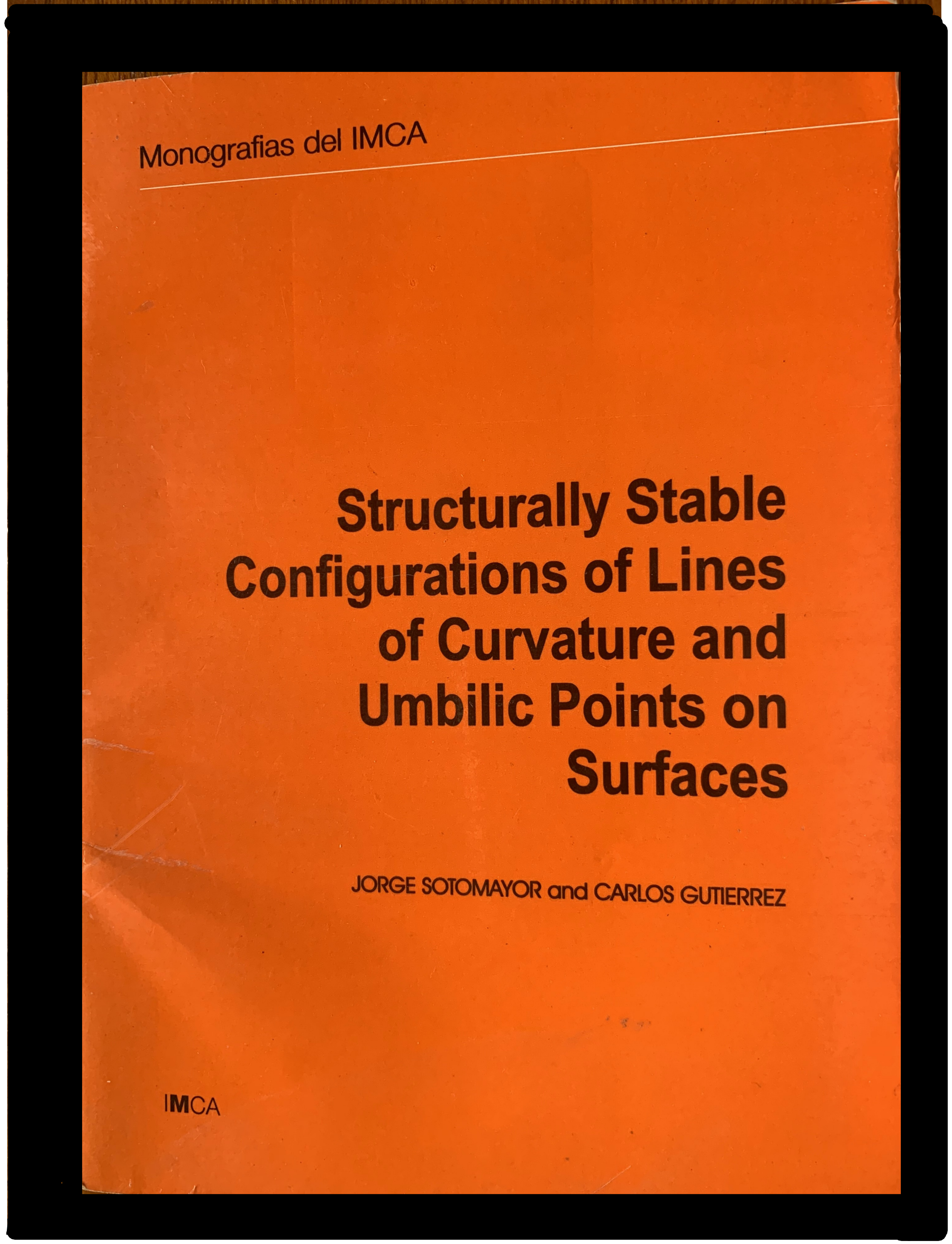
- Livro que influenciou na formação de uma (ou mais) geração de matemáticos.

