

4.4 Wreath products

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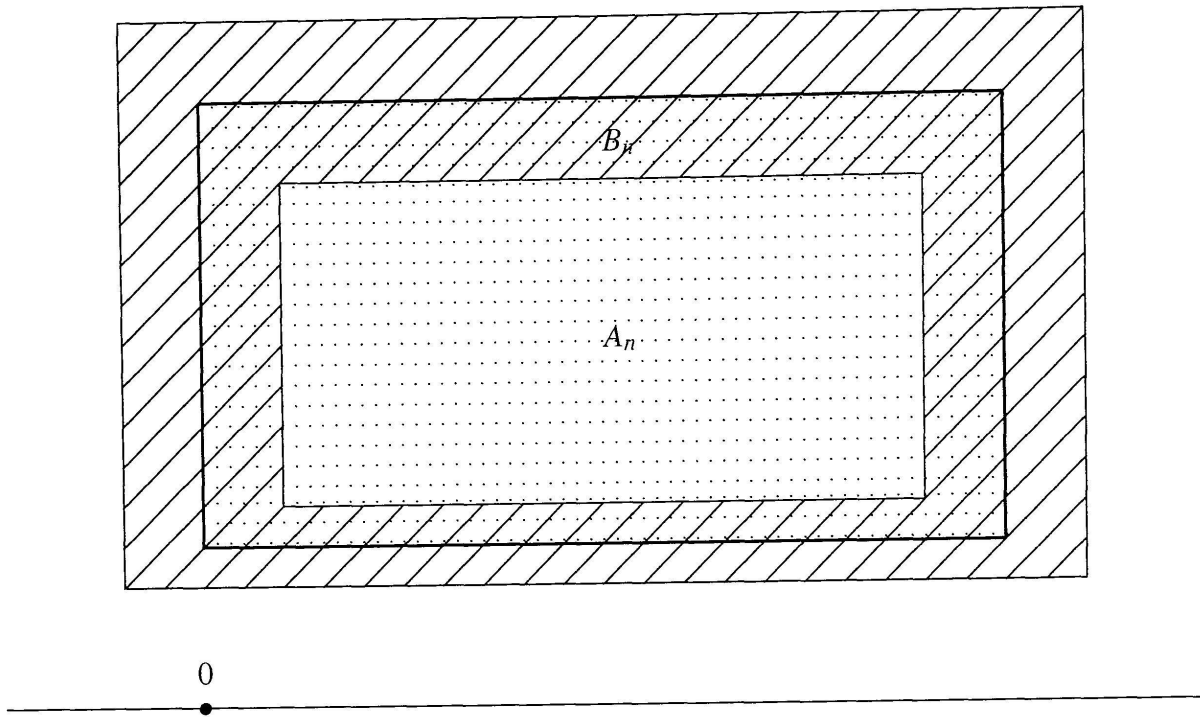


FIGURE 5

Sets A_n and B_n

$$\begin{aligned}
 B_n = & \{z \in H; -R \leq \operatorname{Re}(z) \leq R, e^R \geq \operatorname{Im}(z) \geq e^{-n-R}\} \\
 & \cup \{z \in H; -R+n \leq \operatorname{Re}(z) \leq n+R, e^R \geq \operatorname{Im}(z) \geq e^{-n-R}\} \\
 & \cup \{z \in H; -R \leq \operatorname{Re}(z) \leq n+R, e^R \geq \operatorname{Im}(z) \geq e^{-R}\} \\
 & \cup \{z \in H; -R \leq \operatorname{Re}(z) \leq n+R, e^{-n+R} \geq \operatorname{Im}(z) \geq e^{-n-R}\}.
 \end{aligned}$$

One can see that

$$|B_n|_{f^2} \approx n, \quad |A_n|_{f^2} \approx n^2.$$

This shows that $\{A_n\}_{n=1}^\infty$ is a generalized Følner sequence. Thus

$$\|P\|_{L^2(H, d_H z) \rightarrow L^2(H, d_H z)} = \int_{|z-i|=R} \sqrt{\operatorname{Im}(z)} \, dm_R(z).$$

