Subvarieties in Abelian Variety

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Setting:

- $A/\mathbb{C}$: an abelian variety of dim n
- $Z \subset A$: a (nondegenerate) subvariety of dim r
  Z is a curve C in our talk.

Goal

- *Construct a family of subvarieties in A.*
- *Find their dimension and homology class.*

Example (Jacobian case)

When C is a smooth projective curve over $\mathbb{C}$ of genus $g \geqslant 2$,

$$\begin{aligned} A &:= \mathrm{Jac}(C) && \textit{the Jacobian of } C \\ \mathrm{AJ}_C : C &\hookrightarrow A && \textit{Abel–Jacobi map} \end{aligned}$$

Example (Prym case)

When $h : C \longrightarrow C'$ is an unramified double cover of smooth projective curves, we can define

$$\begin{aligned} A &:= \mathrm{Prym}(C/C') && \textit{the Prym variety of } h \\ \mathrm{AP}_{C/C'} : C &\longrightarrow A && \textit{Abel–Prym map} \end{aligned}$$

We need to assume C is non-hyperelliptic so that $\mathrm{AP}_{C/C'}$ is injective.

Construct new subvarieties

Since A has addition structure, one defines

$$\begin{aligned} C+C &:= \{p+q \,|\, p,q \in C\} \quad &\subseteq A \\ 2C &:= \{2p \,|\, p \in C\} \quad &\subseteq A \end{aligned}$$

and so on.

Remark

Since C is nondegenerate,

$$\underbrace{C+C+\cdots+C}_{\geqslant n \text{ many}} = A.$$

Construct new subvarieties

Question

Can we define a family of subvarieties

$$\{m_1C + \cdots + m_dC \subseteq A \mid m_1, \ldots, m_k \in \mathbb{Z}\}$$

more respect to the addition structures?

They should not be A.

In fact, we can construct a family of subvarieties

$$\left\{Z_\chi \subseteq A \,\middle|\, \chi \in \mathbb{Z}^d\right\}$$

via the conormal variety.

Conic Lagrangian cycle

For a (smooth) subvariety $Z \subset A$, one can define the conormal variety $\Lambda_Z \subset T^*A \cong A \times T_0^*A$ by

$$\Lambda_Z := \left\{ (p, \xi) \in T^*A \;\middle|\; \xi|_{T_p^*Z} = 0 \right\}.$$

Facts

- Λ_Z is a conic Lagrangian cycle in T^*A;
- We have one-to-one correspondence

$$\begin{array}{ccc} \{\text{irr conic Lagrangian cycles in } T^*A\} & \cong & \{\text{irr subvarieties in } A\} \\ \Lambda_Z & \longleftrightarrow & Z \end{array}$$

- The map $\gamma_Z : \Lambda_Z \subset A \times T_0^*A \longrightarrow T_0^*A$ is a generically finite map, when Z is nondegenerate.

Family of subvarieties

Definition

Fix a general point $\xi_0 \in T_0^*A$, and $d := \deg \gamma_Z$,

$$\gamma_Z^{-1}(\xi_0) := \{p_1, \dots, p_d\} \subset Z.$$

Denote $\Lambda_Z^{\mathrm{univ}}$ as the irreducible component of

$$\underbrace{\Lambda_Z \times_{T_0^*A} \cdots \times_{T_0^*A} \Lambda_Z}_{d \text{ many}} \subset A \times \cdots \times A \times T_0^*A$$

containing the point $(p_1, \dots, p_d, \xi_0)$.

For $\chi = (m_1, \dots, m_d) \in \mathbb{Z}^d$, define $\Lambda_{Z_\chi} := f(\Lambda_Z^{\mathrm{univ}})$, where

$$\begin{aligned} f : A \times \cdots \times A \times T_0^*A &\longrightarrow A \times T_0^*A \\ (q_1, \dots, q_d, \xi) &\longmapsto (\textstyle\sum_i m_i q_i, \xi) \end{aligned}$$

Z_χ is then the corresponding subvariety of Λ_{Z_χ}.

Our work

We determine $\dim Z_\chi$ and $[Z_\chi] \in H_*(A;\mathbb{Z})$ in special cases.

Example

In the Jacobian case, $d = \deg \gamma_C = 2g-2$.
Assume that C is non-hyperelliptic. For $\chi = (m_1, \ldots, m_d) \in \mathbb{Z}^d$, when no g of m_i equal to each other, we get

$$\dim Z_\chi = \ g-1$$

$$[Z_\chi] = \ \frac{1}{\deg f|_{\Lambda_Z^{\mathrm{univ}}}} \left(\frac{1}{2^{g-1}} \sum_{\sigma \in S_{2g-2}} \prod_{l=1}^{g-1} \left(m_{\sigma(2l-1)} - m_{\sigma(2l)} \right)^2 \right) \cdot [\Theta]$$

Q & A

Thank you for your listening!

Any questions?

This slide is online available: https://shorturl.at/qqWDe
For more infos (and references) about this topic, please check dim_of_Zchi.pdf and subvarieties_in_abelian_variety.pdf.

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