- Destacamos os exercícios (a maioria exige elaboração e ideias p/ solução).

Destacamos tbém o teorema de contração nas fibras. O teorema de existência, unicidade e dependência diferencial segue desse teorema de ponto fixo.

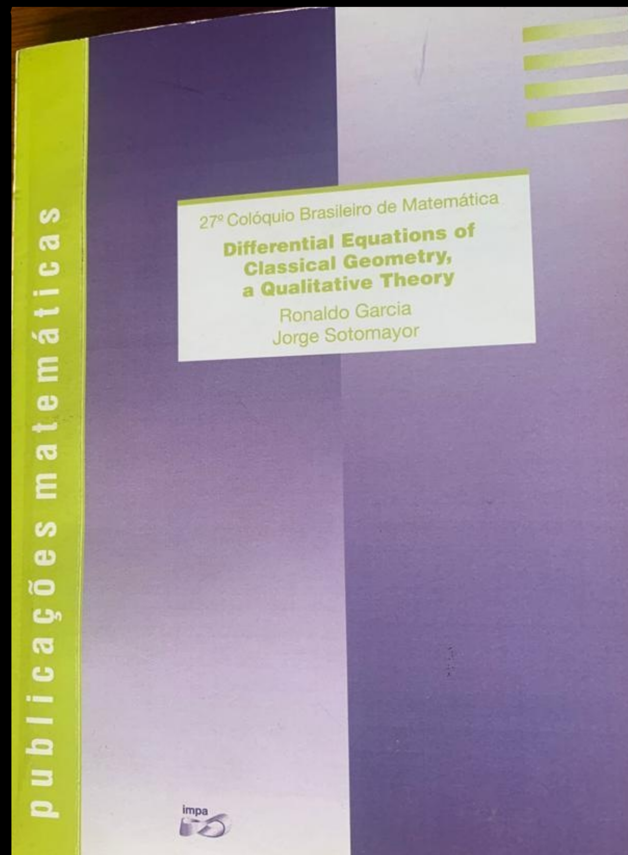
Versão métrica do teorema de Peixoto para campos de vetores em regiões planares compactas c/ bordo regular.

- Acrescentar hipóteses tendo em consideração o bordo da região



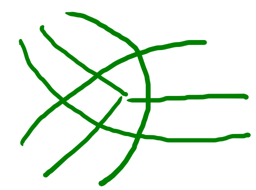
Publicação baseada no livro publicado no Colóquio Brasileiro de Matemática de 1991.

- Apresentação unificada e didática dos artigos germinais dos autores de 1982 e 1983.



- Curso sobre várias classes especiais de curvas em superfícies

(linhas de curvatura, assintóticas, geodésicas) e linhas axiais (sup. em $\mathbb{R}^4$).



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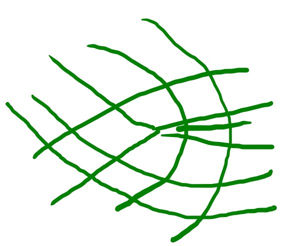

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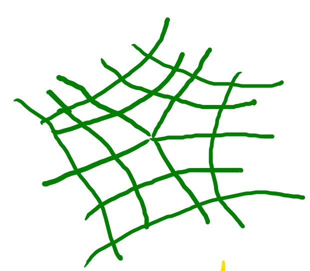