4.4 WREATH PRODUCTS

Let G and F be finitely generated groups. We define the wreath product $G \wr F$ of these groups as follows. Elements of $G \wr F$ are couples (g, γ_1) where $g: F \rightarrow G$ is a function such that $g(\gamma)$ is different from the identity element id_G of G only for finitely many elements γ in F , and where γ_1 is an element of F . The multiplication in $G \wr F$ is defined as follows:

$$(g_1, \gamma_1)(g_2, \gamma_2) = (g_3, \gamma_1 \gamma_2)$$

where

$$g_3(\gamma) = g_1(\gamma)g_2(\gamma\gamma_1) \quad \text{for } \gamma \in F.$$

If S_G and S_F are generators of G and F respectively then

$$\{(g, \gamma); (g(F) = id_G, \gamma \in S_F) \text{ or } (g(F \setminus id_F) = id_G, g(id_F) \in S_G, \gamma = id_F)\}$$

is a generating subset for $G \wr F$.

Let μ and ν be symmetric, finitely supported probability measures on F and G respectively.

As there is a natural embedding of F and G into $G \wr F$, one can view the measures μ and ν as measures on $G \wr F$. More precisely:

$$\nu(g, \gamma) = \begin{cases} \nu(g(id_F)) & \text{if } \gamma = id_F \text{ and } g(F \setminus id_F) = id_G \\ 0 & \text{otherwise,} \end{cases}$$

$$\mu(g, \gamma) = \begin{cases} \mu(\gamma) & \text{if } g(F) = id_G \\ 0 & \text{otherwise.} \end{cases}$$

Then $\mu \star \nu \star \mu$ is a symmetric measure on $G \wr F$. Explicitly we have:

$$\mu \star \nu \star \mu(g, \gamma) = \begin{cases} \mu(\gamma(\gamma_0)^{-1})\mu(\gamma_0)\nu(g(\gamma_0)) & \text{if } g(F \setminus \gamma_0) = id_G \\ 0 & \text{otherwise.} \end{cases}$$

We want to prove:

THEOREM 7. *Let F and G be finitely generated groups. If F is amenable then the spectral radius of ν on G is the same as the spectral radius of $\mu \star \nu \star \mu$ on $G \wr F$.*

Proof. We will prove Theorem 7 by constructing on $G \wr F$ a positive function $\tilde{f}$ which is an eigenfunction for the convolution by $\mu \star \nu \star \mu$ with eigenvalue $\|\nu\|_{l^2(G) \rightarrow l^2(G)}$ and for which there exists a generalized Følner sequence.

Let f be a positive eigenfunction for the operator which is a convolution on $l^2(G)$ by ν , corresponding to the eigenvalue $\|\nu\|$, i.e.

$$(12) \quad f \star \nu = \|\nu\| f.$$

We can normalize f so that

$$(13) \quad f(id_G) = 1.$$

By Theorem 3 (and the remark after its proof) there exists a sequence of finite subsets $A_n \subset G$, such that

$$\frac{\sum_{\gamma \in \partial A_n} f^2(\gamma)}{\sum_{\gamma \in A_n} f^2(\gamma)} \rightarrow_{n \rightarrow \infty} 0.$$

As the group F is amenable there exists a sequence of finite subsets $B_n \subset F$, such that

$$\frac{\#\partial B_n}{\#B_n} \rightarrow_{n \rightarrow \infty} 0.$$

For technical reasons let us choose the sequences B_n and A_n in such a way that

$$(14) \quad \frac{\#\partial B_n}{\#B_n} < \frac{1}{n} \quad \text{and} \quad \frac{\sum_{\gamma \in \partial A_n} f^2(\gamma)}{\sum_{\gamma \in A_n} f^2(\gamma)} < \frac{1}{n(\#B_n)}.$$

Now, on $G \wr F$ we define $\tilde{f}$ as follows

$$\tilde{f}(g, \gamma_1) = \prod_{\gamma \in F} f(g(\gamma)).$$

The function $\tilde{f}$ is well defined because by (13), $f(g(\gamma))$ is different from 1 only for finitely many $\gamma \in F$. This function is of course positive and does not depend on γ_1 . From (12) one has

$$\tilde{f} \star \mu \star \nu \star \mu = \tilde{f} \star \nu \star \mu = \|\nu\| \tilde{f} \star \mu = \|\nu\| \tilde{f}.$$