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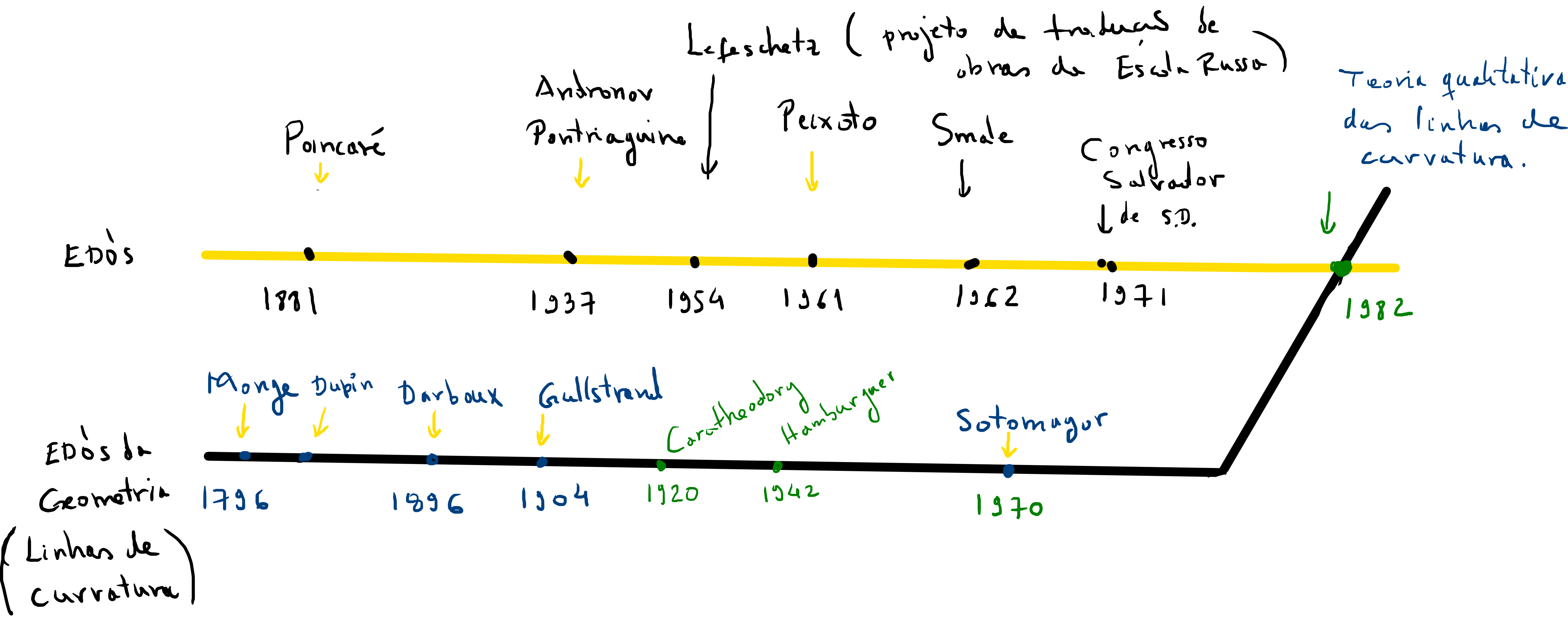
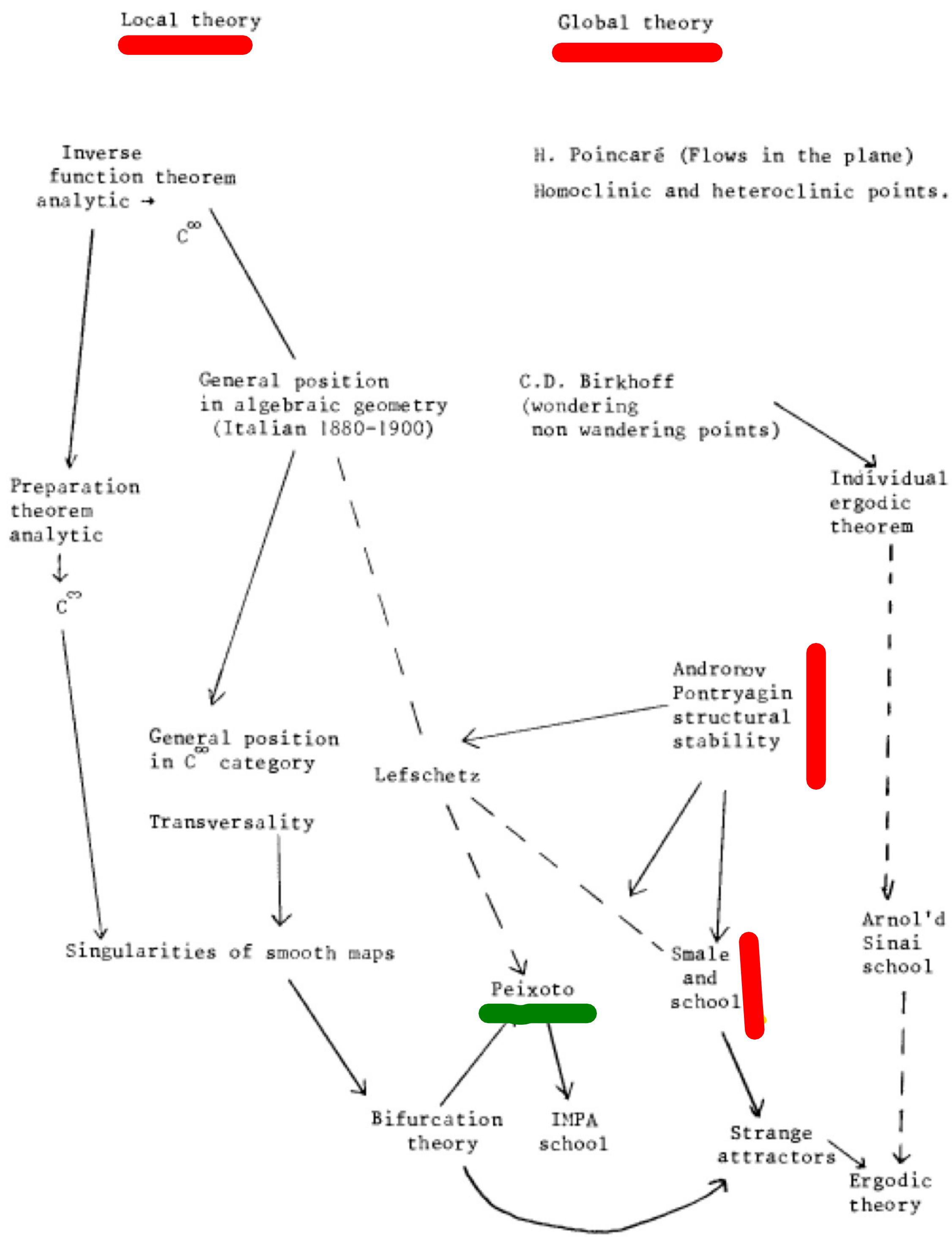
Linha do tempo



René Thom



Local theory
Global theory
Inverse function theorem analytic → C^∞
H. Poincaré (Flows in the plane)
Homoclinic and heteroclinic points.
General position in algebraic geometry (Italian 1880-1900)
C.D. Birkhoff (wondering non wandering points)
Preparation theorem analytic
C^∞
Individual ergodic theorem
Andronov Pontryagin structural stability
General position in C^∞ category
Lefschetz
Transversality
Arnol'd Sinai school
Singularities of smooth maps
Peixoto
Smale and school
Bifurcation theory
IMPA school
Strange attractors
Ergodic theory

Slide de uma palestra de Jorge Sotomayor

Recapitulation and Comments, from R. Gate Version

From slide 4: COMPLEMENTING THE TIMELINE WITH LANDMARKS RELATED TO THE FOUNDATION OF THE BRAZILIAN SCHOOL OF ODEs AND DYNAMICAL SYSTEMS:

* ______ * ___ * ______ * _____ * ______ * ________ * __________ * _____

1881. . 1937 ..38 1952 1959 1962-64 1968 1971

- * Brazil: Peixoto's works, Seminar and Symposium;
- * France: Poincaré QTDE;
- * Russia: The Gorkii School Landmark;
- * USA: Lefschetz, 1949-52, and Smale, Visit to IMPA, 1961, Seminar in Berkeley. 1966-67, and his landmark 1968 Differentiable Dynamical System papers, BAMS.