To complete the proof of Theorem 7 it is enough to construct a generalized Følner sequence $C_n \subset G \wr F$ for $\tilde{f}$. We define C_n as follows:

$$C_n = \{(g, \gamma_1); \gamma_1 \in B_n, g(B_n) \subset A_n, g^{-1}(G \setminus id_G) \subset B_n\}.$$

LEMMA 5. *The sequence $C_n \subset G \wr F$ is a generalized Følner sequence for $\tilde{f}$.*

Proof. Let us define sets D_n and ∂D_n as follows:

$$D_n = \{g: F \rightarrow G; g(B_n) \subset A_n, g^{-1}(G \setminus id_G) \subset B_n\},$$

$$\begin{aligned} \partial D_n = \{g: F \rightarrow G; \text{there exists } \gamma_0 \in B_n \text{ such that } g(\gamma_0) \in \partial A_n, \\ g(B_n \setminus \gamma_0) \subset A_n, g^{-1}(G \setminus id_G) \subset B_n\}. \end{aligned}$$

Thus

$$\begin{aligned} C_n &= D_n \times B_n, \\ \partial C_n &= (\partial D_n \times B_n) \cup (D_n \times \partial B_n). \end{aligned}$$

We have then

$$\begin{aligned} \sum_{(g, \gamma_1) \in C_n} (\tilde{f}(g, \gamma_1))^2 &= \sum_{(g, \gamma_1) \in C_n} \left(\prod_{\gamma \in F} f(g(\gamma)) \right)^2 \\ &= \sum_{(g, \gamma_1) \in D_n \times B_n} \left(\prod_{\gamma \in F} f(g(\gamma)) \right)^2 = \#B_n \sum_{g \in D_n} \left(\prod_{\gamma \in F} f(g(\gamma)) \right)^2. \end{aligned}$$

On the other hand

$$\begin{aligned} \sum_{(g, \gamma_1) \in \partial C_n} (\tilde{f}(g, \gamma_1))^2 &= \sum_{(g, \gamma_1) \in \partial C_n} \left(\prod_{\gamma \in F} f(g(\gamma)) \right)^2 \\ &= \sum_{(g, \gamma_1) \subset (\partial D_n \times B_n) \cup (D_n \times \partial B_n)} \left(\prod_{\gamma \in F} f(g(\gamma)) \right)^2 \\ &= \#\partial B_n \sum_{g \in D_n} \left(\prod_{\gamma \in F} f(g(\gamma)) \right)^2 + \#B_n \sum_{g \in \partial D_n} \left(\prod_{\gamma \in F} f(g(\gamma)) \right)^2 \\ &= \frac{\#\partial B_n}{\#B_n} \sum_{(g, \gamma_1) \in C_n} (\tilde{f}(g, \gamma_1))^2 \\ &\quad + \frac{\sum_{g \in \partial D_n} \left(\prod_{\gamma \in F} f(g(\gamma)) \right)^2}{\sum_{g \in D_n} \left(\prod_{\gamma \in F} f(g(\gamma)) \right)^2} \sum_{(g, \gamma_1) \in C_n} (\tilde{f}(g, \gamma_1))^2. \end{aligned}$$

But

$$\sum_{g \in \partial D_n} \left(\prod_{\gamma \in F} f(g(\gamma)) \right)^2 = \#B_n \frac{\sum_{\alpha \in \partial A_n} f^2(\alpha)}{\sum_{\alpha \in A_n} f^2(\alpha)} \sum_{g \in D_n} \left(\prod_{\gamma \in F} f(g(\gamma)) \right)^2.$$

Thus by (14)

$$\begin{aligned} \sum_{(g, \gamma_1) \in \partial C_n} (\tilde{f}(g, \gamma_1))^2 &= \left(\frac{\#\partial B_n}{\#B_n} + \#B_n \frac{\sum_{\alpha \in \partial A_n} f^2(\alpha)}{\sum_{\alpha \in A_n} f^2(\alpha)} \right) \sum_{(g, \gamma_1) \in C_n} (\tilde{f}(g, \gamma_1))^2 \\ &\leq \frac{2}{n} \sum_{(g, \gamma_1) \in C_n} (\tilde{f}(g, \gamma_1))^2, \end{aligned}$$

which shows that C_n is a generalized Følner sequence for $\tilde{f}$. $\square$

This ends the proof of Theorem 7.