Jorge Sotomayor

Sep 15, 2018

Description of the Project A Mathematics Memoir.

A Mathematics Memoir.

To participate in a Public Competition for a position of Professor of Mathematics in a State University, in 1992 I had to compose a written Mathematics Memoir.

The outcome of an introspective inquiry in preparation for for this endeavor, led me to outline several stages of my contact with Mathematics, going back to my adolescence. I hoped that a rational organization and a concatenation of these stages could help me to present the contributions I had made.

However, after conferring with people with experience in Public Competitions, the final simplified version of the Memoir consisted on a document close to a Curriculum Vitae and a commented Publications List.

The outlines of the above mentioned stages were developed and composed later on different occasions, in the form of independent evocative essays. This may explain why they have disparate styles and some overlapping.

In this project I will post the collection of essays which have been translated into English and deposited in Research Gate. They are listed in chronological order as follows:

My geometry notebook for years 1954–58 Reminiscences of Mathematical Apprenticeship in San Marcos, 1959-62 Mathematical Encounters, for years 1961-73 On a List of ODE Problems for years 1962–64

Wikipedia (Jorge Sotomayor Tello)

Selected publications [edit]

- Sotomayor, J. (1993). "O elipsóide de Monge" (PDF). *Revista Matemática Universitária*. **15**: 33–47.
- Sotomayor, J. (2007). "El elipsoide de Monge y las líneas de curvatura". *Materials Matemàtics*. **01**: 1–25.
- Sotomayor, J.; Garcia, R. (2016). "Historical Comments on Monge's Ellipsoid and the Confgurations of Lines of Curvature on Surfaces". *Antiquitates Mathematicae*. **10**: 348–354.
- Sotomayor, J. (2019). "A Private Mathematical Lesson, Rio de Janeiro,1933". *Nexus Mathematicae*. **02**: 01–04.
- Sotomayor, J. (2020). "Reminiscences of a Mathematical Sojourn at San Marcos, 1959 - 61, and at IMPA, 1962". *Nexus Mathematicae*. **03**: 01–14. doi:10.5216/nm.v3.63724. S2CID 238106577.
- Sotomayor, J. (2020). "On an encounter of two men of mathematics in Lima". *Revista Brasileira de História da Matemática*. **20** (40): 01–07. doi:10.47976/RBHM2020v20n4001-07. S2CID 229001686.
- Sotomayor, J. (2020). "On Maurício M. Peixoto and the arrival of Structural Stability to Rio de Janeiro, 1955". *An. Acad. Bras. Ciências*. **92** (1): 01–07. doi:10.1590/0001-3765202020191219. PMID 32267292. S2CID 215406476.
- Sotomayor, J.; Garcia, R.; Mello, L. (2020). "Maurício M. Peixoto (1921-2019)". *Revista Matemática Universitária da SBM*. **1**: 01–22. doi:10.21711/26755254/rmu202013. S2CID 226539649.
- Sotomayor, J. (1992). "A Caderneta de Geometria". *Revista do Professor de Matemática da SBM*. **21**: 1–5.
- Sotomayor, J. (1974). "Generic one-parameter families of vector fields on two-dimensional manifolds". *Publications Mathématiques de l'IHÉS*. **43**: 5–46. doi:10.1007/bf02684365. S2CID 123134043.
- Dumortier, F.; Roussarie, R.; Sotomayor, J. (1987). "Generic 3-parameter families of vector fields on the plane, unfolding a singularity with nilpotent linear part. The cusp case of codimension 3". *Ergodic Theory and Dynamical Systems*. **7** (3): 375–413. doi:10.1017/s0143385700004119.
- "with C. Gutiérrez: Structurally Stable Configurations of Lines of Principal Curvature", *Astérisque, França, v. 98--99, p. 195--215, (1982).*
- Sotomayor, J. (2021). "An encounter of classical differential geometry with dynamical systems in the realm of structural stability of principal curvature configurations". *São Paulo Math.Journal*. doi:10.1007/s40863-021-00231-6. S2CID 236365729.

M. Peixoto (2002)

Mauricio Peixoto's Testimonial [edit]

``It is a pleasure to say a few words in this occasion, commemorating the 60th birthday of Sotomayor. He was my student and got his PhD at IMPA in 1964. At the same time two other IMPA students of mine, Ivan Kupka and Aristides Barreto, also got their doctorates. These were the first doctorates awarded by IMPA. The theses of Sotomayor and Kupka got quick international recognition and were initial steps in the direction of establishing IMPA as a mathematical research institution, strong in Dynamical Systems. Both Sotomayor and Kupka came to IMPA from Peru, Sotomayor through the shortest geodesic and Kupka through an arc with origin in Strasbourg (France). In the wake of Sotomayor a number of Peruvians got their doctorates at IMPA. Among them, Carlos Gutierrez and Cesar Camacho became distinguished mathematicians and professors at IMPA. Currently Camacho is the Director of IMPA.

Sotomayor is certainly one of the pioneers of the modern theory of bifurcation, put in the context of the theory of Dynamical Systems.

This point of view was introduced in his thesis when he considered a 2-dimensional manifold M and on the space of flows on M, $\Omega(M)$, he considered an arc γ and studied the intersection $\gamma \subset \Sigma$ when $\Sigma \subset \Omega(M)$ is the set of structurally stable flows on M.

In 1982 Sotomayor, together with C. Gutierrez put the concept of structurally stability in the study of the foliation determined by the lines of principal curvature of an ordinary surface in R^3.

This point of view enriched later by the collaboration of R. Garcia and others amounted to a new vision of the classical work of Monge, Dupin, Darboux, Caratheodory.

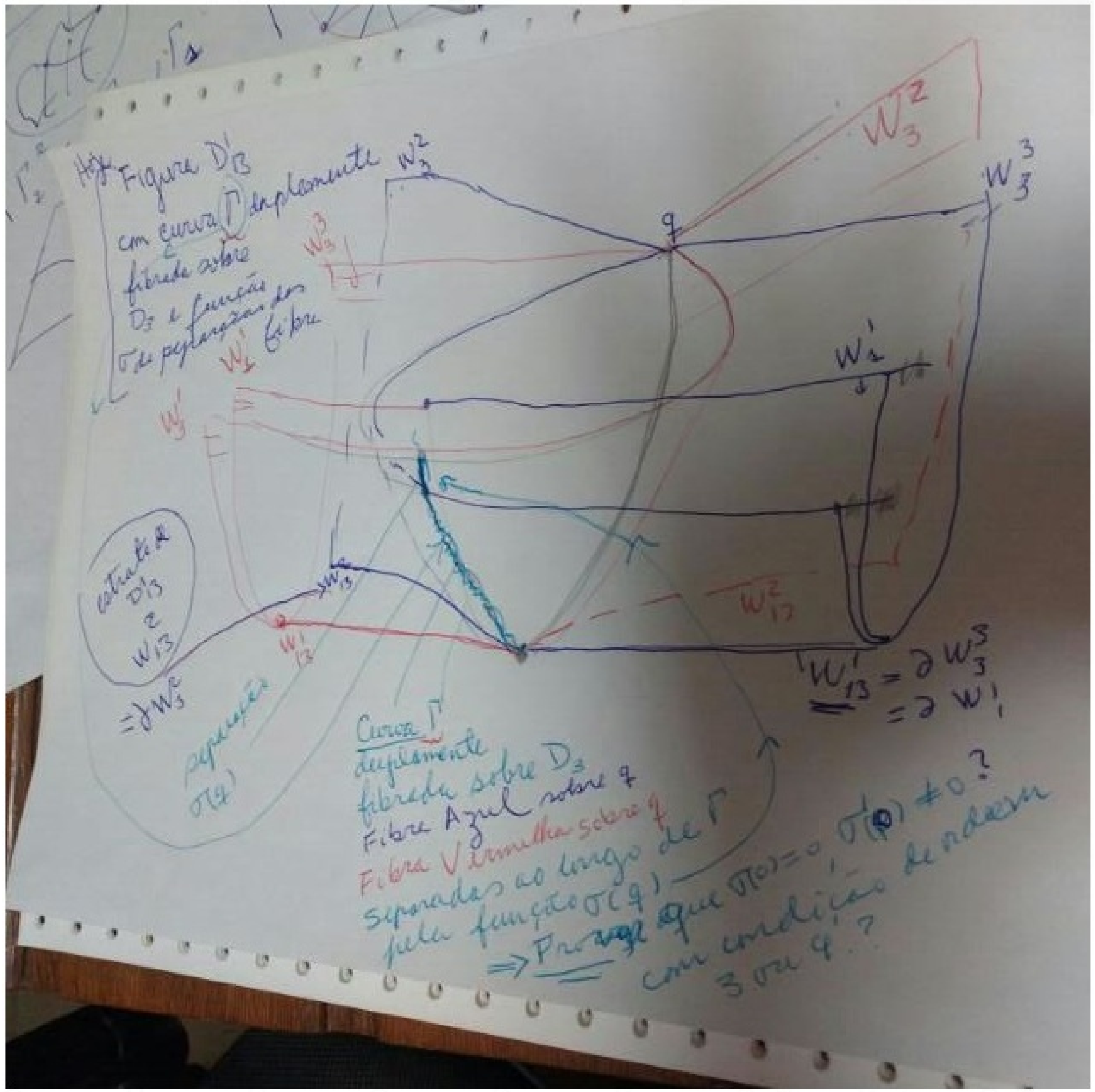
Let Soto continue to produce for many years to come his beautiful, relevant and down to earth mathematics``.

O legado matemático de Jorge Sotomayor (Soto)

Como resumir em poucas palavras o legado do Soto? Poderia dizer que foi um matemático com contribuições pioneiras nas bifurcações das edo's e na teoria qualitativa das linhas de curvatura. Ele possuía grande capacidade de síntese, intuição aguçada, habilidade excepcional em fazer croquis de diagramas de bifurcações e retratos de fase (verdadeiras obras de arte moderna). Alguns ficavam pendurados nas paredes do seu escritório, organizado à sua maneira, onde era possível entrar (caso conseguisse) mas não podia mudar a ordem das pastas etc.

Conheci o Soto, por intermédio do Prof. Genésio Lima dos Reis (1940-2017) quando ainda fazia minha graduação na UFG. O acaso me fez reencontrá-lo no IMPA em 1986 quando me aceitou para orientação no doutorado, concluído em janeiro/1989. Ao longo da minha carreira tivemos uma parceria profícua e uma amizade estabeleceu-se. Toda vez que veio a Goiânia íamos, sempre por sua sugestão, ao restaurante Tucunaré na Chapa.

Conforme depoimento da Marilda, acompanhei a sua luta pela vida nos últimos seis meses (julho/2021 a janeiro/2022), mas ele pediu para não dar publicidade. Acredito que cumpri quase fielmente a sua vontade. Na penúltima vez que falamos por telefone disse-me que eu teria um compromisso com ele no dia 25/03/2022. Nesse momento, espero que ele esteja junto ao meu filho Breno relembrando e recontando a história ``E os cisnes ficaram doidinhos...``



Hoje
Figura D^1_{13}
com curva Γ duplamente fibrada sobre D_3 e função
W^2_3
W^3_3
W^1_1
q
W^2_{13}
W^1_{13}
estrato D^1_{13} e W^1_{13}
$W^1_{13} = \partial W^3_3 = \partial W^1_1$
$= \partial W^2_3$
separação σ(q)
Curva Γ
duplamente
fibrada sobre D_3
Fibra Azul sobre q
Fibra Vermelha sobre q
separadas ao longo de Γ
pela função σ(q)
⇒ Prova que σ(0) = 0
σ'(0) ≠ 0?
com condição de ordem
3 ou 4?